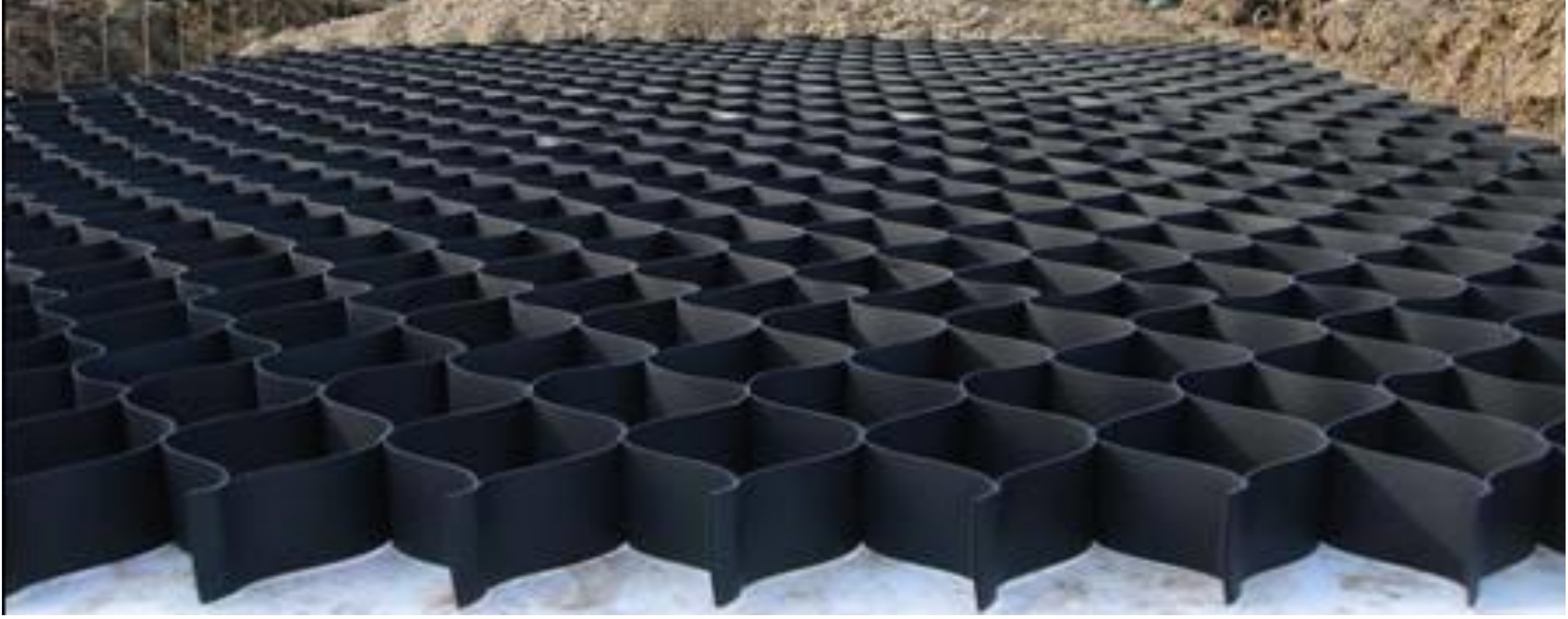

Study on Developing Measures to Promote the Use of Geosynthetics in India

Technology Mission on Technical Textile (TMTT)

December 2013

सत्यमेव जयते

Office of the Textile Commissioner

Ministry of Textile

Government of India

New CGO Building, Marine Lines, Mumbai

डा. कावुरू सांबसिव राव
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NEW DELHI - 110 011

MESSAGE

It gives me immense pleasure to release the report on Study on Developing Measures to Promote the Use of Geosynthetics in India conducted by the Ministry of Textiles as part of the Technology Mission on Technical Textiles. The focus of this study is to lay the foundation and set the roadmap to accrue the economic and social benefits from the usage of Geosynthetics. The final outcome of the study is to provide guidance and recommendations for the promotion of the usage of Geosynthetics materials across the country.

I am proud that the joint and tireless efforts of the stakeholders are being realized and hope that this study will provide the necessary information on the current usage of Geosynthetics along with detailed data on the key interventions required to increase the economic and environment benefits for the nation. I hope that this report leads to increased interactions in the entire Geosynthetics value chain and result in stronger partnerships amongst the various stakeholders.

I eagerly hope that this study proves beneficial to the understanding of the Geosynthetics industry in India by all stakeholders.

(K.S. RAO)

श्रीमती पनबाका लक्ष्मी
Smt. PANABAAKA LAKSHMI

राज्य मंत्री
पेट्रोलियम एवं प्रकृतिक गैस और वस्त्र
भारत सरकार
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MINISTER OF STATE FOR
PETROLEUM & NATURAL GAS AND TEXTILES
GOVERNMENT OF INDIA
NEW DELHI-110 001

Message

In our endeavour to increase the utilization and application of geotextiles in India, I am happy to release the report on Study on Developing Measures to Promote the Use of Geosynthetics in India.

The study ensures that the Indian Geosynthetics sector has been exhaustively analysed and appropriately benchmarked against the most relevant and widely recognized best practices from across the globe. Along with a comparative analysis of the Geosynthetics industry in India and abroad, the study also provides valuable insights into the various Geosynthetic products, theirs uses & applications as well as the associated socio-economic and environmental benefits. Further, the recommendations provide a well-defined direction for promoting the development of the Indian Geosynthetics industry.

The assessment of the Geosynthetics industry in India involved the support of various Government organizations, project teams and individuals associated in the ecosystem. I am proud of our efforts and hope that various stakeholders shall utilize this report and partner with us in our pursuit of accelerating the development of this significant sector.

Panabaka Lakshmi

(Panabaaka Lakshmi)

New Delhi
January 11, 2014

Zohra Chatterji
Secretary

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भारत सरकार
वस्त्र मंत्रालय
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GOVERNMENT OF INDIA
MINISTRY OF TEXTILES
UDYOG BHAWAN, NEW DELHI - 110 107

Message

Geosynthetics have exhibited successful applications across the globe in the areas of roads and pavement stabilization, embankment protection, ground stabilization, soil erosion control, landfills and waste management etc. As our nation further develops, it becomes ever more important that we pay attention to ensuring that our initiatives in infrastructure development are carried out in an environment-friendly and sustainable manner. I, therefore, take great pleasure in the release of the report on **Study on Developing Measures to Promote the Use of Geosynthetics in India**.

One of the major drivers for conducting this study was the fact that India is yet to leverage the economic, environmental and safety benefits that are made possible by the usage of Geosynthetics. Geosynthetics provide better performance and longevity of infrastructure projects such as increasing the life of roads by 10 – 15 years. Such improvements can also be seen in the use of Geosynthetics in embankment projects where loss of life and damage to property can be significantly reduced. Geosynthetics also help prevent contamination of ground water table when used in landfills. The importance of the positive impact generated by the use of Geosynthetics can no longer be ignored. In recent years, the Indian Geosynthetics industry has witnessed increasing demand which has led to the creation of unused capacities that need to be utilized by increasing domestic consumption and further developing export markets. Thus, it is essential that due efforts are accorded to the development of the Geosynthetics industry in India.

In addition to understanding the potential benefits of Geosynthetics it is vital that we are clearly aware of the challenges that lie before us. This report seeks to address those challenges facing the industry today. The key challenges have been identified and defined through various perspectives such aseconomic policies, product specifications, application areas, technologies, manpower requirements etc. and the report includes the necessary steps required to overcome the identified impediments.

As emerging markets further develop, India is well placed to play a major role in the Geosynthetics sector at an international level. The report on Study on Developing Measures to Promote the Use of Geosynthetics in India is a critical first step towards attaining further cooperation with my fellow stakeholders in ensuring that our efforts and objectives are realized.

I congratulate the Joint Secretary, Shri Sujit Gulati and the team of officers which have taken this sector forward with great interest & devotion.

(Zohra Chatterji)

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Acknowledgement

This study is part of the Technology Mission on Technical Textiles (TMTT) Mini Mission II to develop measures to promote the use of Geosynthetics in India.

We would like to express our gratitude to officials and project team of Ministry of Textiles, Government of India, Indian Technical Textile Association (ITTA) and its members, Bombay Textile Research Association (BTRA), the Ahmedabad Textile Industry's Research Association (ATIRA) and National Horticulture Board (NHB), along with all the other stakeholders who have contributed to this report.

We would also like to give our special thanks to individuals within and outside these organizations including honourable Shri Sujit Gulati (Joint Secretary, Ministry of Textiles), Shri A B Joshi (Textile Commissioner, Ministry of Textiles), Shri Ajay Pandit (Dy Director, Textile Commissioner's Office), Smt Shashi Singh (Executive Director, ITTA) and Shri Dr A. N. Desai (Director, BTRA), along with all persons interviewed (refer Annexure B). Their support and guidance along with key insights on the Geosynthetics industry was crucial in authoring this report.

This assessment of Geosynthetics industry in India involved support from various Government officials, project teams and individuals associated in the ecosystem and importantly the study team of Accenture and Suvin Advisors. We express our thanks to all of them for their support and effort during the study.

List of Abbreviations

AASHTO	American Association of State Transportation and Highway Officials
AS	Standards Australia
ASTM	American Society For Testing And Materials
BC	Bituminous Concrete
BRO	Border Roads Organization
BS	British Standards Institution (BSI)
BTRA	Bombay Textile Research Association
CBR	California Bearing Ratio
CDR	Cone Drop Resistance
DBM	Dense Bituminous Macadam
DIN	German Institute for Standardizations
ECB	Erosion Control Blankets
ECM	Erosion Control Mats
EN	European Committee for Standardization (CEN)
EPA	Environment Protection Agency
EPDM	Ethylene Propylene Diene Monomer
EPS	Expanded Polystyrene
FHWA	Federal Highway Authority
FS	Factor of Safety
GCL	Geo-composite Clay Liners
GMA	Geo-synthetic Materials Association
GSC	Geo-textile Sand Containers
HDPE	High Density Polyethylene
ISO	International Organization for Standardization
LCCA	Life Cycle Cost Analysis
LTDS	Long Term Design Strength
MSE	Mechanically Stabilized Earth
MSEW	Mechanically Stabilized Earth Walls
NHAI	National Highway Authority of India
PCC	Portland Cement Concrete
POA	Percentage Open Area
PPT	Pyramid Puncture Test
PVC	Poly Vinyl Chloride
PVD	Prefabricated Vertical Drain
PWD	Public Works Department
RECP	Rolled Erosion Control Products
RESF	Reinforced Embankments Over Soft Foundations
RSS	Reinforced Soil Slopes
SGA	Soil Geo-synthetic Aggregate
TBR	Traffic Benefit Ratio
TRM	Turf Reinforcement Mats
UV	Ultra Violet
WMM	Wet Mix Macadam

Further descriptions, terms and symbols pertaining to Geosynthetics can be found in the IGS (International Geosynthetics Society) publication titled "Recommended Descriptions of Geosynthetics, Functions, Geosynthetics Terminology, Mathematical and Graphical Symbols".

This report is a compilation of literature/data/photographs from various sources (including public sources including internet, manufacturers and sources cited in the appendix) as suggested by key stakeholders during the course of the assignment. This objective of the handbook is to promote the usage of geosynthetics in the country and should be used only for the promotion of this sector.

Executive Summary

Geosynthetics comprise of technical textile products used in geotechnical applications pertaining to soil, rock, earth, etc. The major applications of Geosynthetics include civil engineering works (roads and pavements, slope stabilization and embankment protection, tunnels, rail-track bed stabilization, ground stabilization, drainage, etc.), marine engineering work (soil erosion control and embankment protection, breakwaters) and environmental engineering (landfills and waste management).

India has huge demand of these sectors worth more than Rs. 6 L crore. This segment primarily represents the growth opportunity for Geosynthetics along with urban development (Rs. 1.2L crore) and irrigation (Rs. 2.1L crore). However, its usage is very limited in the India and it makes up a demand of only 100 million square metres vs. 4.7 billion square metres worldwide.

This report attempts to study and provide guidance and recommendations to identify, promote and advance the use of Geosynthetic materials across the country. Based upon the deliverables and scope outlined in the RFP, the report has been segregated into four major thematic sections:

1) *Information on Geosynthetics products, their usage, and the associated benefits*

   a) This section deals with basic information regarding the various geosynthetic products and their applications. This information is further expounded in a handbook for geosynthetic products which additionally discusses implementation instructions and design considerations (Section 3).

   b) Thirteen Indian case studies have been provided highlighting solutions for field level geotechnical problems that can be referred to for guidance on geosynthetic usage (refer Section 4).

   c) Lastly, the economic benefit of using geosynthetics in certain applications with the most potential has been highlighted. These include landfills, roads and canal linings. For road applications the benefits are in the range of 5-10% for upfront material savings depending on geosynthetic used (higher savings for geotextiles, around 4% for geocells), with overall benefit of approximately Rs 8 lakh per km when maintenance costs over a 15 year period are taken into account. These are in line with monetary benefits observed globally. Hence the reason of low uptake in India cannot be contributed to lack of comparable benefits. Methods to calculate the monetary benefit via Life Cycle Cost Analysis for inclusion in various public works manuals have also been provided in the report (Section 5).

2) *Analysis of current usage of Geosynthetics in India*

   a) The assignment involved primary research with the stakeholders which were classified into four major groups (Section 6.1):

      i) Contracting agencies/Deptt.
      ii) Concessionaires, contractors and design consultants

iii) Manufacturers
iv) Government agencies and subject matter experts

b) Feedback from these stakeholders with regards to issues and impediments for the growth of the geosynthetic sector have been summarized. These are categorised under – Awareness, Usage Policies & Regulations and Standards & Specifications. Consequently these areas were focused during subsequent research.

c) A review of Indian regulations, usage policies, tendering process, standards framework and awareness pertaining to Geosynthetics was undertaken. Manufacturing feasibility for various geosynthetic products /technologies was also carried out and summary has been presented within this report (Refer Section 6.2). For regulations governing use in India, the MoRTH (Ministry of Road Transport and Highways) Orange Book, the usage policies of railways, water works department, as well as the Ministry of Environment and Forests' municipal waste management and handling rules has been studied (refer Section 6.3) and relevant suggestion have been made.

3) *Analysis of current usage of Geosynthetics globally*

a) For areas where stakeholders identified areas of improvement, global practices were studied (refer Section 7) to use as a template for practices that could be employed in India. Based upon our study and discussions with experts /stakeholders in countries such as USA, Israel, Turkey, Australia, Spain, China, Taiwan, UK and Netherlands, it emerged that there were very few rules and regulations mandating use of geosynthetics. The few cases where it has been mentioned pertained to road overlays, silt fences, canal linings and landfills. However the use of Geosynthetics in these countries can also be attributed to economic or environmental benefits offered.

b) For contracts which operate on Public Private Partnerships (for example in road applications such as the Daund – Gar Dapoli Rd case in section 4.3)), it makes economic benefit to the concessionaire to use Geosynthetics. However awareness on the economic benefits geosynthetics offer has been low.

c) For ready reference, international tenders with geosynthetic specifications have been provided (refer Annexure K).

d) Lastly, case studies for products and applications which are untapped in India and have great potential for growth have been included so that pilot studies for these can be initiated in India. These include geotextile tubes, Geocells, Geofoam and Geocomposites (refer Section 8.6).

4) *Recommendations*

This report is based on a comprehensive analysis of the current usage of Geosynthetics in India and the best practices across the globe. Based on this exercise, the recommendations have been discussed with various stakeholders. Also a handbook has been developed which details out the various Geosynthetics and their methods of implementation.

a) User Ministries/Policymakers

   i) Inclusion of Geosynthetics(and detailing the usage policy for Geosynthetics MoRTH) in Orange Book so that contractors and concessionaires can adopt Geosynthetics within their design as per specification specifications outlined within the Orange Book (refer Section 9.2).

   ii) Develop standard SoR (Schedule of Rates) item list for Geosynthetics in various States. This will enable the State to include Geosynthetics in the design and pricing of various applications (refer Section 9.3).

   iii) Inclusion of Geosynthetics in various Handbooks and Guidelines of other Government (like Railways etc.). This will encourage the acceptability of Geosynthetic in various applications (refer Section 9.4).

   iv) Introduce stipulations to make geosynthetic use mandatory for certain applications where environmental or holistic economic benefits are significant but do not prove profitable enough for contractors (for e.g. Canal lining) (refer Section 9.10).

b) Contractors/Concessionaires

   i) Changes in the financial bid evaluation and tender specimens to introduce tender evaluation criterion & inclusion of standard specifications will ensure that projects are not only on lowest bidder basis but have scope for technically prowess and value engineering bids can be submitted by concessionaires and contractors. Also use of the sample tender formats will ensure procurement of standard quality materials for use (refer Section 9.5).

   ii) Popularising of Geosynthetics Handbook (Annexure H which covers product descriptions, applications and guidelines for implementation)

c) Ministry of Textiles/COEs (Centres of Excellence)/ITTA (Indian Technical Textile Association)/Manufacturers

   i) Adopt Standards (recommended in this report) and specifications to fill gaps in the existing BIS (Bureau of Indian Standards) Standards for Geosynthetics. This will ensure that a minimum level of quality in the industry (refer Section 9.6).

   ii) Invest in research for newer applications (refer Section 9.7)

   iii) Updating existing and creating new testing facilities for quality control so that both manufacturers and users have the facility to have material tested against predefined quality standards and ensure quality material is both being produced and procured (refer Section 9.8).

iv) Inclusion of Geosynthetics in educational curriculums will ensure that the next wave of civil engineers develops familiarity with Geosynthetic materials and so can plan inclusion in the design phase itself (refer Section 9.9).

1. Background

1.1 Technical Textiles

The history of conventional textiles in our country has its own culture and heritage, but consumer textiles are becoming more and more competitive and facing tough competition. Many companies producing conventional textiles have to continuously struggle to survive in a highly competitive global market. Now, the time is that traditional textile entrepreneurs should move into the lucrative field of technical textiles, while retaining their traditional textile business.

Technical textiles are textile materials and products manufactured primarily for their technical performance and functionality rather than their aesthetic or decorative characteristics. They have been replacing conventional materials with innovative technology, low cost, better efficacy and many added features. They account for over one-fourth of all textile consumption in weight terms. The application of technical textiles can be in consumer as well as industrial products.

Technical Textile Segments

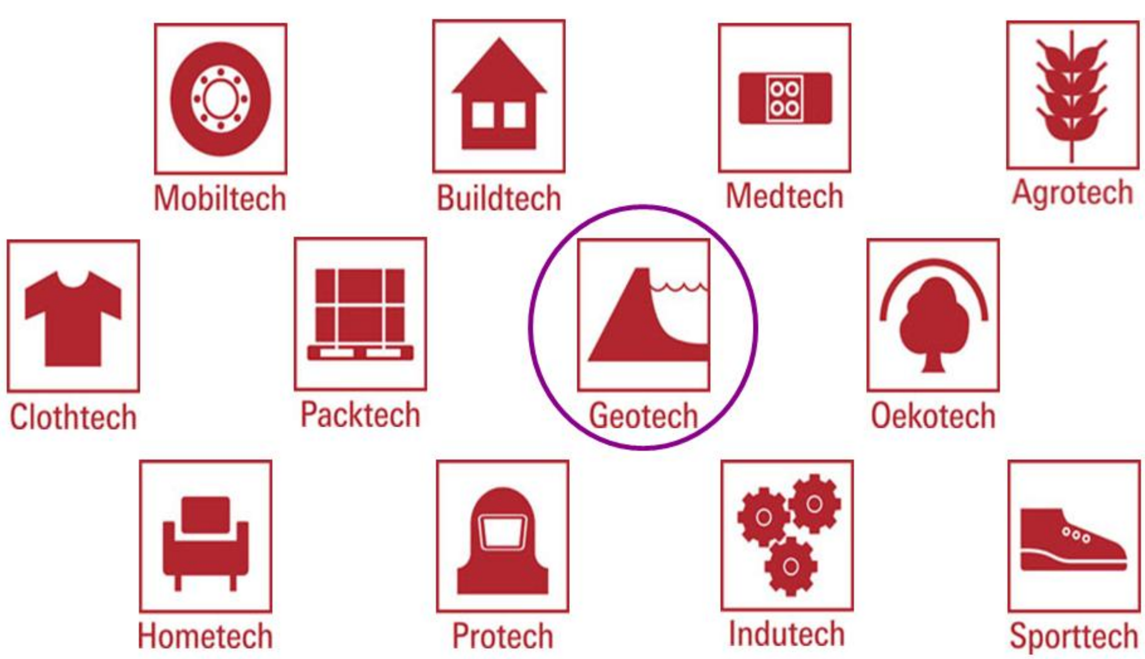

Figure 1.1: Technical Textile Industries

India currently consumes the products under all twelve categories. The percentage of indigenous production varies drastically across various products. India is a large producer of technical textiles products in Packtech, Clothtech, Hometech and Sporttech segments, the products of which are primarily commodities. Technical textiles used in the Geotech segment are known as part of the larger family of Geosynthetics that also includes Geogrids, Geocomposites, Geomembranes, Geomats, Geonets, etc.

Unlike the conventional textile industry in India which is highly export intensive, the technical textile industry is an import intensive industry. Many products like baby diapers, adult diapers, wipes, protective clothing, hoses, webbings for seat belts, etc. are imported to a very large extent. The technical textiles which are exported are those typical commodity products and not very R&D intensive and include products such as flexible intermediate bulk containers (FIBCs), tarpaulins, jute carpet backing, hessian, fishnets, surgical dressings, crop covers, etc.

There are a few multinational companies like Alstom, Johnson & Johnson, Du Pont, Procter & Gamble, etc., who are internationally very large players in technical textiles and have set up their units in India as well. There are some domestic players like SRF, Entremonde Polycoaters, Vardhman, etc., who are also some of the large players in this industry.

With a compounded annual growth rate of 11%, the technical textile market in India has grown to INR 57,000 crore in 2011-12 from INR 42,000 crore in 2007-08, and is expected to touch INR 1.58 lakh crore by 2016-17.[1]

1.2 Geosynthetics

India's economy is big and getting bigger. Nearly all of the infrastructure sectors present excellent opportunities, with roads and highways, ports and airports, railways and power standing out as particular bright spots, with staggering sums of investment planned. The Indian Government, via the National Highway Development Program (NHDP), is planning more than 200 projects in NHDP Phase III and V to be bid out, representing around 13,000 km of roads.

Projected spending in selected infrastructure segments:

- Railways: Rs. 3.6L crore (US $65 billion)
- Road and highways: Rs. 5L crore (US $92 billion)
- Ports: Rs. 1.2L crore (US $22 billion)
- Airports: Rs. 44,000 crore (US $8 billion)

Geosynthetics include a variety of synthetic polymer materials that are specially fabricated to be used in geotechnical, geo-environmental, hydraulic and transportation engineering applications. It is convenient to identify the primary function of a geosynthetic as being one of: separation, filtration, drainage, reinforcement, fluid/gas containment, or erosion control. In some cases the geosynthetic may serve dual functions. Geotextiles are a type of geosynthetic

[1] PTI - Press Trust of India. "Technical textile market to touch Rs 1.58 lakh crore by FY 2017". *The Economic Times.* August 3, 2012. Retrieved November 1, 2012, from <http://articles.economictimes.indiatimes.com/2012-08-03/news/33020000_1_technical-textiles-textile-ministry-officials-office-of-textile-commissioner>

and are permeable fabrics which when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain. Typically made from polypropylene or polyester, Geotextile fabrics come in two basic forms: woven (looks like mail bag sacking), and nonwoven which can be manufactured by needle punch (looks like felt) or heat bonding (looks like ironed felt) processes.

Apart from the geotextiles described above Geosynthetics include products such as Geogrids, Geomats, Geonets and many types of Geocomposites manufactured by combining different basic products. Each configuration can yield benefits in geotechnical and environmental engineering design.

The Indian infrastructure industry is Rs. 1.59L crore industry and accounts for 76% of the construction GDP of India. The outlay for transportation spend in the 11th Five Year Plan stands at Rs. 5.7L crore (trillion), and this segment primarily represents the growth opportunity for Geosynthetics along with urban development (Rs. 1.2L crore) and irrigation (Rs. 2.1L crore).

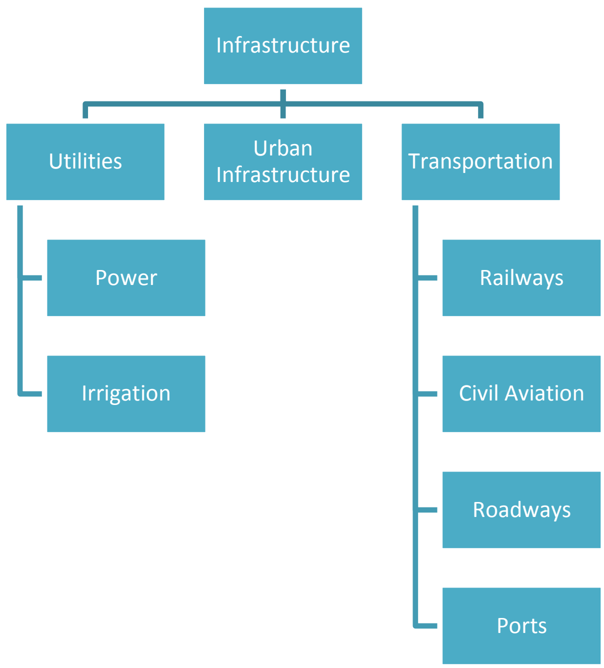

Figure 1.2: A breakdown of the infrastructure industry in India

The global technical textiles industry is around Rs. 7L crore ($127 billion), of which India accounts for around Rs. 0.63L crore ($12 billion), or around 9%[2]. Geosynthetics is an area of technical textiles that has tremendous growth potential due to the significant infrastructure

[2] Lal, Ram Asrey (Director). "Emerging Indian Market Trends in Technical Textiles". Regional Office of the Textile Commissioner, Ministry of Textile, Govt of India. September 13, 2010.

spends as mentioned above. Geosynthetics perform the following functions depending on application and products used:

- **Filtration**: Provides permanent mechanical and hydraulic filter stability as it retains fine particles when water passes from fine-grained to coarse-grained soil.
- **Drainage**: Provides water drainage and gas venting in the plane of the Geosynthetic.
- **Reinforcement**: Increases soil shear strength by providing bonding mechanism of the Geosynthetic-soil system to improve structural stability.
- **Cushioning/Protection**: Allows permanent protection of synthetic sealing systems (Geomembranes) against mechanical damage during installation and after completion of construction.
- **Containment/Waterproofing**: Acts as a support material for impregnations with bitumen or plastic-modified sealing materials.
- **Separation**: Permanently prevents the mixing of two materials.
- **Erosion Control**: The Geosynthetic acts to reduce soil erosion caused by rainfall impact and surface water runoff.

1.3 Need for the Study

1. *Unused domestic capacity and cost competitiveness with Chinese imports*

Five years ago there was a big schism on the supply side in the domestic geosynthetics industry as there were few players producing geosynthetic products a[art from geotextiles such as geogrids, geomembranes, geocomposites, etc. Through inclusion of technical textile capital equipment in TUFS (Technology Upgradation Fund Scheme) and increasing demand manufacturers have since sprung into the market in a significant way. This has led to unused capacities that need to be leveraged either locally or in export markets to ensure entrepreneurs stay committed to the industry.

Also, while imports have reduced, certain specialised products may be imported. Imported products are costly due to high duties of 29.80%, though products imported from China are significantly cheaper from a unit cost perspective and hence tax sops on excise, VAT, exports duty credit scrip, etc. may be considered.

2. *Economic benefits accruing because of these are not being leveraged by our economy*

The primary benefits of Geosynthetics revolve around better performance and longevity of infrastructure projects. In the case of roads where repairs and re-laying often occur within 2 years of road construction, especially in areas of soft soil content, life can be extended to at least 10-15 years. Similarly embankment protection effectiveness can be increased manifold instead of performing protection works using regular sandbags and rocks every 1-2 years.

3. *Environmental Protection*

Major Geosynthetic applications such as landfills offer benefits that are not monetary, but rather environmental. Geomembranes and Geosynthetic Clay Liners (GCLs) help prevent contamination of the ground water table when used in landfills.

4. *Safety*

Other Geosynthetic applications such as embankment protection offer value in preventing loss of life and damage to property that again cannot be quantified in monetary terms.

5. *Indirect Economic & Social Benefits*

Apart from direct monetary benefits there are several indirect benefits of Geosynthetics such as reduction in travel time due to better roads, less pollution due to reduced idling, lower maintenance costs for vehicles, reduction in water treatment costs, increased employment, etc. Such indirect economic and social benefits are crucial for the economy.

Challenges

The afore-mentioned functions are proven benefits of using Geosynthetics in various applications and haven been done so globally as early as the 1960s. Despite such a history of proven performance uptake in India has been slow and lags significantly behind other countries. The major impediments to growth in the domestic market are as follows:

- Lack of awareness and hesitation in adopting globally proven cost effective technologies
- Decentralized infrastructure sector and decision making makes it difficult to implement practices such as inclusion of Geosynthetics in projects
- Absence of required standards to ensure product quality and implementation guidelines
- Absence of product specifications to define standard manufacturing properties
- Deterrents for entrepreneurs in setting up units for Geosynthetics due to:
    - Huge capital expenditure involved
    - Lack of conviction in market potential due to absence of policy and regulatory initiatives to boost demand
    - Lack of skilled manpower and training facilities

This study aims to address these issues and propose steps to overcome these impediments to the Geosynthetics industry.

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2 Approach and Methodology

2.1 Approach of the Study

In this project an approach consisting of distinct yet tightly integrated phases for achieving the targeted outcomes was adopted. The approach contained six distinct phases namely:

I. Project Inception

II. Assess

III. Global Benchmarking

IV. Analysis

V. Recommendations

VI. Stakeholder Discussions

These 6 phases with key activities have been pictorially depicted in the following illustration:

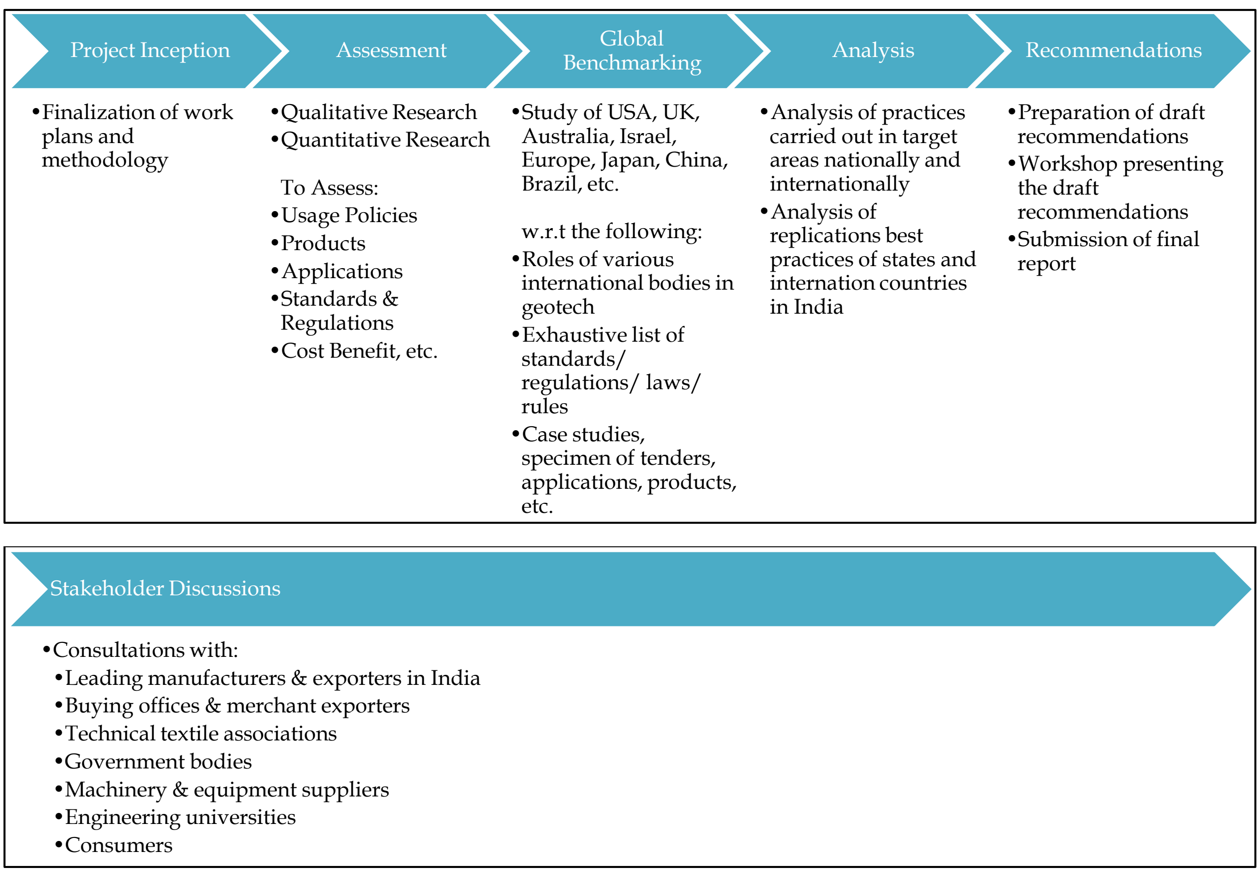
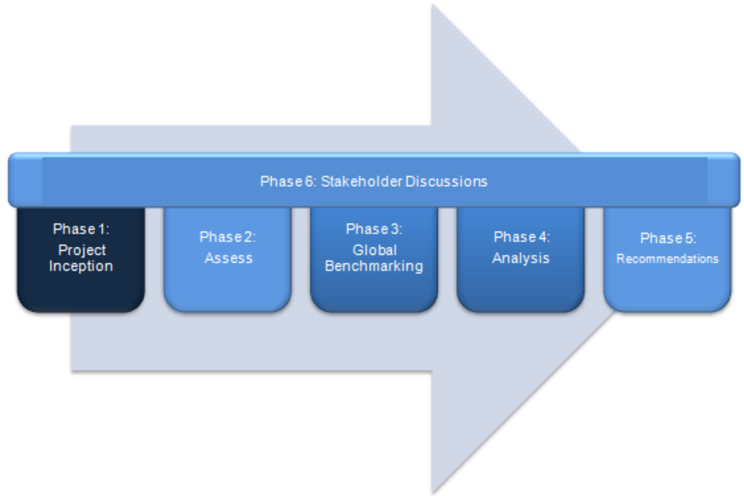


Figure 2.1: The Six Phases

Phase I: Project Inception

During Project Inception phase, the engagement roadmap with activities and timelines of the complete engagement were detailed. The following activities were included under this stage:

- Mobilization of the resources
- Preparation and finalization of a full and comprehensive plan for the engagement
- Determination of all necessary review considerations



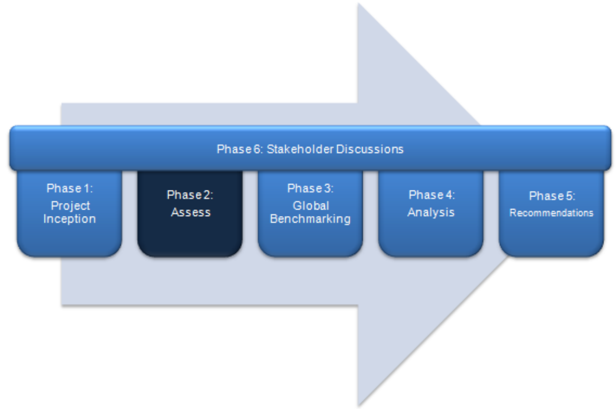
It was important to draw a stakeholder map at this stage to help in understanding the position of each stakeholder with respect to the goals of the project. The following matrix depicts the centres of influence for this engagement:

		Importance of Stakeholder		
		Less Importance	**Moderate Importance**	**High Importance**
Influence of Stakeholder	**Significant**		• Technical Textile Associations	• Centres of Excellence • Govt Bodies
	Moderate			• Consumers
	Less	• Engineering Universities	• Leading Manufacturers	

Figure 2.2: The Stakeholder Matrix

This matrix helped to refine the primary research strategy and prioritise stakeholders according to their importance and influence. Interactions were initiated with the consumers including various contractors and concessionaires, contracting agencies (govt. bodies) such as the NHAI (National Highway Authority of India), PWDs (Public Works Dept.), Water Works Departments; the COEs (Centre of Excellence) as well as the leading manufacturers such as Techfab, Strata Geosystems, Garware Wallropes, Reliance, Maccaferri, etc. Details of people met are included in Annexure A.

Phase II: Assessment



In the Assessment phase, the existing system, processes, and information associated with Geosynthetics in India was studied in detail. The various components intrinsic to the Geosynthetics sector in India were studied, including:

a) Current usage policy of Geosynthetic products in MoRTH

b) Current applications of Geosynthetics used to improve quality and reduce cost

c) Current method of application of Geosynthetic products prescribed in the Orange book of MoRTH.

d) Current Geosynthetic products used for different situation

e) Schedule of rates for Geosynthetic materials provided by MoRTH and all state Govt. agencies.

f) The current level of standardization and regulatory mechanism/laws/rules in place in India

g) Need of standards and regulations for each product category and its impact on overall consumption.

h) Feedback of key institutional consumers in India for such type of products with regard to the issue of lack of Standards faced by them while sourcing such products (either domestically or from overseas).

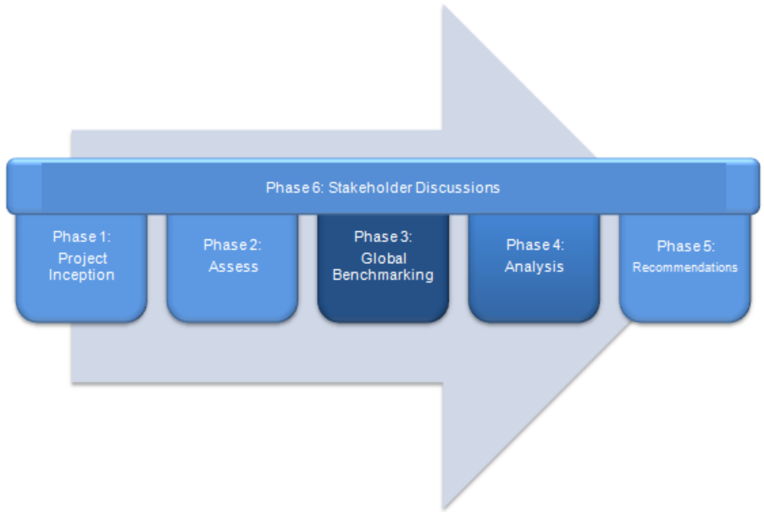
In the Assess phase, an exhaustive study was undertaken covering all the aspects of allied fields and cross-cutting applications of Geosynthetics segment.

This phase also studied details of the regulatory & legal framework governing the Geosynthetics sector in India. In this phase, the project team:

- Studied the Government policies, acts, rules, regulations & office orders governing the Geosynthetics sector in India
- Gained high-level understanding of legal framework & the way it drives the Geosynthetics sector in India
- Identified the key bottlenecks from a legal perspective for Geosynthetics in India.

In studying the legal & regulatory framework, the project team captured the inputs of stakeholders & documented the available information. Further, the report has provides the views and data provided by the stakeholders on legal and regulatory aspects only.

Phase III: Global Benchmarking



In this phase, Accenture studied international markets to identify areas of improvement in the Geosynthetics sector in India. A Gap Analysis was carried out that involved determining, documenting, and approving the variance between stakeholder requirements and current capabilities. Gap analysis naturally flowed from benchmarking and other assessments.

This phase involved a study of global best practices in terms of conceptualization, implementation, key learnings, etc. The details covered in this phase include:

Study of regions with mature and well established markets including

- Israel
- USA
- UK
- Europe
- Japan
- China

List of various international bodies which are involved in developing measures to promote usage of Geosynthetics

Exhaustive list of standards available globally for products in the Geosynthetics segment

Summary of all relevant regulations/laws/rules that mandate the usage of Geosynthetics in various applications

Case studies on usage of Geotech in illustrative projects of reasonable scale

Specimen of tenders used for awarding contracts which have well defined specifications and guidelines for usage of Geosynthetics

Global (USA, UK, Germany, France, Japan, China, Brazil and Israel) details on

- Applications of Geosynthetics used to improve quality and reduce cost
- Usage policy of Geotech products in various applications
- Geotech products used in different situations etc.

In this phase, the good practices implemented within and outside India to conduct a benchmarking exercise with respect to the existing implementation of sector initiatives were studied. The key learnings from national and international research were identified and incorporated into the recommendations.

Phase IV: Analysis

On the basis of the international study & as-is-analysis, in the Analysis phase a gap analysis was conducted to identify areas of improvement in the Geosynthetics sector and devised ways to plug these gaps. The gap analysis involved determining, documenting, and developing agreement between stakeholder. Gap analysis naturally flowed from the global benchmarking and assessment phases.

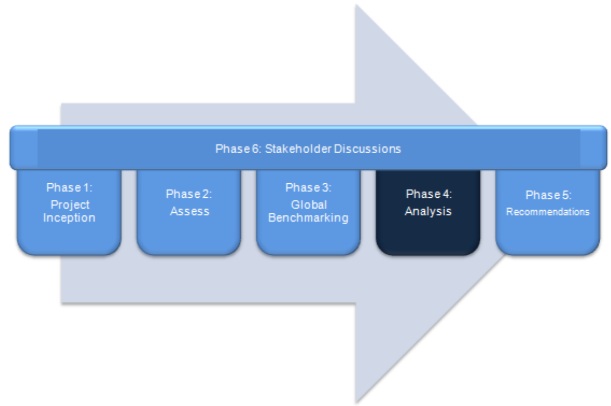
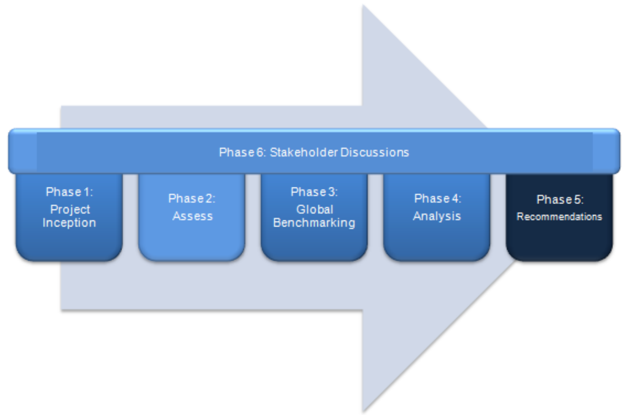


Figure 2.3: Key activities in the analysis phase

Based on this analysis and discussions with the key stakeholders the impediments that exist in growth of the Geosynthetics industry were identified and the steps that can be taken to overcome the same.

Phase V: Recommendations



The purpose of this phase was to first ascertain the gap between the current framework for the Geosynthetics sector and the envisaged way, and then dovetail it with the best practices.

Activities involved:

On basis of previous stages, a draft section-wise areas of improvements / modifications for the Geosynthetics sector in India was prepared.

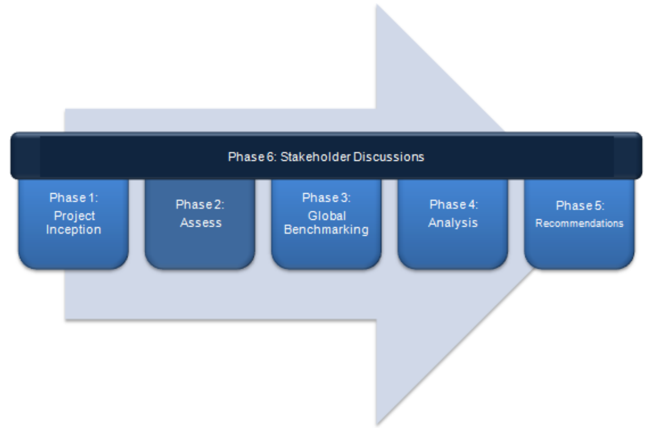
These recommendations have been discussed in meetings with key stakeholders in various meetings. Feedback has been sought and incorporated suitably to finalise the deliverables.

Accenture continued to work with the client project team to arrive at acceptable and pragmatic outcomes. Some activities as part of these interactions included the following:

- Workshops with the key stakeholders to re-valuate the issues and constraints based on which the recommendations were designed.
- An implementation plan which was feasible and could be achieved within the desired time frame of the client.
- Designed recommendations for improvements in institutional, procedural, infrastructural, technological, and personnel related areas.

Phase VI: Stakeholder Consultations

It was important to involve the key stakeholders during all the phases of the project. This was an overarching phase and activities under it were carried out throughout the project.



Voice of Customer (VoC)

Consultants engaged with the key stakeholders and understood their perspective towards the project.

The VoC was gathered through the following means:

1. Face to face interviews of key stakeholder personnel
2. Focus groups with key stakeholders
    a. Group of 5-6 members from the same domain (e.g. – all members being Senior officers of Govt. of India of relevant departments like Textile etc)
    b. Group of 5-6 having representative of all the key stakeholders
3. Workshops / Brainstorming sessions

Questionnaires were prepared for noting and understanding the requirements and needs of the stakeholders and their views towards the project. The key stakeholders of the project include:

- Leading manufacturers & exporters in India like Maccaferri, TechFab India, Kusumgar Corporates, Garware Ropes, Strata Geosystems, Virendra Textiles, Hrishikesh Industrial Fabrics Pvt. Ltd., Gorantla Geosynthetics Pvt. Ltd., Gayatri Polymers & Geosynthetics etc.
- Technical textile associations like Indian Technical Textile Association (ITTA), Association of Nonwoven Industry (INDA), European Disposables and Nonwovens Association (EDANA) etc.
- Government bodies like Public Works Department (PWD), Ministry of Road Transport and Highways (MoRTH), Ministry of Water Resources, etc.
- Machinery and equipment suppliers like Fleissner Gmbh, Rando Machine Corporation, AUTEFA Solutions Germany Gmbh, Reifenhauser Gmbh, Germany, etc.
- Engineering universities like Indian Institute of Technology, National Institute of Construction Management and Research (NICMAR) etc.
- Consumers i.e. NHAI, BRO, CPWD, CRRI, IRC and Railways, etc.

In this phase, discussion with these stakeholders on Geosynthetics sector in India & their recommendations were solicited.

- Workshops with relevant stakeholder groups to understand the pros and cons of the various draft intervention measures.
- Study to ascertain the possible improvement opportunities.
- Based on this study and discussions with the key stakeholders such as the Ministry of Railways, Ministry of Road Transport and Highways, and the CPWD the recommendations have been finalized.

2.2 Methodology

We adopted a two-fold approach to our research in this engagement:

A. Quantitative Research

Quantitative research focused on statistical data gathering & analysis. Tools such as information capturing templates, surveys and other equipment were used to collect numerical and measurable data.

Secondary research was initiated before the primary research was rolled out and encompassed information collected from the following sources.

- Trade associations
- Industry publications and databases
- Government databases
- International trade magazines
- Technical textile magazines
- Sector reports /publications on Geosynthetics
- Our corporate library

Need for secondary research

- It improved the focus of the primary research to be conducted
- It helped to frame questionnaire for primary research
- It gave a neutral and outside perspective

B. Qualitative Research

The primary aim of qualitative research is to provide complete, detailed descriptive information on current status of various components of Geosynthetics sector in India & abroad. The following data gathering strategies were used in this stage:

- Study of various journals, websites, literature and directories for generating information on the Geosynthetics.
- In–depth structured and non-structured interviews of with key stakeholders
- Focus group discussions & brainstorming sessions
- Documentary analysis & archival research
- Brainstorming sessions

Questionnaires were prepared - different questionnaires for manufacturers, machinery suppliers, government bodies, contracting agencies and concessionaires/contractors. The following points were considered while preparation of the questionnaires:

- Short and to the point questions
- Simple and specific questionnaire
- Questions which can accommodate all possible answers
- Variety of questions like open-ended, closed-ended, likert-scale, multiple-choice, ordinal, categorical, numerical etc.
- Using balanced scales like Strongly Disagree, Disagree, Somewhat disagree, Undecided, Agree
- Questionnaire of not more than two pages

In the Primary Research, information was collected from key people to arrive at best estimates for the required information. The list will include some of the following:

- Leading manufacturers & exporters in India like Maccaferri, TechFab India, Kusumgar Corporates, Virendra Textiles, Garware Ropes, Strata Geosystems, Hrishikesh Industrial Fabrics Pvt Ltd., Gorantla Geosynthetics Pvt Ltd., Gayatri Polymers & Geosynthetics etc.
- Technical textile associations like Indian Technical Textile Association (ITTA), Association of Nonwoven Industry (INDA), European Disposables and Nonwovens Association (EDANA) etc.
- Government bodies like Public Works Department (PWD), Ministry of Road Transport and Highways (MoRTH), Ministry of Water Resources, etc.
- Machinery and equipment suppliers like Fleissner Gmbh, Rando Machine Corporation, AUTEFA Solutions Germany Gmbh, Reifenhauser Gmbh, Germany, etc.
- Engineering universities like Indian Institute of Technology, National Institute of Construction Management and Research (NICMAR) etc.
- Contracting agencies such as i.e. NHAI, BRO, CPWD, CRRI, IRC and Railways.
- Concessionaires and contractors such as Afcons, L&T, etc.

The primary research was conducted in the following ways:

- Personal interview survey
- Telephone survey

First preference was always to personally meet the respondents but in cases where the respondent was not available, other methods of conducting the interview were adopted

Need for primary research:

- First-hand information of what is happening in the sector
- Addressing specific research issues which cannot be taken care by secondary research like problems faced by contractors with respect to use of Geosynthetics, actual implementation of standards etc.
- Higher level of control on the information collected

Through this phase of research industry stakeholders were contacted domestically and internationally. The list of stakeholders can be seen in Annexure A. The breakup is as follows:

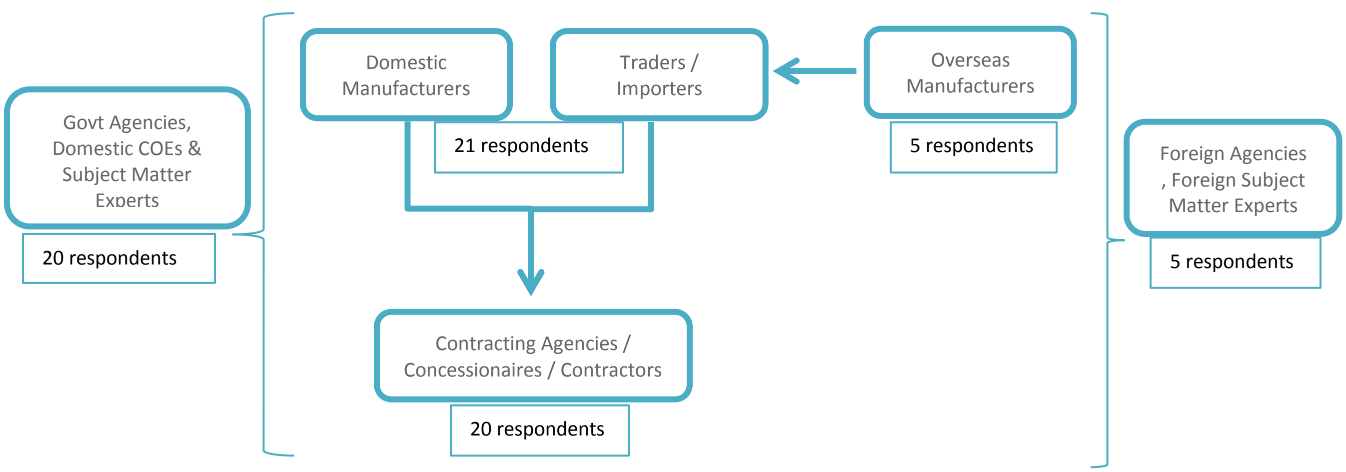


Figure 2.4: Stakeholders and Interviews Completed

A focus group discussion with various industry stakeholders was also conducted on August 28th, 2012. A second focus group discussion was conducted on October 19, 2012 specifically for Geosynthetics. These sessions were used to address certain points of contention that had become apparent while conducting the primary research.

2.3 About the report

This report is structured in a manner to allow for a logical progression of information.

First off it was important to identify the approach and methodology for this engagement. This was based upon two key activities – identifying stakeholder groups and outlining research methods along with a work plan to complete them.

The next section i.e. Chapter 3 focuses on the information regarding Geosynthetic products and their applications. The following deliverables as per the RFP are included in this section.

i) Current applications of Geosynthetics used to improve quality and reduce cost

ii) Current Geosynthetics products used for different situation

Chapter 4 consists of case studies relevant to the Indian context:

iii) Solutions for different field level realities to help engineers to choose appropriate material for a given situation (which consists of various real world case studies highlighting the problems and how Geosynthetics were used to solve these problems)

One of the deliverables for this engagement was a handbook containing information with regards to Geosynthetic products for roads and highways, applications, implementation guidelines and design considerations. In addition to roads and highways we have included other Geosynthetics products and their applications as well. This handbook can be found in Annexure H.

iv) Hand book in Geosynthetics application for Roads & Highways

Chapter 5 consists of various methods of quantifying the cost benefit of using Geosynthetics in various applications. The first section consists of two different models for conducting the Life Cycle Cost Analysis for using Geosynthetics in road applications. The section of this chapter contains various applications not restricted to roads where the cost benefit analysis of that particular application has been carried out. The following deliverables as per the RFP are included in this Chapter:

v) Inclusion of Life-Cycle Cost method of analysing cost-effectiveness of Geosynthetics and technical preference for superior construction methods using geotech in 'Orange Book' of MoRTH

vi) Business case (Cost Benefit Analysis) for usage of Geosynthetics for select applications

Chapter 6 discusses the as-is scenario in India and outlines current usage policies in India as well as feedback from the key stakeholders in the Geosynthetics industry. It also includes manufacturing feasibility for the various technologies. Another highlight is the prevalent India specific standards that are available currently. The deliverables as per the RFP also covered in this section include:

vii) Discussions with the ultimate end users & out come

viii) Consultations with technical textile manufacturers to study the feasibility of indigenous manufacturing at an affordable cost

ix) Details of regulatory mechanism/laws/rules for these products in India, if any.

x) Schedule of Rates for Geosynthetic given in MoRTH & and other States

xi) Applicable standards for each of the products in India, considering variations arising due to application segment and the end user type.

Chapter 7 focuses on the scenario prevalent internationally with respect to the key policies and regulations providing a fillip to the Geosynthetics industry, the various bodies involved in promoting Geosynthetics use, as well as the different organizations involved in standards setting and implementation. The deliverables as per the RFP also covered in this section include:

xii) Details of international bodies involved in development, certification or accreditation of standards for different products in the geotech segment.

xiii) Standards and regulatory mechanism/laws/rules in place for the target products in place in developed countries like USA, Germany, Japan, UK, etc. Relevant section of such acts / rules / regulations should be cited in separate annexure to the report.

Chapter 8 includes the gap analysis and outlines the interventions required, which is then built upon by Chapter 9 which contains - recommendations regarding usage policies for the MoRTH, comparative analysis for the standards and regulatory mechanism prevalent internationally, the areas where new research and pilot studies are required as well as where cross cutting applications can be explored, as well as proposed regulatory and policy changes and the approach towards implementing these. The deliverables as per the RFP also covered in this section include:

xiv) Upgraded/Modified usage policy of Geotech products in MoRTH (Ministry of Road Transport & Highways).

xv) Standard Schedule of Rates for specific Geosynthetic and related materials required for road construction involving Geosynthetics which may be adopted by all States

xvi) Specimen of tenders used for awarding contracts which have well defined specifications and guidelines for usage of geotech.

xvii) Comparative analysis of standardization and regulatory mechanism/laws/rules in developed countries. This will include a clear benchmarking and identification of gaps in terms of product standards and regulatory / policy interventions for Geotech segment, between India and the countries where the market for particular products is mature and well established.

xviii) Areas for amending the existing Indian laws/rules/regulations & new regulations required to be brought for mandatory usage of Geosynthetics in Indian context.

xix) Areas for application based research for appropriate utilization of geotech in infrastructure development.

xx) Report should also cover all the aspects of allied fields and cross-cutting applications of Geotech segment.

xxi) Approach to be followed for facilitating the identified regulatory and policy changes

xxii) Benefits and cost involved for such Regulatory Measures.

These recommendations have been arrived at via discussions and feedback from various stakeholders via the following activities:

xxiii) Convening series of interviews and compilation of the recommendations.

xxiv) Discussions with user Ministries, State Govt. agencies and agencies involved in decision making for enacting those recommended regulations.

3 Current Usage of Geosynthetics

3.1 Introduction

The Geosynthetics segment comprises of technical textile products used in geotechnical applications pertaining to soil, rock, earth, etc. However Geotextiles specifically refers to fabric or synthetic material, woven or non-woven, which can be used with geotechnical engineering material. ***In laymen's parlance the terms "Geosynthetics" and "Geotextiles" are often interchanged which sometimes leads to confusion. "Geotextiles" are actually a type of product under Geosynthetics.***

The principal functions performed by Geosynthetics as highlighted earlier are confinement /separation, reinforcement, filtration, drainage, and protection. Application areas include civil engineering (roads and pavements, slope stabilization and embankment protection, tunnels, rail-track bed stabilization, ground stabilization, drainage, etc.), marine engineering (soil erosion control and embankment protection, breakwaters) and environmental engineering (landfills and waste management).

The Geosynthetics market in India (imports and domestic production) in 2007-08 was around INR 272 crore, comprising imports of an estimated INR 105 crore and domestic production of around INR 167 crore. In terms of product category, the market includes INR 241 crore of synthetic woven/non-woven Geosynthetics (INR 85 crore of woven and INR 67 crore of Non-woven) as well as other products like Geogrids and Others (Geomembranes, Geonets and Geocomposites). Agro-based Geosynthetics (made of Jute and Coir) are also developing and finding acceptance as a class of products. Market size for these products is around INR 31 crore.

Market Size of Geosynthetics (in INR crore)	
Geosynthetic Products:	241
a. Woven Geotextiles	85
b. Non-Woven Geotextile	67
c. Geogrids	35
d. Geomembranes / Geocomposites (PVD, etc.)	54
Agro based Geotextiles	31
Total	**272**

Table 3.1: 2007-08 Market Distribution of Geosynthetics in INR crore as per IMaCs Report, 2009

The global demand for Geosynthetics (including Geotextiles) is expected to be 4.7 billion m^2. in 2013 and 5.8 billion m^2 by 2015[3]. For India 2008 Geosynthetics demand was 56 million m^2 and for 2013 Geosynthetics demand was expected to be 100 million m^2 (forecasted). In 2018 this figures

[3] Global Industry Analysts, Inc. "Geosynthetics – A Global Strategic Business Report". Feb 2010.

is expected to rise to 178 million m^2. [4] Of this geotextiles demand is projected to decrease as a fraction of overall demand from 66% to 63% by 2018.

For India	2008	2013	2018
Geotextile Demand	37 million m^2	65 million m^2	113 million m^2
Total Geosynthetics Demand (incl. Geotextiles)	56 million m^2	100 million m^2	178 million m^2
Geotextiles as a % of Geosynthetics	66%	65%	63%

Table 3.2: 2000-10 Market Distribution of Geosynthetics in sq. yards as per Freedonia Group Report, 2007

In contrast, in a market like the US the share of Geotextiles to the overall Geosynthetics demand is 73% by volume.

U.S. Geosynthetics Demand (million square yards)					
				% Annual Growth	
Demand for:	**2000**	**2005**	**2010**	**2000-05**	**2005-10**
Geotextiles	505	514	637	0.4	4.4
Geomembranes	81	87	101	1.4	3.0
Geonets	33	32	41	-0.6	5.1
Geogrids	31	31	43	--	6.8
Other	37	36	48	-0.5	5.9
Totals	687	700	870	0.4	4.4

Table 3.3: 2000-10 Market Distribution of Geosynthetics in sq. yards as per Freedonia Group Report, 2007

On the other hand, the difference in market distribution by value for India versus the US is the other way around:

[4] Freedonia Group. "Geosynthetics to 2015". May 2011.

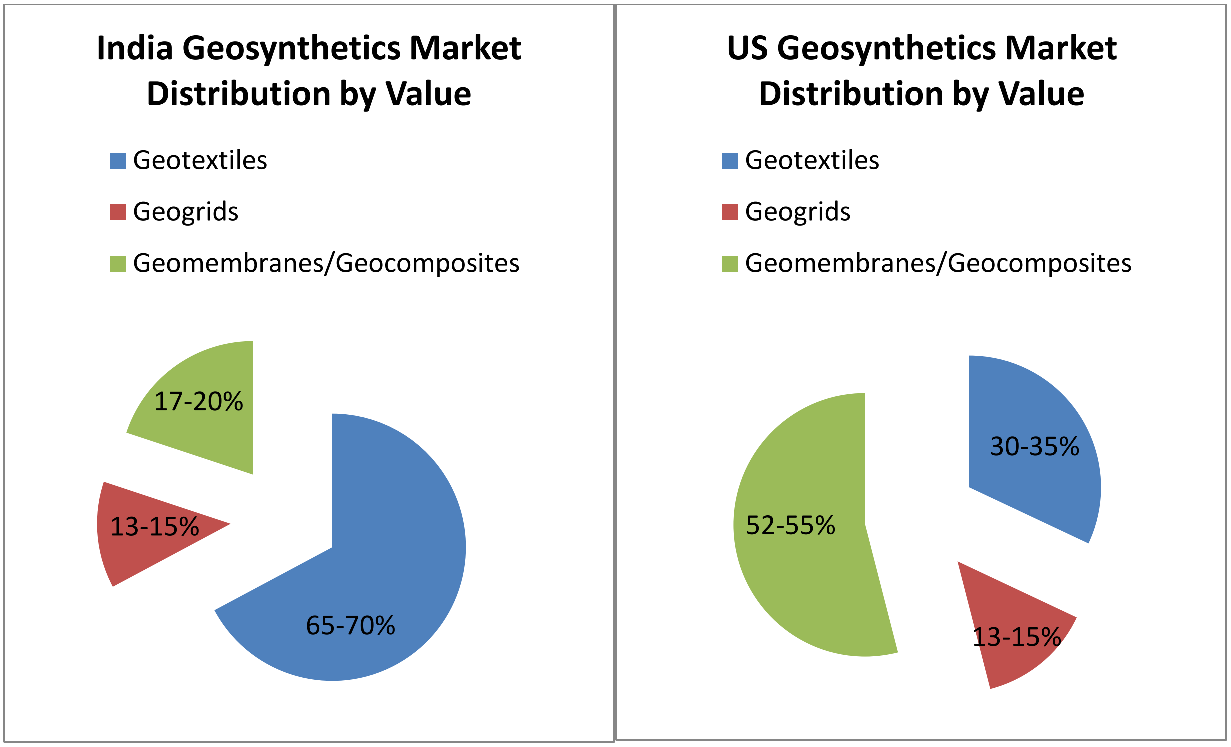


Figure 3.1: Derived Market Distribution of Geosynthetics by Value

As can be seen, the share of Geotextiles in the total Geosynthetics market by value is significantly greater in India compared to countries like the US. Coupled with the smaller overall market size this points to great untapped potential for other Geosynthetic products such as Geomembranes and Geocomposites (specifically drainage composites). This reinforces the data in tables 3.2 and 3.3 where market distribution by volume shows the Indian market dependence on low value Geotextiles.

3.2 Geosynthetic Products

In general, the vast majority of Geosynthetics are made from polypropylene (PP), polyethylene (PE) or polyester (PET) formed into fabrics based on type of process. The mechanical and hydraulic properties vary widely depending on type of application designed for. Depending on type (woven/non-woven), process (thermal bonded/mechanical bonded), desired performance specifications (load bearing ability, tear resistance etc.), Geosynthetics can range from under 40 GSM (gram per square metre) to over 3000 GSM (used in landfill applications). Products such as Geogrids are usually knitted and PVC (poly vinyl chloride) coated. Products are designed to be resistant to mildew, bacteria, soil acids (PP) and alkalis (PE, PET) and most chemicals. Apart from the above, agro based Geosynthetics (woven textiles based on Jute, Coir) are also a niche but growing segment. These have the advantage of being bio-degradable as well as being cheaper.

The list of Geosynthetic products with some salient characteristics has been given below. Further details such as detailed applications, design considerations and implementation guidelines can be seen in the handbook compilation in Annexure H:

1. Geotextiles

These are non-biodegradable synthetics that perform discrete functions such as separation, reinforcement, filtration, drainage and moisture containment. Through discussion with stakeholders in various organizations such as the NHAI (National Highway Authority of India), Techfab, Reliance, various PWDs (Public Works Department) the use of Geotextiles is predominantly in road and railways subgrade stabilization, protection of membranes in water proofing application, and as secondary stabilization in RS (Reinforced Soil) Walls. All the stakeholders spoken to mentioned the underwhelming prevalence of Geotextile use within road and railway construction and thought this was the area of highest potential, especially in pavement overlays. Geotextiles can be woven, non-woven and knitted, referring to the manufacturing process employed. These are described in more detail below:

1.1. <u>Non-woven Geotextiles</u>

1.1.1. Needle-punched

Needle-punching is a mechanical process which, rather than using heat, fixes the fibres relative to each other by entanglement. The manufacturing machines consist of reciprocating banks of barbed needles compact loose fibre into a labyrinth of interconnected fibres. The use of continuous filament fibres or high tenacity long filament fibres creates Geotextiles with the separation and filtration functionality. Using staple, crimped fibres enables the production of thicker Geotextiles with higher water transitivity that are suitable for filtration and drainage applications. Due to their interwoven nature they are also more flexible and hence less prone to tears or damage. Needle-punched non-woven Geotextiles are of relatively higher cost.

1.1.2. Spun-Bonded

These Geotextiles are created when continuous filament fibres are extruded from spinnerets to form a swirling pattern of fibres across a web. This web then undergoes needlepunching, which may then be followed by thermal bonding in which the web passes through a pair of heated rollers or an oven, and the fibres are bonded together to form a uni-planar Geotextile. In some cases the needlepunching step can be avoided and heat-bonding carried out straight away. Bonded

Geotextiles are stiffer and possess high strength with low strain and are thus used in sub-base/subgrade reinforcement and stabilization as well as for filtration and drainage. They have lower filter efficiency than needle-punched Geotextiles because of which they do not perform as well in filtration and drainage applications as pore size is reduced due to the heat treatment leading to clogging. But purely bonded Geotextiles are cheaper than needle-punched and are quicker to manufacture, thus providing value in certain applications.

1.2. Woven Geotextiles

Woven geotextiles are made from weaving monofilament, multifilament, or slit film yarns. Slit film yarns can be further subdivided into flat tapes and fibrillated (or spider web-like) yarns. There are two steps in this process of making a woven geotextile: first, manufacture of the filaments or slitting the film to create yarns; and second, weaving the yarns to form the geotextile. Slit film fabrics are commonly used for sediment control, i.e. silt fence, and road stabilization applications. Though the flat tape slit film yarns are quite strong, alternatively, fabrics made with fibrillated tape yarns have better permeability and more uniform openings than flat tape products. Monofilament wovens have better permeability, making them suitable for certain drainage and erosion control applications. High strength multifilament wovens are primarily used in reinforcement applications. (Ref. Handbook of Geosynthetics, GMA)

1.3. Knitted Geotextiles

These are similar in material to woven Geotextiles but the yarns are knitted instead of weaved. A knitted geotextile is produced by intermeshing loops from one or more yarns, fibres, filaments or other elements. They have exceptional tear strength and are strength-for-strength lighter than woven Geotextiles which makes them easier in handling and laying onsite.

2. Geogrids

Geogrids are Geosynthetic materials that have an open grid-like appearance. The principal application for Geogrids is the reinforcement of soil. There are various Geogrids available in market. Commonly used Geogrids can be classified based on the manufacturing process - woven, knitted, thermally bonded and extruded. Similarly Geogrids can be classified based on coating like: PVC coated and PE coated.

Three processes are commonly used for manufacture. The first heats and stretches polymer that has been pre-punched with a regular pattern of holes. The second comprises bundles of polymer fibres in a mesh pattern that are coated with bitumen or PVC (polyvinyl chloride). The third takes sheathed bundles of fibres that are then welded.

Polymeric strips are the strips used to manufacture Geogrids and are actually used as a substitute for Geogrids in Reinforced Soil/Earth wall applications where cost cutting is required. They consist of high-strength PET filaments protected by a PE coating shaped like strips. They can only be used where the soil is good. In the Indian context use of these polymeric strips in the north eastern region is not advisable as the soil available there is clayey and chances of failure are more.

In speaking with the NHAI (National Highway Authority of India), the PWDs (Public Works Department), and the various contractors and concessionaires as listed in Annexure A, it was universally mentioned that Geogrids are used rather frequently in India for RS (reinforced soil) wall applications for stabilization and reinforcement. The awareness of the benefits provided by use of Geogrids in RS walls such as reduction in slope and hence material, additional strength and longevity of construction is extremely high.

3. Geocells:

Geocells are a three dimensional structure with interconnected cells which resemble a honeycomb which can be filled with soil/granular material or sometimes concrete, forming a mattress for increased bearing capacity and manoeuvrability on loose or compressible subsoil base. They are also known as Cellular Confinement Systems (CCS). Geocells are manufactured by welding/gluing strips of HDPE (High Density Poly Ethylene) together at equal length intervals so that when the strips are perpendicularly pulled apart they form a honeycomb pattern. Geocells are also made of geotextiles. In some cases 0.5 m to 1 m wide strips of polyolefin geogrids have been linked together with vertical polymeric rods used to form deep geocell layers called Geomattresses.

Feedback from manufacturers pioneering use of Geocells such as Strata Geosystems and Garware Wall Ropes has us understand that Geocells are in their infancy in India and have been used sparingly in India for subgrade reinforcement and stabilization in road construction. Geocells also have utility in erosion control via use on slopes to stimulate growth of vegetation and prevent erosion of top soil.

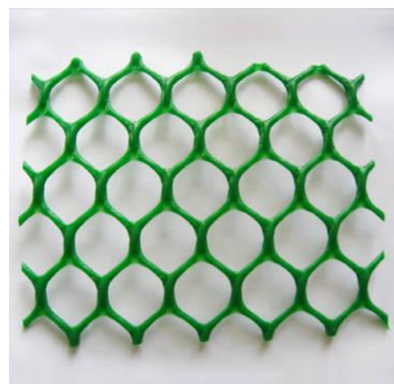
4. Geomembranes:

Geomembranes are also synthetic materials but they are impervious and made of thin sheets of rubber or plastic materials used primarily for lining and cover of liquid-or solid-storage facilities. Geomembranes are manufactured by taking a polymer sheet that is extruded flat or as a tube to be slit in the machine direction. The textured (roughened) versions are for use on slopes where higher levels of interface friction angles are required.

Speaking to various PWDs as well as design consultants as listed in Annexure A it has been learnt that Geomembranes in India are primarily used for landfill lining and capping, as well as for pond and reservoir linings. Private industries are required to ensure hazardous waste does not pollute the ground water table and hence they employ Geomembranes for landfills. HZL, Cairn and Hindalco are some companies that are leading the way in this practice. Municipal corporations around the country are becoming gradually aware of Geomembranes for landfills but are unable to implement them due to lack of conviction and policy as well as paucity of funds. An area of tremendous growth potential as per feedback received is canal linings where there is a direct monetary benefit by preventing water leakage and waste.

5. Geonets:

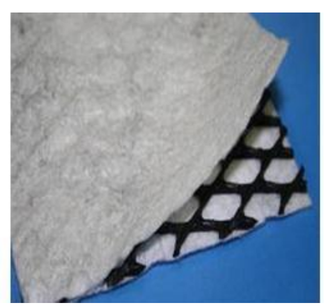
Another specialized segment of Geosynthetics - Geonets are open grid-like materials formed by two sets of coarse, parallel, extruded polymeric strands intersecting at a constant acute angle. The network forms a sheet with in-plane porosity that is used to carry relatively large fluid or gas flows. Polymer mesh is extruded in a tubular form & slit in the machine direction to create a sheet. A third layer can be introduced to increase thickness and, thus, flow capacity.



Geonets are frequently laminated with Geotextiles on one or both sides to form a Geocomposite (see below).The market for Geonets in India is nascent as per stakeholder feedback.

6. Geocomposites:

Geocomposites are geosynthetics made in laminate from a combination of two or more geosynthetic types or composite form and used for applications such as reinforcement (grids + geotextiles) and drainage (mats or nets + geotextiles) among others.



Heat and/or adhesives are used to create single components by bonding barriers, drains, filters, protectors and reinforcement in different combinations. The objective is to produce materials which are multi-functional and are faster to install than the individual components. Interface friction becomes an issue when Geosynthetics are placed on slopes and bonded materials address this potential problem. Geosynthetic Clay Liners (GCL) and Prefabricated Vertical Drains (PVD) are the two predominant forms of Geocomposites.

6.1. *Geosynthetic Clay Liners:*

Geosynthetic clay liners, or GCLs, are an interesting juxtaposition of polymeric materials and natural soils. They are rolls of factory fabricated thin layers of betonies clay sandwiched between two Geotextiles. Structural integrity of the subsequent composite is obtained by needle-punching, stitching or physical bonding.

GCLs are used primarily in landfill applications and in India their use has been seen in some of the cases highlighted in the Geomembranes section of this chapter.

6.2. *Prefabricated Vertical Drains (PVD)*

The prefabricated vertical drain is a long flat tube of woven or non-woven Geotextile with a core inside. For construction of structures on sites underlain by thick strata of soft cohesive soils, a method of foundation soil improvement is generally required to prevent bearing capacity failure and/ or to avoid excessive total and differential settlements. These soft soils have a very low bearing capacity due to their lower shear strength in their often saturated state; the PVDs are used to increase the bearing capacity of the soil by removing the excessive water present inside and accelerating consolidation of soft soil. Instances of use in India are few and far between as per stakeholder feedback and it is an area where application based research can be focused upon.

7. Geofoam:

Geofoam is a product created by a polymeric expansion process resulting in “foam” consisting of many closed, but gas-filled, cells. The skeletal nature of the cell walls is the unexpanded polymeric material. The resulting product is generally in the form of large, but extremely light, blocks which are stacked side-by-side providing lightweight fill in numerous applications, primarily for subgrade/base reinforcement in road construction as the lightweight makes it extremely easy to transport and installresulting in drastically reduced construction time for roads and such. Geofoam is also used for thermal insulation and as a compressible vertical layer to reduce earth pressures against rigid walls.

Instances of use in India are almost negligible and it is an area where application based research can be focused upon.

8. Polymer Gabions:

Polymer Gabions are rectangular or cylindrical baskets fabricated from polymer meshes and usually filled with stone and used for structural purposes such as retaining walls, revetments, slope protection and similar applications. Their lack of strength and longevity as compared to steel gabions has resulted in slow uptake of these gabions.

An example of use can be seen in Case Study 7 of Chapter 4 - the Konkan railway line. As per feedback from officials with Konkan Railways slope protection and ballast retention were achieved by gabions and rockfall netting. As per feedback from Garware PP gabions are also extensively used in riverbank protection such as the Narmada River, Gujarat, and the Tapi river in Surat.

9. Geobags

Geobags are sand-filled high-strength bags using Geotextile fabric and available in the various sizes. They are used in riverbank, beach protection and offshore breakwater. In India Geobags have been used in some riverback protection works such as the Sharda river, Pilibhit, Uttar Pradesh.

10. Geotextile Tubes

Geotextile Tubes are large tube like structures fabricated from high strength Geotextile with soil-in-fills. Geotextile Tube is formed in situ by the hydraulic pumping of local soil into the prefabricated Geotextile Tube. This leads to a flexible, monolithic, continuous structure that is highly resistant to water currents. Sand is widely used as the soil in-fill material because of its low compressibility but other hydraulically pumped soil types can be used. Geotextile Tubes are normally characterized in terms of theoretical diameter.

Applications in India include sea walls at Uppada, Andhra Pradesh and Shankarpur in West Bengal. Geotextile Tubes can also be used for land reclamation works and is an area in its infancy in India (one installation at Hazira in Surat) and should be an area of application based research. They can also be used for dewatering of sediment in riverbed clean-up type applications.

11. **Geomats –** Geomats are made of synthetic material filaments (typically polyamide and polypropylene but not always) tangled together to form a high deformable layer of 10-20 mm thickness, featuring very high porosity (greater than 90% on average). Geomats may be used on slopes to improve resistance to erosion caused by the impact of rain drops and rills, acting as superficial reinforcement allowing time for vegetation to grow. In certain cases Geomats may be used as protection against erosion for the banks of canals and small river courses; their use is basically limited to protect the part of bank that's normally dry and therefore only affected by the action of rain water or rills. Like geonets, geomats may also be used as elements for conveying liquids (drainage) in combination with geotextiles and geomembranes.

12. Geopipes

Geopipes are perforated or solid-wall polymeric pipes used for drainage of liquids or gas (including leachate or gas collection in landfill applications). In some cases the perforated pipe is wrapped with a geotextile filter.

13. Natural Geosynthetics (Jute Geotextiles)

Versatility of some natural fibres such as jute has made it possible to manufacture natural Geosynthetics to meet the specific technical requirements. Both woven and non-woven fabrics can be made out of jute yarns possessing the requisite tenacity, initial strength, extensibility and other physical properties for a variety of end-uses related to geotechnical applications. By far the most preferred application of Jute Geotextiles is Mats in the sector of slope and surface soil erosion control. Open weave Jute Geotextiles with thickness of 4 mm and above helps in reduction of velocity of surface runoff, enables ground storage due to its hygroscopic nature and facilitates vegetative growth.

3.3 Application Areas

As mentioned above, the principal functions performed by Geosynthetics are confinement /separation, reinforcement, filtration and drainage, and protection. Each application of Geosynthetics may require multiple functionality and also multiple products to achieve the required functionality.

After discussions with stakeholders listed in Annexure A the functionality requirement in the Indian scenario was mapped as per relevance and is explained in the following sections along with further details regarding each function:

a. **Confinement / Separation**: Confinement provides a media between the aggregate and the subsoil which absorbs the load in the form of tension and prevents change in alignment of the aggregate. Geosynthetics economically help the separation keeping two dissimilar materials apart to maximize the physical attributes of each of those materials. The object of separation by Geosynthetics is to prevent a well-defined material or rich material from penetrating the sub-grade or the poor soil. If the separating media of Geosynthetics is absent, the infiltration of the sub-grade decreases permeability of the aggregate to the point where it cannot adequately transport the water reaching it.

   Suitable Geotextile fabric with good puncture/tear resistance when used as a separator media - eliminates the loss of costly aggregate material into subsoil, prevents upward pumping of subsoil, eliminates contamination and maintains porosity of different levels. For separation purposes, both woven / nonwoven Geotextiles may be used. The users in the India context are the contracting agencies – NHAI, PWD, BRO, etc. or the concessionaires/contractors suggesting the use of Geosynthetics in their designs.

b. **Reinforcement**: The purpose of Geosynthetics in the reinforcement function is to reinforce the weak sub-grade or subsoil. It helps to strengthen the soil surface and to increase the soils ability to stay put especially on the slopes. Further, it might additionally help in preventing water from pervading the slope and controlling the amount of infiltration that occurs during various rain events.

   Reinforcing aspect of Geosynthetics can be used for roads, temporary roads, pavements, air strips, stabilized road slopes, retaining walls, containment systems, controlling reflective cracking, etc. The users in the India context are again the contracting agencies for roads as well as water works departments in charge of embankment protection – NHAI, PWD, BRO, Water Works Dept., etc. or the concessionaires/contractors suggesting the use of Geosynthetics in their designs.

c. **Filtration**: The purpose of Geosynthetics with reference to drainage and filtration is simply to retain soil while allowing the passage of water. When Geosynthetics are used as drains, the water flow is within the plane of the Geosynthetic itself i.e., they have high lateral permeability. At the same time, Geosynthetics must possess adequate dimensional stability to retain their thickness under pressure. The life of pavement of highways/air fields, etc. is affected by the time for which the water remains under the structural section and its drainage system which is responsible for the removal of free water which is fed directly from the stone base course beneath the structure. Nonwovens are the preferred Geosynthetic for such applications where the primary requirement is filtration.

Applications are again road and railway construction. Another critical area is airport runways and taxiways which come under the AAI (Airports Authority of India).

d. **Drainage**: The use of Geosynthetics in drainage has made significant strides in changing the conventional procedure of using graded filters. Drainage composites are largely used to replace in one-product the standard package done by the filtration geotextiles and a draining natural gravel intermediate layer. Outstanding advantages of Geosynthetics in drainage are:

- It eliminates the filter sand with the dual media backfill
- In some cases, it eliminates the need for perforated pipes
- In situations where only sand backfill is available, it is possible to wrap the drainage pipe with fabric to act as a screening agent. The fabric, thereby, prevents the sand from entering perforation in the pipe
- With Geosynthetics, trench excavation is considerably reduced
- Many times the use of Geosynthetics eliminates the need for trench shoring

Needle-punched nonwoven Geotextile is preferred where drainage is the primary functional requirement. PVDs (Prefabricated Vertical Drains) are also applicable Geosynthetics for drainage solutions. Since drainage is required mostly in road and rail construction the key stakeholders are contractors to ensure pre-construction drainage as well as maintain CBR and water content.

e. **Containment**: This function means isolating one material from another. The most frequent use of this function is in landfills where impermeable linings prevent contamination of surrounding soils.

The barrier function is the primary purpose for any Geomembrane and GCL. This includes Geomembranes manufactured from polymeric, bituminous and Geocomposite clay liners (GCL). They are used to prevent the escape of liquids from containments or to prevent or reduce the flow of liquids through soils or other parts of construction works. PWDs (Public Works Department), Municipal Corporations, and private industries such as Cairn, HXL are the key users in India for these products as per the feedback received during the primary research.

f. **Protection**: Lining is used for cushioning and protection of membrane used for applications such as land fill and waste containment from puncture or training by sharp stone or stress. Geosynthetics can also be impregnated with polymeric or mineral sealing materials such as bentonite clay to provide flexible barriers to mixture. Usually needle-punched nonwovens are preferred for such applications, often in the form of

Geocomposites such as GCLs (Geosynthetic Clay Liner). Other key products catering to the protection function are Geotextile Tubes and Geobags for embankment protection from river/sea water, as well as Geonets and Polymer Gabions in retaining walls. PWDs (Public Works Department), Municipal Corporations, and private industries such as Cairn, HXL are the key users in India for these products as per the feedback received during primary research.

g. **Erosion control**: The geosynthetic acts to reduce soil erosion caused by rainfall impact and surface water runoff. For example, temporary geosynthetic blankets and permanent lightweight geosynthetic mats are placed over the otherwise exposed soil surface on slopes. Geotextile silt fences are used to remove suspended particles from sediment-laden runoff water. Some erosion control mats are manufactured using biodegradable wood fibres.

Each of these functions calls for highly specific textile performance characteristics. As the functional requirements are to be met over many years of the life of the civil construction, durability is often a very key requirement. Many applications require several of the above functions to be met simultaneously. Further, the cost of the geotechnical solution is also an important factor to be taken into account in evaluating solutions. This cross functionality can be seen in the table below.

Type of Geosynthetic (GS)	Separation	Reinforcement	Filtration	Drainage	Containment	Protection	Erosion Control
Geotextile	■	■	■	■		■	
Geogrid		■					■
Geonet				■			
Geomembrane					■		
GCL					■		
Geofoam	■	■					
Geocells	■	■					
Geocomposite	■	■	■	■	■		
Polymer Gabion						■	■
Geobags						■	■
Geotextile Tubes				■		■	■
PVDs			■	■			
Geomats		■		■			■
Geopipes				■			
Natural Fibre Geosynthetics	■	■	■	■			

Mostly used →	■

Table 3.2: Multifunctional nature of Geosynthetics and functionality within various applications

The various Geosynthetic products, their functions, applications and implementation guidelines are included in the attached “Handbook for Geosynthetics” in Annexure H. This handbook also includes information on the various manufacturers and design consultants for Geosynthetic products in India.

4 Solutions for different field level realities to help engineers choose appropriate material for a given situation

Through research conducted one of the primary impediments to the adoption of Geosynthetics is the fact that most of the consumer agencies like the NHAI, MoRTH, PWDs and Municipal Corporations do not believe that Geosynthetics are the most effective and generally economical option for applications requiring reinforcement, separation and drainage. While there are certainly other options, Geosynthetics have proven to be the preferred solution globally and have been implemented in some cases in India as well.

The cases below highlight certain real world scenarios where Geosynthetics provided solutions to these peculiar yet not uncommon problems. In this chapter the solutions actually implemented in India are listed, providing reference material for Indian projects. The solutions implemented abroad for which no pilot studies in India could be found are included in Chapter 7.4 of this report. These will be highlighted as areas for application based research going forward. The cases given below should be used in correspondence with consumer agencies by the O/o the TxC to drive home this point. The benefits in each of these cases manifest themselves either in reduced construction costs due to reduction in subgrade material, or in reduced maintenance costs through the life of the project, or by pure performance benefits such as in the case of drainage or embankments, or finally by environmental benefits that could not be achieved otherwise such as in the case of landfills.

4.1. Case study 1: Assam Railway Line Ballast Sinking

Location: 100 m long stretch extending from km 323/0 to 323/2 between Jamguri and Oating stations, in Golaghat District of Assam

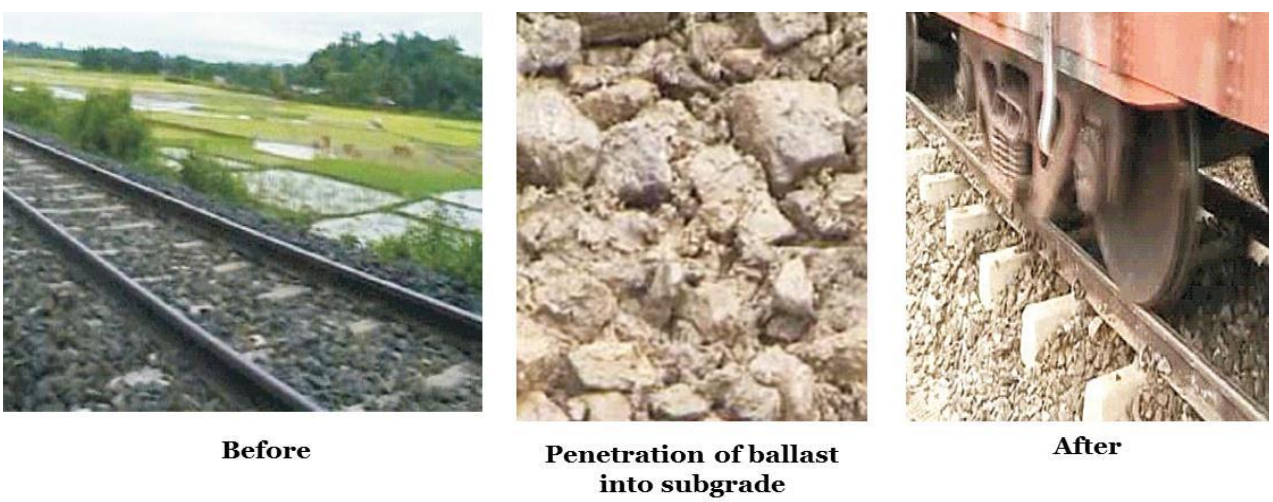


Figure 4.1: Ballast reinforcement – before & after

Problem:

- Ballast sinking due to following reasons:
  - Absence of a suitable blanket course.
  - The embankment fill seemed to be a fine grained plastic soil with an appreciable content of clay and silt.
  - Small lateral channels were cut into the soil to drain the runoff. If these channels were clogged water could pond and create problems.
  - A combination of factors could have allowed the subgrade to become excessively wet – heavy rainfall in the area; ponding of water on the formation because of lack of proper grading and cross fall of formation; capillary rise due to standing water in the paddy fields.
- Excavation of the formation revealed a mixture of ballast particles and fine grained subgrade soils (centre picture above). This shows that penetration of ballast into the subgrade was one of the major causes for the problem.

Solution:

- Building up / dressing the embankment to the correct level.
- Providing a nonwoven Geotextile (6 m width) as a separator and filter between the subgrade and the ballast. A polyester needle-punched nonwoven Geotextile available with roll width of 6 m was used for this application. The physical, mechanical and hydraulic properties of the Geotextile.
- Providing a biaxial Geogrid reinforcement (5 m width) below the ballast: Knitted and PVC coated biaxial Geogrid with a tensile strength of 40 kN/ m in both machine and cross-machine directions, aperture dimensions of 25 x 25 mm and roll width of 5 m was proposed for this purpose. The Geogrid is manufactured from superior grades of high tenacity, high molecular weight and low carboxyl end group polyester yarns which are formed into a grid structure using a highly sophisticated warp-knitting process and is then precision coated with a specially formulated PVC plastisol to produce a strong, flexible, tough, dimensionally stable and durable Geogrid.

Results:

- Embankment design: This is to minimize the infiltration of rain water into the embankment/subgrade and to avoid ponding of water.
- Geotextile: The Geotextile acts as a filter which prevents the pumping of subgrade fines into the ballast. Thus the Geotextile ensures that the effective thicknesses of ballast is not reduced with time and also keeps the ballast clean and free draining.
- Geogrid: This reduces the lateral spreading of ballast and minimizes the associated track settlements. When the ballast is locked into the apertures of the Geogrid the particle movements are substantially reduced. Hence abrasion and wear and tear of ballast particles will be reduced. Also, abrasion of the Geotextile caused by the ballast particle movements also would be controlled to an appreciable extent. The Geogrid

reinforcement increases the strength and stiffness of the ballast layer and thereby enhances its ability to distribute loads over a wider area. This will result in reduced vertical stresses and more uniform stress distribution on the subgrade. Placing cleaned ballast over the Geogrid and restore the track to the desired geometry.

Conclusion:

A case study pertaining to the rehabilitation of a portion of NF railway tracks with a serious ballast sinking problem, using Geogrids and Geotextiles was presented and the initial results seem to be very promising.

4.2. Case study 2: Calicut Bypass Embankment Instability

Location: Calicut Bye pass phase III, NH – 17, Kerala

Before

After

Figure 4.2: Embankment Stabilization – before & after

Problem:

It was required to construct a three km. long road embankment with heights of up to 5 m on very soft ground. The thickness of the soft clays at the site varied from 3 m to 8 m. Hence issues of embankment stability. Also, the upper most clay layer was extremely soft with very high water content. Therefore, it was not possible to carryout normal construction operations. However, removal of this layer was not a viable option because of uncertainty in thickness of layer, cost and time involved in excavation and removal and environmental objections to disposal of the excavated material.

Solution:

A woven Geotextile to stabilize the subgrade was used. A woven polypropylene tape Geotextile was selected for this purpose. Woven Geotextile installed at the surface of the sub-grade functioned as a separator between the very soft clay and the better quality fill material allowing placement of fill material without mixing and excessive rutting.

Results:

The Geotextile had a combination of mechanical and hydraulic characteristics making it suitable to function as a separator and reinforcement. In addition, it had a width of 5 m to minimize overlaps. It also acted as a reinforcement supporting the loads imposed by the initial lifts of embankment fill and construction traffic without inducing shear failure of the clay foundation. The restraint offered by the Geotextile, enabled the proper compaction of the initial lifts of embankment fill.

Conclusion:

The woven Geotextile resulted in an environment friendly solution and enabled the successful completion of the project with appreciable savings in cost and time.

4.3. Case study 3: Road Failure Due To Soft Subsoil

Figure 4.3: Geotextile reinforcement – before & after

Figure 4.4: Geotextile reinforcement layer on top of subgrade below the granular base which is being placed onto the Geotextiles

Location: Daund – Gar Dapoli Road (Pune District)

Project:

Construction of Daund – Gar Dapoli Road (Pune District) km 14/500 to 16/500 with the use of woven slit film tape polypropylene Geotextile fabrics as reinforcing layer at the interface of existing subgrade & granular base..

Problem:

The road passes through sugarcane area having black cotton soil as a natural subgrade and has inadequate drainage. The root cause of road failure was attributed to CH type of soil, with low cohesion under saturated and un-drained conditions, reasonably heavy traffic and high axel loads and inadequate drainage arrangement

Solution

An indigenously designed PP woven slit film Geotextile was introduced along the interface between existing subgrade and granular base over a 2 km long stretch of road along MDR 82 in Daund region of Pune district. This is carried out to enable to compare the performance of reinforced stretch with an unreinforced stretches in adjoin areas.

Results

In Geotextile reinforced section of the road after black top: there are no visible sign of distress even after a period of three years & nine months, whereas the earlier experience showed that the road constructed without any Geotextile layer or strengthening measures was observed to deteriorate within 6 months . This shows a significant influence of the Geotextile layer on the performance of the road.

4.4. Case study 4: Geogrid Reinforced Soil Walls With Segmental Panel Facia

Location: Vadodara – Bharuch Section of NH-8 in the State of Gujarat

Material Used: Geogrid, Non-woven Geotextile

Salient Features of the Reinforced Soil Walls:

Wall Facing Area: 68,323 sq. m.

Wall Height: 10m

Soil Reinforcement: Knitted & PVC coated polyester Geogrids with Tensile Strength of 40 to 250 KN/m

Facing: Segmental Panel Fascia

Design Methodology: BS 8006: 1995 (Static Condition)

FHWA-NHI-00-043 (Seismic Condition)

Figure 4.5: Reinforced Earth Wall using Geogrids

Project Overview:

There were two ROB approaches, eleven flyovers and one vehicular underpass for reinforced soil work for approaches. Total stretch length of the project was around 70 Km, which starts from Vadodara city to Bharuch city in Gujarat, India.

Problem:

Area is located, where the black cotton soil is available up to the depth of 3 to 8m. It was difficult to achieve required safe nearing capacity at the depth to 1 to 1.5 meter. Maximum height of the reinforced soil wall is 10 meter as it has to connect the ROB's as well as Flyover's.

Solution:

Figure 4.6: RE Wall elevation using Geogrids

Detailed soil investigation has been carried out to know the actual extent of black cotton soil. Area, where the depth of soil is up to 2.0 to 2.5 meter has been replaced with good quality granular fill. Other areas, where the depth of black cotton soil is on higher side, it has been replaced up-to 2.5 meter, then provide the plate form with the layers of Geosynthetic material with granular fill with maximum of 500mm to 750mm. Over the plate form levelling pad has been placed for the erection work. Also to ensure the increased safe bearing capacity, plate load test has been done for verification.

The borehole and foundation soil test report showed existence of black cotton soil in the area where the RS Wall was to be constructed. Thereby experts' advice was taken and multi layers of good soil were provided by excavating the black cotton soil to achieve the required safe bearing capacity that will be sufficient to withstand the bearing pressure exerted by the weight of the infill and other external loads. The design of the walls was carried out using the BS 8006: 1995 for Static Condition & FHWANHI- 00-043 for Seismic Condition, which comprised checks for external, internal and global stability under static and seismic conditions.

Property/Fill	Cohesion (C) – KN/m2	Angle of Internal Friction (ϕ)	Unit Weight (γ) – KN/m3
Reinforced Infill Soil	0	35	20
Retained Soil	0	35	20
Foundation Soil	0	30	18

Results:

The project was successfully completed in August 2009.

4.5. Case study 5: Improvement In Unpaved Landfill Access Road Using Geocells

Location: West Boragaon, Guwahati, Assam, India

Material Used: Geocells

Problem:

The approach road to the proposed landfill site was subject to heavy settlements because it was built with filled up soil on a low lying area with high water table. This resulted in a very weak road which created challenges for the heavy vehicles (like garbage dumpers) to operate. Previously no treatment was done except simple dumping of locally available soil with rolling & compaction. The water table of the area was only about 100mm to 500mm below the existing ground level. The continuous process of dumping soil & compacting it was offering little benefit, as with repeated compaction the settlement kept increasing thereby making the area fully unusable for vehicular movement. Matters were becoming severe during the monsoons. The surrounding water was hampering the movement of the garbage dumping trucks. The garbage trucks were increasingly dumping garbage much before the demarcated area, thus triggering a total mismanagement of the landfill and creating financial losses for the project. Moreover, with the impending monsoon season and ongoing frequent showers, conditions were getting increasingly difficult and posed major challenges in maintaining the serviceability of the approach road.

Figure 4.7: Before laying Geogrid

Solution:

Figure 4.8: Geogrid being laid

Geocell are a proven solution for slope stabilization, load support, earth retention and channel applications. The product is light and easily transported to remote areas. This expandable, honeycomb-like cellular structure can be collapsed and easily transported. The Geocell remains flexible during installation and also is inert against naturally found chemicals. Another cost saving factor was that the amount of infill needed at the site could be estimated due to the system's uniform depth, and that no training or special tools were required for installation. The cells of the Geocell System provide a permanent flexible form while acting as a series of expansion joints adjusting to the shape and grade of the soil. The sections were transported in folded forms by trucks and placed in designated areas. Geocell installation was complete in 3 days' time, whereas the total road was completed in less than 40 days.

Results:

In normal construction method, to stabilize the soil and to sustain heavy vehicular traffic, at least 800mm to 1m murrum infill would have been required, but by using Geocells the client managed to save precious natural resources & also lower the carbon footprint. Geocells being a fast and all-weather installation solution, no time was wasted because of the ongoing heavy rains. Both the savings in natural resources and time resulted in substantial savings for the client.

4.6. Case study 6: Seepage Control With Geomembrane

Figure 4.9: Lining for water pond being laid

Location: Bombay Presidency Golf Course, Chembur, Mumbai

Material Used: Geomembrane, jute Geotextile

Project Overview:

Mumbai was constructed by placing huge amount of sand and gravel to make a well drained golf course. Some lakes were also built as obstacles for the game.

Problem:

In summer, water from the lakes would seep out through the well-drained soil with which the golf course was built. The lawn water requirement in summer was high and water was not available. In order to solve this problem seepage control treatment was implemented.

Solution and Results:

Figure 4.10: Lining for water pond complete

The technique selected was by the use of 1.0 mm thick HDPE Geomembrane. The water in Lake No 11 was at its minimum. The residual water was evacuated and a Poklane was used to excavate 30 cm thick layer of mud from the bottom and the slopes. The slopes were dressed to achieve desired contours and evenness. Nonwoven needle punched Geotextile was placed on the soil to provide protection to the Geomembrane and decrease chances of puncturing of the Geomembrane. 1 mm thick HDPE Geomembrane was laid over the Geotextile and welded to form a water tight structure. The Geotextile and Geomembrane were anchored in trenches of size 60 cm X 60 cm approximately, around 1m away from the start of slope. A 30 cm thick layer of stoneless soil was placed over the Geomembrane at the bottom and a 30 cm thick layer of fertile soil was placed on the slopes to support grass and other vegetation. In order to help quick establishment of vegetation and to control erosion of soil from the slopes, coir Geotextile was placed on the slopes. It was anchored in a trench and weighed down to the slopes by bamboo stakes. Thus completed, water was released into the lake. Grass saplings were planted on the slopes through the opening in the coir Geotextile. The slopes were watered for a few days. Soon monsoon rains lashed Mumbai. Grass and other vegetation established fast and the area was restored to its original state. Fountains were installed for aeration and aesthetics. Seepage was thus controlled and water available in summer.

4.7. Case study 7: Chennai Reservoir Erosion and Lack of Stabilization

Location: Construction of Kandaleru Earthen Bund Reservoir, Chennai

Problem: Kandaleru reservoir earthen dam was eroded at chainage 7.50KM to 8.12KM due to high force currents from the reservoir. Slope stabilisation of existing Kandaleru Dam for a length of 500m was another issue. The height of Earthen Dam is 45m.

Figure 4.11: Slope stabilization – before & after

Solution: Laying the drainage layer – Using Polypropylene instead of conventional filter materials. Fill with Riprap of 450mm thick. Then tie the Riprap with gabions

Results: Polypropylene is an excellent filter material for drainage. It has been physically observed for the last 2 years and the Kandaleru reservoir dam has not faced any problems. The use of polypropylene as a filter material is being proposed for similar projects in India. This prevents excessive migration of soil and reduced excavation.

4.8. Case study 8: Landslides Impacting Konkan Railway

Location: Konkan Railway Route, India - Environmental/ Slope Protection/Ballast Retention - Gabions, Baby Gabions & Rockfall Netting

Problem

Konkan Railway Project can be considered as one of the most prestigious projects in the Construction Industry of India. The project was launched in 1989 and the track became operational in the year 1998.The 760 km line passes through complex terrains. In many of the stretches, the available space was restricted and the side slopes were very steep. This formidable terrain and the short construction period necessitated the use of several technological innovations.

Figure 4.12: Gabions for landslide mitigation constructed in 2001

The construction and widening of the track called for large quantities of cutting in rocks of lateritic and basaltic origin. The exposed lateritic terrains were subjected to heavy rainfall and in the presence of water; the laterite loses all of its cohesiveness, strength and become very vulnerable to cause heavy slides and slips. This problem necessitated the provision of several landslide mitigation techniques like construction of proper retaining walls and rock fall prevention measures.

Figure 4.13: A typical KRCL stretch with narrow tracks & steep side slope

Figure 4.14: Gabion Structure for abutment protection during construction

The ballast which is laid below the tracks primarily serves the purpose of load dispersion apart from giving added resilience. Conventionally, a ballast layer of depth 250 mm is adopted below the sleepers with a depth of 500mm on the sides, sloping outwards. This requires a greater utilisation of space on the sides, with sufficient width for embankment. Further over a period of time, due to the repeated use of track, the ballast has a tendency to roll out of tracks.

Solution & Result

Gabion walls with stepped rear face were adopted in many vulnerable stretches of hill cuttings of Konkan Railway. Backfill soil was carefully selected ensuring the omission of clayey soil. Additional arrangements included provision of transverse drainage system, comprising of 2.9mm dia heavy duty PVC pipes per metre lay at a slope of about 1:20.to carry water away from the foundation. The foundation comprised basically of lateritic soil. Owing to the

Figure 4.15: Gabions for Platform construction at Ratnagiri & Kudal Railway Stations

relatively high level of water table, the foundation depth was restricted to a minimum of 0.5m. At places where the foundation comprises of very fine clayey soil, Geotextile was placed at the bottom of the Gabion Wall in addition to the backside in order to prevent the ingress of fines. Gabion walls were selected due to its flexibility, speed in construction and fine draining nature.

Along the Konkan Railway Route, instead of using the conventional methods, Gabion boxes were used for the construction of about 12 railway platforms. This innovative step resulted in easy and speedy construction of railway platforms. After successful installation at one platform, they found it a very cost effective solution. The cost was reduced to around 50% as compared to traditional construction methods.

Figure 4.16: Baby Gabions for ballast retention

For the retention of ballast and reduce periodical maintenance, an entire new size of Gabions were adopted in Konkan Railway tracks. These Gabions are referred as baby Gabions and are of much smaller size; say 4mx.3mx.3m and 2mx0.5mx0.5m with a mesh opening size of 60 mmx80 mm, and 2.2mm wire diameter. Apart from less maintenance and retention of ballast, Baby Gabions, it was possible to reduce the width of embankment and thus to reduce the quantity of earthwork to a great extent by the adoption of Baby Gabions.

Figure 4.17: Slope after vegetation has grown

To prevent rock fall from the side hill slopes, double twist hexagonal PVC Coated netting of type 10x12 was laid along the slope and then anchored into the trench using suitable anchoring techniques. Double twist Mesh was selected over chain link mesh as it is not prone to unravelling. Their high tensile strength, punching resistance and low installation costs also helped the adoption of this system.

4.9. Case study 9: Erosion Control and Seepage Control of embankment of closed red mud pond

Location Details:

Area: 9000 sqm.

Slope Angle: 40 to 45 degrees.

Height of red mud pond embankment: 17 to 18 m

Rainfall: 150 cm annually.

Figure 4.18: Prefabricated Drain

Overview:

When Aluminium is extracted from Bauxite, a waste known as Red Mud is generated. This Mud is highly alkaline and contains Oxides of Iron, Titanium and Calcium. It may also contain traces of heavy metals and sometimes radioactive materials. The red mud pond was built many years ago near a river, without any bottom lining system and subsequently closed, when full, by covering with a thick layer of cinder and soil. Some afforestation work was also carried out to make the dump area green.

Problem:

During monsoon, there was erosion of the top surface of the embankment. Soil was entering the river from the embankment. There was also a problem of seepage of caustic materials along with infiltrated rain water and this too entered the river water.

Figure 4.19: Coir Geocells

Solution:

The ideal solution was to cap the whole area with a Geosynthetic lining system so that rain water ingress could be stopped. However, due to financial constraints a simpler solution was offered. The idea was to limit the ingress of water by removing all surface water before it infiltrated deep into the fill. This way the water would be devoid of any chemicals from the red mud. The Erosion was proposed to be controlled by growing vegetation.

Material Requirement:

Nonwoven Geotextile as filter, coir Geocells, a prefabricated drain and perforated pipes.

Method of installation:

1. The slope was cut and filled and compacted to make the slope uniform.
2. Trenches 1m depth and 0.5m wide were excavated on the top flat surface. The excavated earth from trenches was used to fill the non-uniform slope or in backfilling the trench after installing the viadrain. One viadrain trench at the bottom of the slope was also excavated. The trench horizontal to the embankment should be excavated in a slope of 1 in 50.
3. Trenches were cut on slopes and completed with laying of Viadrain and perforated pipes.
4. The soil from these trenches was used as backfill.
5. A trench drain was made parallel to the embankment 1.5 m away from the edge. The trench was 1 m deep and 0.5 m wide. Nonwoven Geotextile material was laid filled with stone metal.
6. In the bottom trench Viadrain was placed and the trench was filled with excavated soil.
7. Coir Geocell was placed over the whole sloped area. The Geocell layer was extended 1.5 m over the shoulder of the slope.
8. Geocell was half filled with top soil and seeds.
9. Watering of slope was not required as rainy season began soon after installation

Figure 4.20: Barren slope after drainage works

Figure 4.21: Vegetation growing after 40 days

Figure 4.22: Vegetation growing after 100 days

Results:

After the first monsoon it has been found that the area has become totally green with no visible signs of erosion. There has been no seepage from the embankment. The water is clear and contains pollutants within specified limits.

4.10. Case study 10: Protection Of Shoreline and Restoration of Beach at Dahanu in Maharashtra

Location: Dahanu, Maharashtra.

Client : Maharashtra Coastal Department

Product : Geotextile Tube, 20m in length

Overview

Dahanu is located on the western coast of India, facing Arabian Sea on the border of Maharashtra and Gujarat. The 1500m long beach is continuously eroding due to abrasive action of the sea waves. The increasing erosion of the beach has also endangered the adjoining structures and habitation near this location.

Problem:

The conventional methods for restoration of the beach and erosion control have been tried and found ineffective.

Solution:

The Geotextile Tubes made of engineered high strength woven fabric, have been thought of as an effective solution to the problem due to their capability of controlling the shore erosion caused by strong wave action on the one hand and facilitating the natural deposition of sand layer behind them in longer term. The Geotextile Tubes that have been proven worldwide as an effective alternative to conventional methods of shore protection, erosion control, and reclamation was proposed as a solution to the problem here. These systems have been successfully installed in various parts of the world for the construction of different type of marine and coastal structures. The schematic diagram of the proposed solution is shown here.

Figure 4.23: Geotextile tube being installed

The system has three components

a) Main tube (3.0m theoretical dia.)
b) Anchor tube (1.0m theoretical dia.)

c) Scour Apron made of high strength woven Geotextile to prevent scouring of the base.

The above system performs as erosion control mechanism for protection of shoreline and deposition of natural sand behind it. On the present project site the problem was that of continuous erosion of shoreline due to wave action. To solve the problem a Groyen was proposed made of 3.0m theoretical diameter Geotextile Tube and an anchor tube of 1.0m theoretical diameter was installed in front of this as an anchor toe.

Installation:

Submersible slurry pumps were deployed to fill the Tech-tubes. A sand slurry mix of 70% water and 30% sand was pumped through 10 BHP pumps. This mix was pumped from the excavated pits made specifically to pump the sand slurry. The slurry was pumped into the Tech-tubes through the inlet ports provided on top of the tubes. The pumping operation was conducted in stages and planned according to the tides. After each filling operation the Tech-tubes are left for expulsion of water from fabric and consolidation of sand.

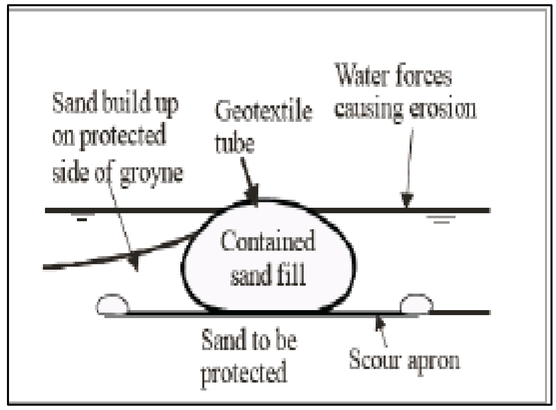


Figure 4.24: Illustration of Geotextile tube installation

Results:

The Geotextile Tubes have been installed on part of the eroded beach line. The flexible groyen made up of Geotextile Tubes is 1.6m high after consolidation. This coastal structure is found to fulfil the desired objective in successful manner.

4.11. Case study 11: Low CBR in West Bengal Rural Roads

Location: West Bengal – Construction under PMGSY – Jute Geotextile


Figure 4.25: JGT laid over subgrade


Figure 4.26: Finished road

Problem

Low CBR resulted in constant cratering and potholes in rural roads in West Bengal and so under PMGSY Jute Geotextile (JGT) was used on the sub-grade for improving its CBR (California Bearing Ratio).

Details

Construction of Andulia-Boyratala road was undertaken by the North 24-Parganas Zilla Parishad under PMGSY scheme. The road starts from Lauhati-Haroa State Highway and ends at Boyalghata. Total length of the road is 3.50 km and the estimated cost is Rs. 147.71 lakhs. The type of soil at Andulia-Boyratola Road is generally brown silty clay with admixture of small quantities of sand.

Results

The pavement thickness by using JGT was reduced by 85 mm from the conventional method of design. There was thus a saving of 75 mm thickness of jhama brick aggregates. The cost of the same as per prevailing Schedule of Rates of the area is Rs. 2,44,267.00 per km. The cost of JGT including laying at site was Rs. 1,83,595.00 per km only. Thus there was a net savings of Rs. 60,672.00 per km or 25% of the material cost of jhama brick agregates with the use of JGT.

Conclusion

One aspect that needs special mention is that brief effective life of JGT is not as much of a discouraging factor as soil gets consolidated to its maximum within 1-2 years. The consolidation is a result of arrested movement of soil particles on top with concurrent release of pore water due to imposition of extraneous loads. Separation of sub-base and sub-grade also contributes to gradual and natural consolidation of the sub-grade. It has been found from extensive experiments that the consolidation time required for the purpose varies between one and two years depending on the type of soil, its moisture content and the extent and frequency of extraneous loads. In any case, Geosynthetic be it man-made or natural does not technically need an effective life beyond two years. JGT can be made to last to two to three years without impairment of strength. Considering the economy, easy availability and environmental advantages, JGT could deserve larger patronage from the highway and geotechnical engineers pending further pilot studies.

4.12. Case study 12: Destruction of Paddy Fields in Kerala

Location: Kuttanad, Kerala

Problem:

Kuttanad is situated in the Alleppey district of the state of Kerala that is known as the Venice of the East. Kuttanad, a low lying area at about 1 meter below MSL, is known as the rice bowl of the state of Kerala in the southernmost part of India. The deltaic formations of four major river systems criss-crossing this region are Pampa, Achencoil, Manimala and Meenachil, consolidating into the Vembanad Lake. The average rainfall is 316 cm, therefore, during the rainy season the whole area gets submerged due to overflowing of river/canal waters resulting in loss of its fertile soil and destruction of the paddy fields due to water logging.

Figure 4.27: Cross cutting application of coir yarn for paddy field protection

Solution:

Two treadle basket weave fabric (warp3 x weft3) made from coir yarn was chosen for the construction of a mud wall on a high velocity stream bank. The coir Geotextiles were applied on the stream bank for a stretch of 250meters. The basket weave fabrics were chosen as those are the thickest woven coir Geotextiles.

Results:

The mud wall erected using the coir Geotextile and bamboo poles provided protection from rice crop damage due to flooding. Now lush green paddy fields growing near the protected bank of stream can be observed. Due to slow biodegradation of coir Geotextiles the vegetation should be able to sustain and provide extra support to the mud wall even after 8 years of its erection.

Conclusion:

Woven coir Geotextile represent a typical peat soil. This Geotextile is also a proven effective separator and drainage filter. The strength of soil has been found to increase over the course of time as the organic skeleton has remained in place in compressed form that acts as a filter cake providing sustainable protection to the stream bank. Local vegetation grown over the embankment has been providing extra protection against erosion of the mud wall.

This is a case of a cross cutting application of Geosynthetics – in agriculture.

4.13. Case study 13: Coastal Embankment Protection using Geobags

Location: Jamuna-Meghna River, Bangladesh

Problem:

Protection of the river bank along the major rivers of Bangladesh has always been considered as a challenging engineering task against nature and the Bangladesh Water Development Board (BWDB) has been practicing different technology for controlling river bank erosion with the purpose of protecting lives and livelihoods. Its impact on environment especially on ecosystem is also an issue.

Solution:

BWDB has adopted sand-filled geo-textile bag (Geobag) technology during FAP-21 project to protect the riverbank erosion of the Jamuna River. The Jamuna-Meghna River Erosion Mitigation Project (JMREMP) is using geo-bags substantially from the year 2002 to protect the riverbank erosion of Jamuna River. The design includes, earth filled compaction, slope pitching works over geotextile, assorted block placing and Geobag placing on berm and Geobag dumping. There are three different sizes of Geobags that were used in protective works: Type A-175 kg, Type B-150 kg, and Type C-126 kg.

Results:

In comparison to conventional erosion protection work using C.C. (cement-concrete) block, gravel, hard rock etc., sand filled Geobag technology involves less installation and maintenance cost, light weight equipment, less space for construction works, lower transportation cost and lesser energy requirement. A joint study of Bangladesh University of Engineering and Technology (BUET), BWDB and Institute of Water Modelling (IWM) reveals that Geobag used in different revetment work along the major rivers of Bangladesh (Jamuna and Meghna) results 40% to 60% cost reduction. The constructing materials (sand) of Geobag are locally available and cost-effective compared to importing boulders from other countries. The manufacturing of geobags and quality control of the bags are easy compared to the C.C blocks and boulders.

Conclusion:

It can be concluded that, in comparison to C.C. block use, Geobags are more ecosystem and fisheries friendly with a cost saving of 40-60%, involves less construction activity, generating less construction waste and no chemical alteration to water quality. Despite the cost effectiveness, there are some potential negative impacts like short term shifting of some surface and bottom fish, temporal alteration of benthonic habitat and local shifting of dolphin migratory route due to induced sedimentation. However, these impacts are acceptable and could be reduced by adopting mitigation measures.

Based upon the discussions with various manufacturers the recent examples of Geobag installations are given below where they have been used for embankment protection.

Type of Structure	Name of River	Agency	Cost (Rs.)
Revetment (Geobags)	Ganges (Raghupur, Bihar)	Flexituff/ Bihar Govt	55 cr
Revetment (Geobags)	Sharda River, Pilbhit UP	UP Govt	13.5 L
Revetment (Geobags)	Brahmaputra (Majuli & Dholla)	Brahmaputra Board	9.3 cr

5 Environment and Economic Benefits

Today an infrastructural development holds a key thrust in India. The use of Geosynthetics is gaining popularity, particularly for road construction, repairs and rehabilitation. Roads across our nation are constructed over a wide variety of water sensitivity subgrade sol including silt, clay and loess. This soil condition, in combination with moisture results in the deterioration of the roads with time. Potholes, ruts and uneven pavements are not only a safety concern but affect the movement of goods and services that depend on reliable surface transportations system. Other applications where there is tremendous scope of Geosynthetic use includes landfill applications and canal lining applications.

In all of these areas it is important to equip engineers and project managers to have a tangible idea of the environmental and cost benefits of using geosynthetics, whether they are upfront benefits in the form of lower initial costs, or more importantly lifetime benefits of the project resulting in a cleaner environment, lower maintenance and savings in other ancillary costs in the future. This section aims to provide Life Cycle Cost Analysis methods for four key Geosynthetic applications – roads, landfills, reinforced soil walls and canals.

5.1 Environmental Benefits

Certain key applications where monetary benefit can be calculated have been identified and should be used to demonstrate the advantages of using Geosynthetics. More important are the qualitative and environmental benefits that these products provide such as:

1) Geosynthetic Clay Liners (GCLs) and Geomembranes in landfill applications prevent toxification of ground water and hence benefit the local ecology.
2) Geotextiles in road reinforcement applications lead to better roads with minimal degradation resulting in reduction in travel time, pollution due to slower travel with more traffic, etc. and are relatively intangible benefits that also need to be taken into account.
3) Use of Geomembranes in canal linings that helps prevent loss of water and has numerous indirect benefits. These indirect benefits consist of increased agricultural productivity as well as increased employment along with prevention of water logging and loss of fertile land.
4) Geocells in road laying helps increasing longevity resulting in benefits such as reduction in travel time, reduction in pollution due to slower travel with more traffic, etc.

5.2 Life Cycle Cost Method of Analysing Cost Effectiveness of Geosynthetics in Road Construction

Worldwide, over the past thirty years, using Geotextiles in roads to stabilize weak subgrades has been a well-accepted practice. However, from an Indian standpoint, it is important to understand the economics of using Geotextiles in such road applications. A complete life cycle cost analysis (LCCA), which includes not only costs to agencies but also cost to users, is urgently needed to assess the benefits of using Geotextile in various road applications.

The design and construction cement concrete pavement for highways involves the selection, specification and construction of a number of concrete pavement features. Among these features are foundation support, concrete slab thickness, concrete strength, etc. There are a variety of options available for each of these features resulting in several hundred of combinations of concrete pavement design possibilities. The highway agencies select the best combination of features based on experience, preference, perceived performance, perceived constructability and estimated cost.

The two criteria of performance and cost are usually interrelated. Features which improve performance often increase construction cost. The relationship between performance and cost varies from feature to feature. Some features cost relatively little to construct, but significantly increase pavement performance. Other features may significantly increase construction costs, but do little to improve performance.

Specifying agencies must balance these two criteria when selecting concrete pavement design features. Specifying a feature which adds to construction cost without a suitable increase in performance is a misuse of funds. In some cases, choosing a feature or features which considerably increase construction cost can make concrete completing unfeasible for the paving project. Likewise, selecting design features that don't provide adequate performance is also undesired. Less-than-adequate performance leads to early repairs, rehabilitation or reconstruction. Such procedures are costly and can cost more than the savings achieved from the lower construction costs. Additionally, the roadway users are inconvenienced sooner and more often. Safety concerns, both for the motoring public and contractor's or agency's workforce, are increased.

The concrete pavement designer's challenge is to select the features which give the proper balance of performance and cost for the desired level of service over the facility's life. The designer must choose features which provide more performance benefit than they cost. Adding a feature or changing a feature that increases the construction cost must be accompanied by a suitable increase in pavement performance.

Making Comparisons of Pavements with Different Design Features

Changing a concrete pavement design feature will change both construction costs and expected performance. The designer's challenge is to select features which add more performance benefit than cost. For such comparisons to be meaningful, it is essential to use a rational method of comparison.

One challenge is the dissimilar criteria used to measure performance and cost. While cost is measured in monetary terms, performance on the other hand is more difficult to quantify in a single unit of measurement.

One method of measuring performance is the number of vehicle loads that a pavement can carry before it deteriorates to a minimum level of serviceability. This measurement method is used in the AASHTO[5] rigid pavement design model. The number of traffic loads, expressed as 80 kN (18,000 lb.) equivalent single axle loads (ESAL's), carried until the pavement deteriorates to a minimum acceptable level of pavement condition, expressed in terms of pavement serviceability index (PSI), is calculated. Pavement rehabilitation is required when the minimum acceptable value, called the terminal pavement serviceability index, is reached. The difference between the pavements initial PSI and terminal PSI is the serviceability loss, ΔPSI, where:

$$\Delta PSI = PSI_{Initial} - PSI_{Terminal}$$

The ΔPSI can be used to compare the impacts of design features on pavement performance. For instance, the AASHTO model may show that changing from a dense-graded aggregate base to a lean concrete base, with no other design changes, will increase the number of ESALs required for the same ΔPSI by 35%. However, one must be careful, however, not to directly compare increases in load-carrying capacity to construction cost. Construction costs, in monetary terms, and pavement performance, in terms of ESAL capacity or other performance measurement, cannot be directly compared because the units of measurement are different. Likewise, changes in costs and ESALs brought about by changes in other design features cannot be directly compared because the units of measurement are completely dissimilar.

5.2.1 Life Cycle Cost Method of Analysing Cost Effectiveness of Geosynthetics in Road Construction – Approach #1

5.2.1.1 Features

LCCA is well suited for the evaluation of alternative concrete pavement designs with different design features because it systematically accounts for both the monetary costs and benefits that the feature provides over the life of the pavement. For instance, by comparing life cycle costs of two pavement designs, one design with a specific feature and the other without the feature, the designer can determine which pavement design has the lower life cycle cost. The design with

[5] *AASHTO Guide for Designer of Pavement Structures.* American Association of State Highway and Transportation Officials, Washington DC, 1994

the lower life cycle cost would be considered more cost-effective. The most cost effective pavement design is that with the lowest life cycle costs.

5.2.1.2 Framework for Pavement Type Selection

The basic methodology for project pavement type selection is based on evaluating mutually exclusive strategies. Fundamental quantifiable factors, agency cost, delay cost and performance are important in evaluating strategies and quantification of these fundamental factors is essential in making rational decisions. These factors can be combined to give reasonable output economic indicators. Figure 3.1 outlines an integrated framework for pavement type selection. The LCCA approach forms the primary basis for comparing alternative pavement strategies.

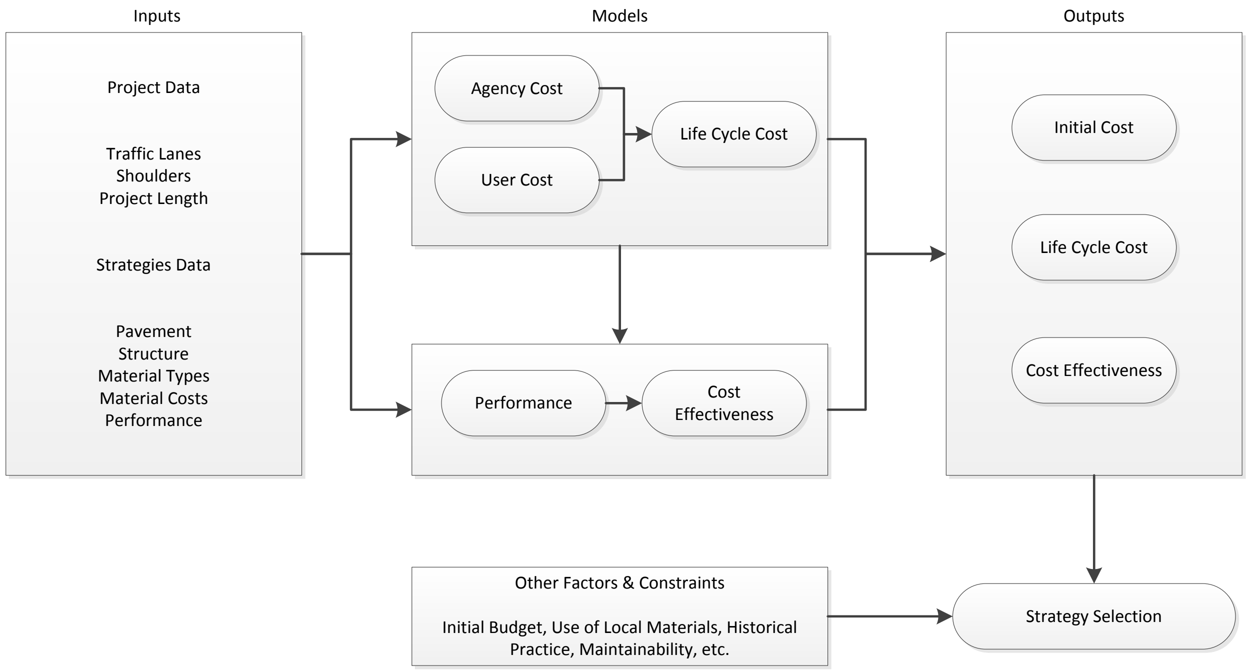


Figure 5.1: Framework for Pavement Type Selection Process

5.2.1.3 Factors to Consider in LCCA

There are two categories of costs be considered in the economic evaluation of alternative pavement strategies – Agency Costs are User Costs.

Agency costs include:

- Initial construction costs
- Future construction or rehabilitation costs
- Maintenance costs recurring throughout the design period
- Salvage or residual value at the end of the design period (a negative cost)
- Engineering and administrative costs
- Traffic control costs

User costs included:

- Travel time
- Vehicle operation
- Accidents
- Discomfort
- Time delay and extra vehicle operating costs during resurfacing or major maintenance

5.2.1.4 Initial Construction Cost

Initial construction cost savings are usually realized when constructing over a low subgrade. The amount of calculated savings may vary with the method and/or Geosynthetic used in design. However, the approach to quantify the cost savings is independent of the design method and Geosynthetic. A step-by-step procedure for computing an initial construction cost savings follows. This procedure assumed that the preferred design procedure has already been selected.

Step I – Quantify costs

a. Base course material in-place (Rs.BC), Rs/mm/sq.m (rupee/millimetre thickness/square meter of pavement)

b. Over excavation removal and disposal (Rs.OE), Rs./mm/sq.m

c. Geosynthetic in-place (Rs.G), Rs./sq.m

Step II – Quantify base course and over-excavation thickness reductions with Geosynthetic.

Thickness reduction, Δt_r, from the selected design procedure.

Step III – Compute initial construction cost savings (or increase)

a. Compute construction cost savings (Rs.CCS) per square meter of pavement area.

   Δt_r (Rs.BC + Rs.OE) – Rs.G = Rs.CCS Rs./sq.m

b. Compute cost savings on a lane-kilometre basis.

   Rs.CCS Rs./sq.m [(1000m)(3.7m lane width) = Rs.CCS Rs./lane-km

Step IV – Evaluate whether a more detailed analysis is justified

a. If initial construction costs are lower with Geosynthetic, use of Geosynthetic is justified. Perform a life-cycle cost analysis is cost savings over the life of the project must be quantified.

b. If initial construction costs are greater with the Geosynthetic, cost benefits may be realized over the life of the project. Therefore, perform life-cycle cost analysis

5.2.1.5 Using Existing LCCA Models to Determine the Cost-Effectiveness of Design Features

By comparing alternative designs with LCCA, it is possible to determine if a design feature is cost-effective. Existing LCCA which have been developed by state highway agencies and are based on observations of pavement performance tempered by engineering judgment models can be used. They are most commonly used for pavement type decisions, but can also be used for evaluating the cost-effectiveness of concrete pavement design features.

Example # 1 – Cost-Effective Analysis of Asphalt-Stabilized Drainable Bases Using Wisconsin DOT LCCA Model

The State of Wisconsin Department of Transportation (DOT) has developed a LCCA model for concrete pavements which can be used to compare the cost-effectiveness of subsurface drainage for concrete pavements. For purposes of this illustration, the following assumptions about relative costs will be used:

- Initial construction without drainage – cost = 100
- Initial construction with asphalt-stabilized drainable base – cost = 123
- First repair and grinding – cost = 20
- Subsequent repairs and overlay – cost = 25

Initial construction cost includes materials ~42-45%, construction equipment ~21-23%, labour ~10-12%, finance ~7-8%, enabling (includes design & consultancy) expenses ~5.5-6.5%, admin cost ~3.5-4.5%.

This example uses average values for service lives of construction and rehabilitation options from the Wisconsin DOT LCCA model. The relative net present worth values are calculated at a real discount rate of 5% (as used by the State of Wisconsin DOT in LCCA).

- Relative net present worth of un-drained design = 114
- Relative net present worth of drained design = 132

By comparing the relative life cycle costs it is apparent asphalt-stabilized drainable base is not cost-effective using Wisconsin DOT's LCCA model. In this example, a comparison between the relative net present worth of the un-drained pavement design to the relative initial cost of the drained pavement design is also informative:

- Relative net present worth of the undrained design including all expected rehabilitation costs over the next 50 years = 114
- Relative initial cost of design that includes asphalt-stabilized open graded base = 123

The LCCA shows that the relative initial cost of concrete pavement with asphalt-stabilized open graded base is greater than the relative net present worth of un-drained concrete pavements accounting for all expected rehabilitation for 50 years using Wisconsin DOT's LCCA model. This indicates that even if concrete pavement with asphalt-stabilized open graded base were to need no rehabilitation for 50 years, the design would not be cost-effective compared to a similar pavement section construction on dense graded aggregate base.

<u>Example # 2 – Cost-Effectiveness of Sealing Transverse Joints Using Wisconsin DOT LCCA Model</u>

Similar LCCA can also be used to assist in judging whether a change in design features is cost-effective. Again consider the Wisconsin DOT LCCA model for un-drained concrete pavements to evaluate the cost-effectiveness of transverse joint sealant. The current Wisconsin DOT standard practice is to leave transverse joints unsealed. The current LCCA model is based on this practice. What increase in performance is necessary to make silicone joint sealing cost-effective? For purpose of illustration, the following assumptions about relative costs will be used:

- Initial construction with unsealed joints – cost = 99 (unsealed transverse joints at 4.6 m (15 feet) spacing)
- Initial construction with silicone sealed joints – cost = 104 (sealed transverse joints at 4.6 m (15 feet) spacing)
- First repair and grinding – cost = 20
- Subsequent repairs and overlay – cost = 25

In this case, the additional life until first rehabilitation required to make joint sealing cost-effective will be calculated. The time between subsequent rehabilitations will be assumed to remain unchanged.

Through the model, it is clear that the silicone joint sealant must increase the pavements performance from 23 years to 28 years before the first rehabilitation is done in order to be cost-effective compared to unsealed transverse joints using the Wisconsin DOT life cycle cost analysis model.

Note: It is important to recognize that these examples are for illustration purposes only. Assumptions about relative costs of rehabilitation procedures may or may not be realistic. Furthermore, the examples did not include any consideration of user costs as the Wisconsin DOT generally does not include user costs directly in LCCA for pavement type selection. The purpose of these examples was to show how existing LCCA models can be used to evaluate the cost-effectiveness of concrete pavement design features.

In the examples shown in this study, user costs were not included in the relative cost of any rehabilitation procedures in LCCA. This is because user costs are not considered by highway agencies when performing life cycle cost analysis for pavement type selection. A recent study of similar models indicated that approximately 35% of the agencies include user cost in LCCA but it does not directly indicate if user costs are specifically used in LCCA of pavement design alternatives.

User delay costs can considerably impact LCCA and should considered when using LCCA for pavement type determination and for determining the cost-effectiveness of pavement design features. It is essential, however, that the user delay costs be applied consistently if they are to be used. If LCCA for pavement type selection does not include user delay cost, then this factor should likewise be ignored when determining the most cost-effective concrete pavement design. If user delay costs are used in LCCA for pavement type selection, they should be included in selecting the most cost-effective design features.

Inclusion of user delay cost in LCCA for determining the cost-effectiveness of design features can be shown by revisiting the Wisconsin DOT LCCA model for drained and un-drained pavements using relative costs and the following assumptions and estimates:

- Project length 8 km (5 miles) of four-lane divided highway
- One lane closed for rehabilitation
- Duration of lane closure = 30 days per lane, 120 days total
- Speed reduction 105 km/hour (65 miles/hour) to 64 km/hour (40 miles/hour)
- Restricted flow length 8 km (5 miles)
- Restricted flow for 7.5 minutes (8 km at 64 km/hour) (5 miles at 40 miles/hour)
- Overall increased travel time = 2.9 minutes
- Value of time lost (cars) = $.25/minute
- Value of time lost (trucks) = $1.00/minute
- Average daily traffic (cars) = 25,000
- Average daily traffic (trucks) = 5,000
- Delay cost (cars) = 120 x 2.9 x .25 x 25,000 = $2,175,000
- Delay cost (trucks) = 120 x 2.9 x 1.00 x 5,000 = $1,740,000
- Total delay cost = $3,915,000
- Relative cost of user delays for rehabilitation = 0.59

When rehabilitation costs are adjusted to include an additional relative cost of 59 for each rehabilitation operation the relative net present worth as calculated by the LCCA is:

- Relative net present worth of undrained design = 151
- Relative net present worth of drained design = 156

Although the relative net present worth of drained designs are closer when user delay costs are included, the use of an asphalt-stabilized in open graded drainage layer is not cost effective using the Wisconsin DOT LCCA model based on the conditions and assumptions used in this example.

Note: As with previous examples, these LCCA including user delay costs are for illustrative purposes only. Conclusions on the cost-effectiveness of any design feature in this study are only for illustration and are based on the assumed relative costs of rehabilitation operations (including user delay costs), and time periods between rehabilitation operations, which may or may not be valid.

5.2.2 Life Cycle Cost Method of Analysing Cost Effectiveness of Geosynthetics in Road Construction – Approach #2

A more basic Life Cycle Cost Analysis calculation used in a few case studies in India can be seen below. This formula takes into account only direct costs and not user costs as outlined in the previous section. Hence factors under consideration are:

x = initial cost of a flexible pavement section

r_m = maintenance cost of un-reinforced pavement

C_{UR} = Cost of un-reinforced pavement for a period of 15 years

n_{oL} = number of overlays in design life of road

y = cost of overlay per lane per km

r_{mR} = maintenance cost of reinforced pavement

C_R = Cost of reinforced pavement for a period of 15 years

Here the upfront cost of the Geosynthetics is compared to the maintenance costs over a typical lifetime of 15 years for the road. The maintenance costs are calculated as the cost per overlay times the number of overlays required during the lifetime of the road i.e. 15 years. The difference in the 2 amounts including total up front cost gives the Net Cost Savings (NCS) over the 15 year lifetime of the road. The formulas used to calculate this difference can be seen below:

$$C_{UR} = \left(1 + \frac{r_m}{100}\right)x + n_{OL}y$$

$$C_R = \left(1 + \frac{r_{mR}}{100}\right)x + n_{OL}y + x_G - x_{\Delta h}$$

$$NCS = C_{UR} - C_R$$

Initial construction cost includes materials ~42-45%, construction equipment ~21-23%, labour ~10-12%, finance ~7-8%, enabling {includes design & consultancy} expenses ~5.5-6.5%, admin cost ~3.5-4.5%). *Source*: *"Tenth Five Year Plan 2002-07 Vol. 2, Sectoral Policies & Programmes"*

An example of a cost benefit analysis using this method can be seen in section 5.3.2 of this report.

5.2.3 Life Cycle Cost Analysis of Analysing Cost Effectiveness of Geosynthetics in Landfill Applications

Geosynthetic Clay Liners (GCLs) represents an innovative way (and fast gaining wider acceptance) as a barrier system in municipal solid waste landfill applications. Several regulations specify design standard for bottom liners and final covers. GCL technology offers some unique advantages over conventional bottom liners and covers. Some of the benefits of using GCLs have been listed below:

- Fast and easy to install
- Low hydraulic conductivity (i.e. low permeability)
- Have the ability to self-repair any rips or holes caused by the swelling of properties of the bentonite from which they are made
- Cost effective
- Not as thick as traditional clay, enabling engineers to construct landfills that maximize capacity while protecting area ground water

Use of GCL in landfills can lead to substantial life cycle cost savings either by increasing the slopes of the landfill (making the slope more steep), thus increasing the capacity of the landfill or by reducing maintenance cost of the landfills.

One of the ways to calculate the benefits using the life cycle cost analysis of using GLC in a landfill is to compare the capacity of the landfill with and without the use of GCL. As mentioned above, use of the GCL structurally allows the engineer to expand the area of the landfill (and thus its capacity) by constructing steeper slopes. Studies have shown that GLCs provides sufficient resistance to the internal shear and physical displacement to maintain good slope stability for landfills.

The benefit can be calculated using the following formula:

- Increase in revenue due to the extra airspace (capacity) of the landfill by increasing slope of landfill side walls as compared to a landfill using conventional clay liners
- Extra airspace means more sand/soil/gravel that needs to be excavated, which can be sold in the market
- Use of geosynthetic requires relatively a thinner layer of clay for construction, resulting into substantial cost savings owing to the cost of clay as well as transportation of clay
- Increase in waste volume also significantly increases the life of the landfill due to additional capacity more time required to fill the landfill

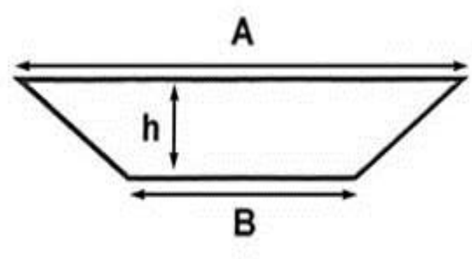


Figure 5.1: Trapezoidal cross section of a landfill

Volume of landfill = (A+B) * (1/2) * h * L

Where "L" is the length of the landfill perpendicular to the cross section.

If slope is made steeper then "B" increases, resulting in larger volume. This new dimension shall be called "B_2".

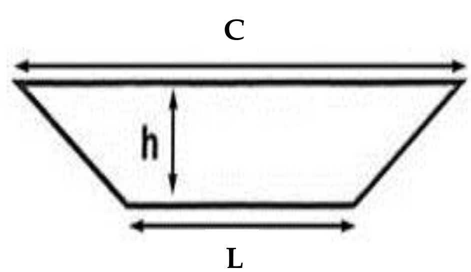


Figure 5.2: Trapezoidal cross section of a landfill in other dimension

Hence the increase in volume of the landfill will be:

$[(A+B_2) * (1/2) * h * L] – [(A+B) * (1/2) * h * L]$

In addition to this, a similar difference in volume will have to be calculated along the parallel direction of the cross section.

If slope is made steeper then "L" increases, resulting in larger volume. This new dimension shall be called "L_2".

The increase in volume alone this dimension will be:

$[(C+L_2) * (1/2) * h * B_2] – [(A+B) * (1/2) * h * B_2]$

Adding the two together gives us the total increase in volume "V_{DIFF}" of the landfill. This can be multiplied by the waste disposal revenue per unit volume "R_{WD}" to get total additional revenue from increase in size of landfill.

Increase in revenue (additional landfill volume) = V_{DIFF} (m^3) * R_{WD} (Rs./m^3)

This difference in volume is also additional excavated material (sand/gravel) that can be sold per unit volume "R_{EM}".

Increase in revenue (additional excavated material) = V_{DIFF} (m^3) * R_{EM} (Rs./m^3)

The cost difference is a result of:

- Reduction in liner area as surface area decreases due to decrease in slope hence less clay required
- Additional cost of geomembrane and GCL (Geosynthetic Clay Liner) calculated on per unit area basis
- Reduction in liner thickness reducing the cost of clay itself as well as transportation costs on a per unit volume basis

The sum of the cost difference as well as the increase in revenue gives us the total cost benefit of using geosynthetics in landfill applications. An example of this analysis can be seen in section 5.3.1.

5.2.4 Life Cycle Cost Analysis of Analysing Cost Effectiveness of Geosynthetics in Canal Lining Applications

As clean water becomes more difficult to acquire, the need for secure water containment and transport grows. This problem is exacerbated by urban water demands and increased agricultural production in remote areas around the world. To mitigate this problem, canals have been constructed to transport water from the source to where it is needed. Many of these canals have been either earthen or concrete lined. Earthen canals, while relatively inexpensive to construct, not only lose 50 percent or more of the water they transport to seepage but are also prone to erosion, vegetative growth and other problems. Concrete canals solve the problems of erosion and vegetative growth, but are more costly to construct and prone to cracking over time, resulting in significant loss of water to seepage. In fact, a concrete lined canal may still lose 30 percent of water to seepage.

Geosynthetics, either alone or in conjunction with a concrete veneer, can greatly increase the effectiveness of a canal lining system. Studies indicates that seepage can be reduced by 50 percent or more for earthen canals to 10 percent for geomembrane lined canals and less than 5 percent for canals using geomembrane in conjunction with a concrete cover. Not only are erosion and vegetative intrusion mitigated, but leakage is greatly reduced as compared to a concrete alone system. While the concrete veneer may still crack over time, the geomembrane remains in place underneath the veneer to prevent seepage until the concrete can be repaired. In addition to geomembranes, geotextiles may be used underneath the geomembrane to cushion it from rocky or uneven subgrade. Geomembranes are well suited not only for new construction, but also for lining over existing earthen or concrete canals that may be cracked and leaking. Different sections of the canal may be repaired over time to reduce leakage at the critical points if the current budget does not allow for a complete relining.

Table 5.1 below, details the construction and maintenance costs for the various systems as well as life expectancy, effectiveness of seepage reduction and benefit/cost (B/C) ratios. The B/C ratio is defined as the amount of water saved per dollar spent. Additionally, the B/C ratio for maintenance is 10–12 for all types of systems. That is, for every Rs. 1 spent on maintenance, the end user conserves Rs. 10–12 worth of water.

Type of Lining System	Concrete Alone	Exposed Membrane	Geomembrane with Concrete Cover
Construction Cost (Rs./ft^2)	105-128	43-84	134-140
Anticipated Lifetime	40-60	10-25	40-60
Maintenance Cost (Rs./ft^2/year)	0.27	0.55	0.27
Seepage reduction (% effective)	70	90	95
B/C Ratio	3.0-3.5	1.9-3.2	3.5-3.7

Table 5.1: Cost, Life and Effectiveness

Using the variables described in the table above, a cost-benefit analysis can be done while constructing a new canal with geomembrane lining or while repairing an old one. An example of some of the direct cost benefits of canal linings using geomembrane as well as some indirect benefits can be seen in section 5.3.3.

5.2.5 Measuring Data

Calculating financial viability of any geosynthetic project is heavily dependent on the robustness of the data. It is necessary to capture data in two distinct buckets:

1. Upfront Cost/Initial Costs – This is the expenditure carried out in the construction phase of the project and will typically consist of materials costs plus installation costs (labour, etc.). The breakup is as follows: materials ~42-45%, construction equipment ~21-

23%, labour ~10-12%, finance ~7-8%, enabling (includes design & consultancy) expenses ~5.5-6.5%, admin cost ~3.5-4.5%[6].

2. Lifetime/Maintenance Costs – This is the expenditure required towards maintenance over the lifetime of the project/product. This is typically recorded on an annual basis.

The cases below have been based upon a combination of data collected from real world installations and industry expenditure norms/benchmarks which were used wherever actual project data was not available.

5.3 Cost Benefit Analysis

Certain key applications where monetary benefit can be calculated have been identified and should be used to demonstrate the advantages of using Geosynthetics. A summary of benefits can be seen below:

Sr #	Application	Cost of Geo Syn impl. (A)	Up Front Savings (B)	Lifetime Savings (C)	Net Savings (D)	ROI (D/A)
1	Geotextiles in Road Subgrade Reinforcement per km	₹375,000	₹ 15,55,688 (Breakeven = 0 years)	₹ 49,17,354	₹ 64,73,042	1762%
2	Geomembrane & Geotextile in Canal Lining per km	₹ 4,93,00,000	- ₹ 2,95,00,000 (Breakeven = 10-15 years)	₹ 4,35,00,000	₹ 1,40,00,042 (+₹3,11,00,000 /km in tangible indirect benefits)	28%
3	Geocells in Road Subgrade Reinforcement per km	₹16,12,500	₹ 3,18,187 (Breakeven = 0 years)	₹ 31,84,354	₹ 35,03,042	217%
4	Geogrid in Reinforced Soil Wall (8m height) per m	₹14,800	₹ 8,153 (Breakeven = 0 years)	₹ 0	₹ 8,153	55%
5	Geotextiles & Geomembranes in Landfills for 5.9 Mn m^3 **US Case Study*	$47,414	$201,864 (savings through sales of additional sand excavated & decrease in cost for liner) (Breakeven = 0 years)	$773,625	$975,489	2057%
6	Geobags in Embankment Protection[7] (per km)	$2.5 million	$1.4 million (Breakeven = 0 years) (vs. RCC revetments)	0	$1.4 million	56%

Table 5.2: Summary of Cost Benefit Analyses

[6] Planning Commission, "Tenth Five Year Plan 2002-07 Vol. 2, Sectoral Policies & Programmes".
[7] Md. Lutfor Rahman, B.C. Basak and Md. Showkat Osman. "Low cost techniques to recover agricultural land through river bank erosion protection". 15-23 Oct 2011. 21st ICID.

5.3.1 Cost Benefit using Geotextiles and Geomembranes in Landfills

While landfills aren't the most obvious applications where a cost benefit can be seen via use of geosynthetics, in some cases there is an increase in volume due to the following innovative modifications to landfill design: Increasing the internal cut slopes of the excavation from 3 horizontal to 1 vertical (3:1) to a slope of 2:1 that was only possible by utilizing a Geosynthetic clay liner in place of a compacted clay liner

Increasing the final refuse slopes of the landfill from 4:1 to 3:1 using a textured HDPE Geomembrane for increased stability, which then expands the waste capacity.

The associated revenue benefits and cost savings that would result from these changes are outlined below.

Note: Figures are in USD as assumptions and revenues are based on US scenario

Increasing Internal Cut Slopes

Cutting the west slope from 3:1 to 2:1		
Increase in volume =	*39,435 cu. m.*	
Approx. waste disposal rate =	*$19.62 per cu. m.*	
Increase in Revenue =		$773,625
Excavated sand		
Volume =	*39,435 cu. m.*	
Sand commercial sales value =	*$4.90 per cu. m.*	
Increase in Revenue =		$193,406
Slope area & liner system modification		
3:1 slope area =	*11,889 sq. m.*	
Avg. cost of construction for clay liner of thickness 0.67 m =	*$7.01 per cu. m.*	
Construction cost for clay liner on 3:1 slope =	*$55,872*	
2:1 slope area =	*8,314 sq. m.*	
Avg. cost of installation for Geosynthetic Clay Liner =	*$5.70 per cu. m.*	
Construction cost for GCL on 2:1 slope =	*$47,414*	
Decrease in slope area and liner system modification results in construction cost net savings of =		$8,458
Initial Cost Benefit =		**$894,516**

Table 5.3: Cost Benefit by increasing cut slopes using Geosynthetics in $ USD

Increasing Final Slopes

The final refuse slopes at the MPL were permitted at a slope of 4:1. By increasing the final slope of the refuse to 3:1, a significant amount of additional waste volume could be realized. This increased waste volume would also significantly extend the site life of the MPL. Based on an analysis of the entire MPL site development, an increase in the final refuse slopes to 3:1 would result in a gain in capacity of 5.9 million cubic meters.

5.3.2 Cost Benefit using Geotextiles in Subgrade Reinforcement

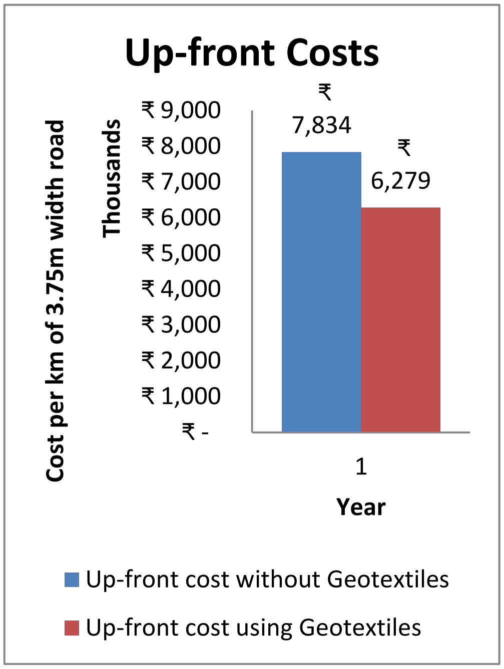
The use of a geotextile layer along the interface between existing subgrade and granular base helps extend the life of the road by reducing annual maintenance costs as well the intervals between pavement overlays required. This is in addition to initial cost savings due to reduction in thickness of the various road layers. The quantitative Cost Benefit analysis can be seen below:

		Without Geotextiles		With Geotextiles	
Layers	Rate (Rs/m^3)	Thickness (m)	Rate (Rs/m^2)	Thickness	Rate (Rs/m^2)
BC (Bituminous/Base Course)	₹ 7,060	0.05	₹ 353	0.05	₹ 353
DBM (Dense Bitumen Macadam)	₹ 6,365	0.17	₹ 1,082	0.14	₹ 891
WMM (Wet Mix Macadam)	₹ 1,588	0.25	₹ 397	0.1	₹ 159
GSB (Granular Sub Base)	₹ 857	0.3	₹ 257	0.2	₹ 171
Geotextile					₹ 100
TOTAL =		0.77	₹ 2,089	0.49	₹ 1,674
Area/km (3.75m width) =	3750	sq m			
Total Upfront Cost/km (3.75m width) =			₹ 7,834,313		₹ 6,278,625

Table 5.4: Initial savings using Geosynthetics

Lifetime Maintenance Costs (all figures Rs/km)								
	Without Geotextiles			With Geotextiles				
Year	Overlays	Maintenance	Cost/km	Overlays	Maintenance	Cost	Savings (Rs)	PV @8% Rate
1		2.5%	₹ 195,858		1.5%	₹ 94,179	₹ 101,678	94147
2		2.5%	₹ 195,858		1.5%	₹ 94,179	₹ 101,678	87173
3		3.5%	₹ 274,201		2.0%	₹ 125,573	₹ 148,628	117986
4		3.5%	₹ 274,201		2.0%	₹ 125,573	₹ 148,628	109246
5	₹ 937,500	3.5%	₹ 1,211,701		2.0%	₹ 125,573	₹ 1,086,128	739201
6		3.5%	₹ 274,201		2.0%	₹ 125,573	₹ 148,628	93661
7		3.5%	₹ 274,201		2.0%	₹ 125,573	₹ 148,628	86723
8		4.5%	₹ 352,544		3.0%	₹ 188,359	₹ 164,185	88704
9		4.5%	₹ 352,544	₹ 937,500	3.0%	₹ 1,125,859	₹ -773,315	-386850
10	₹ 937,500	4.5%	₹ 1,290,044		3.0%	₹ 188,359	₹ 1,101,685	510293
11		4.5%	₹ 352,544		3.0%	₹ 188,359	₹ 164,185	70416
12		4.5%	₹ 352,544		3.0%	₹ 188,359	₹ 164,185	65200
13		6.0%	₹ 470,059		4.0%	₹ 251,145	₹ 218,914	80494
14		6.0%	₹ 470,059		4.0%	₹ 251,145	₹ 218,914	74532
15		6.0%	₹ 470,059		4.0%	₹ 251,145	₹ 218,914	69011
TOTAL =			₹ 6,810,617			₹ 3,448,950	₹ 3,361,667	
GRAND TOTAL COST/KM (3.75m RD) =			₹ 14,644,929			₹ 9,727,575		
Net Present Value ---->					NPV with Geotextiles =	₹ 1,524,938		

Table 5.5: Lifetime savings using Geosynthetics



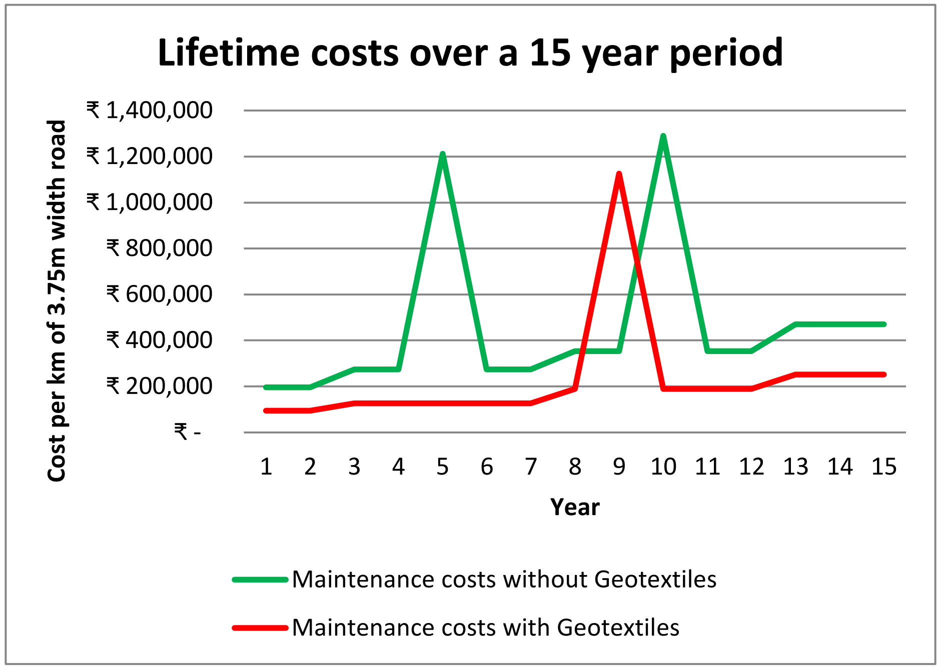


Figure 5.3: Lifetime cost comparison over 15 yr period

Initial construction cost includes materials ~42-45%, construction equipment ~21-23%, labour ~10-12%, finance ~7-8%, enabling {includes design & consultancy} expenses ~5.5-6.5%, admin cost ~3.5-4.5%). *Source*: *"Tenth Five Year Plan 2002-07 Vol. 2, Sectoral Policies & Programmes"*

* *It may be noted that savings may vary depending on CBR ratio. Maximum savings will be achieved when Geotextiles are used where subgrade soil has CBR ration of less than 3.*

5.3.3 Cost Benefit using Geotextiles and Geomembrane Canal Lining

Cemented canals often suffer from severe leakage and seepage of canal water that results in upto 40% loss of water flowing through the canal. Adjoining creeks and villages see greater incidences of water logging and marshy terrain due to this seepage. The solution consists of the following steps:

- Repair the existing concrete lining
- Line the canal with 22,000 m^2/km of Geomembrane and 44,000 m^2/km of nonwoven Geotextile:
    - Nonwoven Geotextile, 250 gsm for Drainage
    - HDPE Geomembrane, 1mm thick for the Barrier
    - Nonwoven Geotextile, 250 gsm for Protection
    - Concrete cover, 75mm (M15 grade)

Costs per km

Using Geosynthetics =	Rs 493 Lacs
-- Conventional Method =	Rs 198 Lacs
Difference in Cost =	**Rs 295 Lacs**

Direct Benefit using Geosynthetics per km

Water Savings = 62 m^3/s
=> Additional Water Revenue = Rs 87 Lacs
+ Savings in Maintenance = Rs 348 Lacs
Total Direct Benefit = Rs 435 Lacs
-- Net Cost = Rs 295 Lacs
Net Direct Benefit = Rs 140 Lacs

Indirect Benefits using Geosynthetics per km

- Additional Farm Products = Rs 276 Lacs
- Generation of Employment = 767 people
- Value Addition due to Extra Irrigation = Rs 35 Lacs

5.3.4 Cost Benefit using Geocells in road laying applications

Geogrids are increasingly finding use in road laying applications around the world due to their prefabricated nature and structural properties which allow for extremely swift laying of base/sub-base allowing for a reduction in pavement and sub base thickness while providing extremely effective stabilization and reinforcement properties to the pavement. It also helps in reducing thickness of upper layers such as WMM (Wet Mix Macadam), DBM (Dense Bituminous Macadam) and BC (Bituminous Concrete).

Geogrids also allow for use of low quality aggregates to fill the geocells that can be sourced locally, eliminating the need to import better quality material. The difference in pavement layers and the reduction in thickness can be seen below.

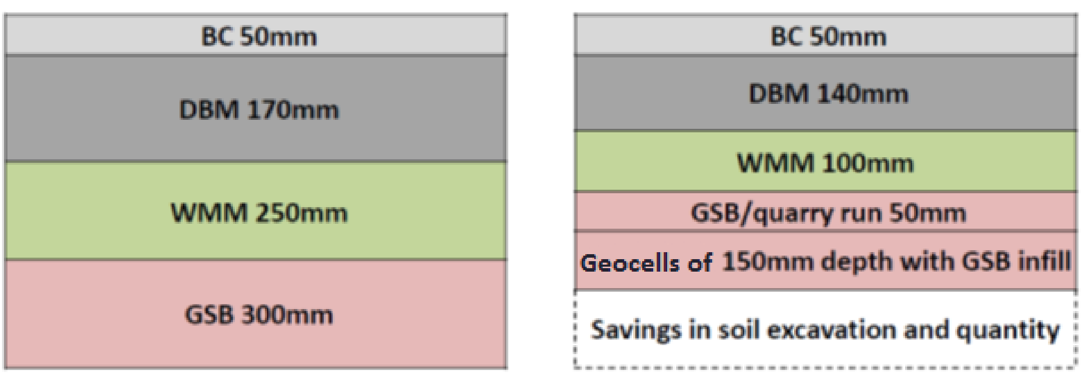


Figure 5.4: Illustration showing difference in pavement layers by using Geocells

A cost analysis carried out by Strata Geosystems comparing the two scenarios – the conventional method, with the use of Geocells in road laying application similar to the manner above gives the following savings in up front material cost.

		Conventional		With StrataWeb	
Item	Rate (Rs/m³)	Thickness (m)	Amount (Rs/m²)	Thickness (m)	Amount (Rs/m²)
BC	7060.00	0.050	353	0.050	353
DBM	6364.70	0.170	1,082	0.140	891
WMM	1588.00	0.250	397	0.100	159
GSB	856.60	0.300	257	0.200	171
Geocell Layer (Within GSB)		-	-	0.150	430
TOTAL =		0.77	2,088	0.49	2,004
Savings in %					4.03 %

Table 5.6: Material Cost Analysis using Strata Geocells in road laying application

Further savings due to reduction in maintenance costs and increased life of road can be calculated as per previous example in section 5.3.2.

		Without Geosynthetics		With Geosynthetics	
Layers	Rate (Rs/m^3)	Thickness (m)	Rate (Rs/m^2)	Thickness	Rate (Rs/m^2)
BC (Bituminous/Base Course)	₹ 7,060	0.05	₹ 353	0.05	₹ 353
DBM (Dense Bitumen Macadam)	₹ 6,365	0.17	₹ 1,082	0.14	₹ 891
WMM (Wet Mix Macadam)	₹ 1,588	0.25	₹ 397	0.1	₹ 159
GSB (Granular Sub Base)	₹ 857	0.3	₹ 257	0.2	₹ 171
Geocell (within GSB)				0.15	₹ 430
TOTAL =		0.77	₹ 2,089	0.49	₹ 2,004
Area/km (3.75m width) =	3750	sq m			
l Upfront Cost/km (3.75m width) =			₹ 7,834,313		₹ 7,516,125

Table 5.7: Up front savings using Geosynthetics

Initial construction cost includes materials ~42-45%, construction equipment ~21-23%, labour ~10-12%, finance ~7-8%, enabling {includes design & consultancy} expenses ~5.5-6.5%, admin cost ~3.5-4.5%). *Source*: *"Tenth Five Year Plan 2002-07 Vol. 2, Sectoral Policies & Programmes"*

Lifetime Maintenance Costs

	Without Geosynthetics			With Geosynthetics				
Year	**Overlays (Rs)**	**Maintenance**	**Cost (Rs/km)**	**Overlays (Rs)**	**Maintenance**	**Cost (Rs/km)**	**Savings (Rs)**	**PV @8% Rate**
1		2.5%	₹ 195,858		1.5%	₹ 112,742	₹ 83,116	76959
2		2.5%	₹ 195,858		1.5%	₹ 112,742	₹ 83,116	71259
3		3.5%	₹ 274,201		2.0%	₹ 150,323	₹ 123,878	98339
4		3.5%	₹ 274,201		2.0%	₹ 150,323	₹ 123,878	91054
5	₹ 937,500	3.5%	₹ 1,211,701		2.0%	₹ 150,323	₹ 1,061,378	722356
6		3.5%	₹ 274,201		2.0%	₹ 150,323	₹ 123,878	78064
7		3.5%	₹ 274,201		2.0%	₹ 150,323	₹ 123,878	72282
8		4.5%	₹ 352,544		3.0%	₹ 225,484	₹ 127,060	68647
9		4.5%	₹ 352,544	₹ 937,500	3.0%	₹ 1,162,984	₹ -810,440	-405422
10	₹ 937,500	4.5%	₹ 1,290,044		3.0%	₹ 225,484	₹ 1,064,560	493097
11		4.5%	₹ 352,544		3.0%	₹ 225,484	₹ 127,060	54494
12		4.5%	₹ 352,544		3.0%	₹ 225,484	₹ 127,060	50457
13		6.0%	₹ 470,059		4.0%	₹ 300,645	₹ 169,414	62293
14		6.0%	₹ 470,059		4.0%	₹ 300,645	₹ 169,414	57679
15		6.0%	₹ 470,059		4.0%	₹ 300,645	₹ 169,414	53406
TOTAL =			₹ 6,810,617			₹ 3,943,950	₹ 2,866,667	
GRAND TOTAL COST (RS/KM) (3.75m RD) =			**₹ 14,644,929**			**₹ 11,460,075**		
Net Present Value ---->				**NPV with Geotextiles (Rs) =**		**₹ 32,465**		

Table 5.8: Lifetime savings using Geosynthetics

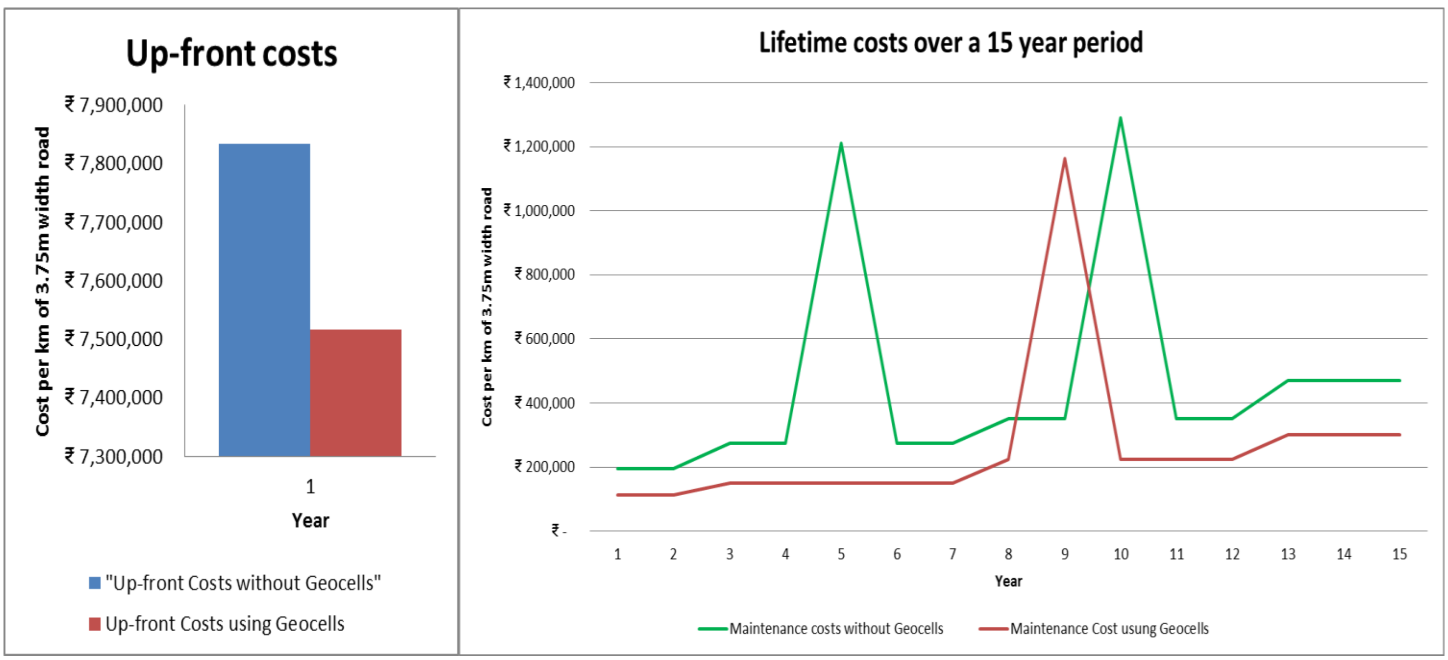


Figure 5.5: Lifetime cost comparison over 15 yr period

** It may be noted that savings may vary depending on CBR ratio. Maximum savings will be achieved when Geotextiles are used where subgrade soil has CBR ration of less than 3.*

5.3.5 Cost Benefit using Geogrids in Reinforced Soil Wall applications

The use of Geogrids in reinforced soil walls is perhaps the biggest success story for Geosynthetics in India. This is because of the design and space advantages that can be leveraged by Reinforced Soil Walls (RS) when compared to Reinforced Cement Concrete (RCC) Walls are significant as the footprint of the foundation is smaller hence requires less land and material. A cost benefits analysis is as follows.

<u>Cost Consideration for RCC Wall</u>

Considering a 10m length of wall of 7m height:

Component	Number	Length (m)	Height (m)	Width (m)	Volume (m^3)
Base Slab	1	10	0.3	4.9	14.70
Vertical Wall (W_1)	1	10	8.7	0.3	26.10
Counterfort (W_3)	3	3.75	8.7	0.3	14.68
Shear Key (W_2)	1	10	0.6	0.3	1.80
				Total =	**57.28 m^3**

Table 5.9: Lifetime savings using Geosynthetics

Hence total consumption of concrete for 7m high retaining wall above ground level is 57.28 m^3 for 10 m length of wall, or 5.73 m^3 per running metre of wall.

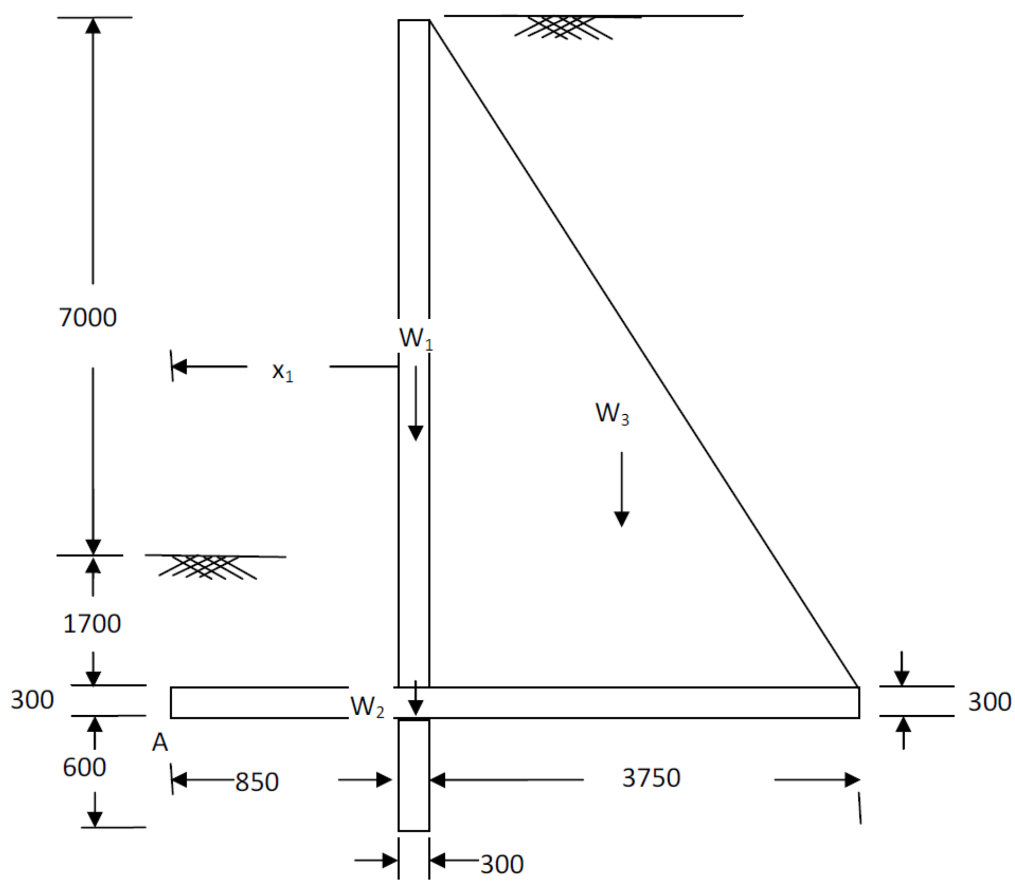


Figure 5.6: RCC Counterfort Wall cross section

Cost estimation for the RCC counterfort wall using M_{35} concrete with Fe415 reinforcement:

Quantity = 5.73 *m*³

Rate = ₹6100 *per m*³

Total = **₹34,953** *per metre running length for 7m high (above ground) RCC wall*

<u>Cost estimation for Reinforced Soil Wall (RSW)</u>

Design for the reinforced retaining wall is based on BS-8006 for static and seismic with FHWA-043 and uses knitted and PVC coated polyester Geogrids.

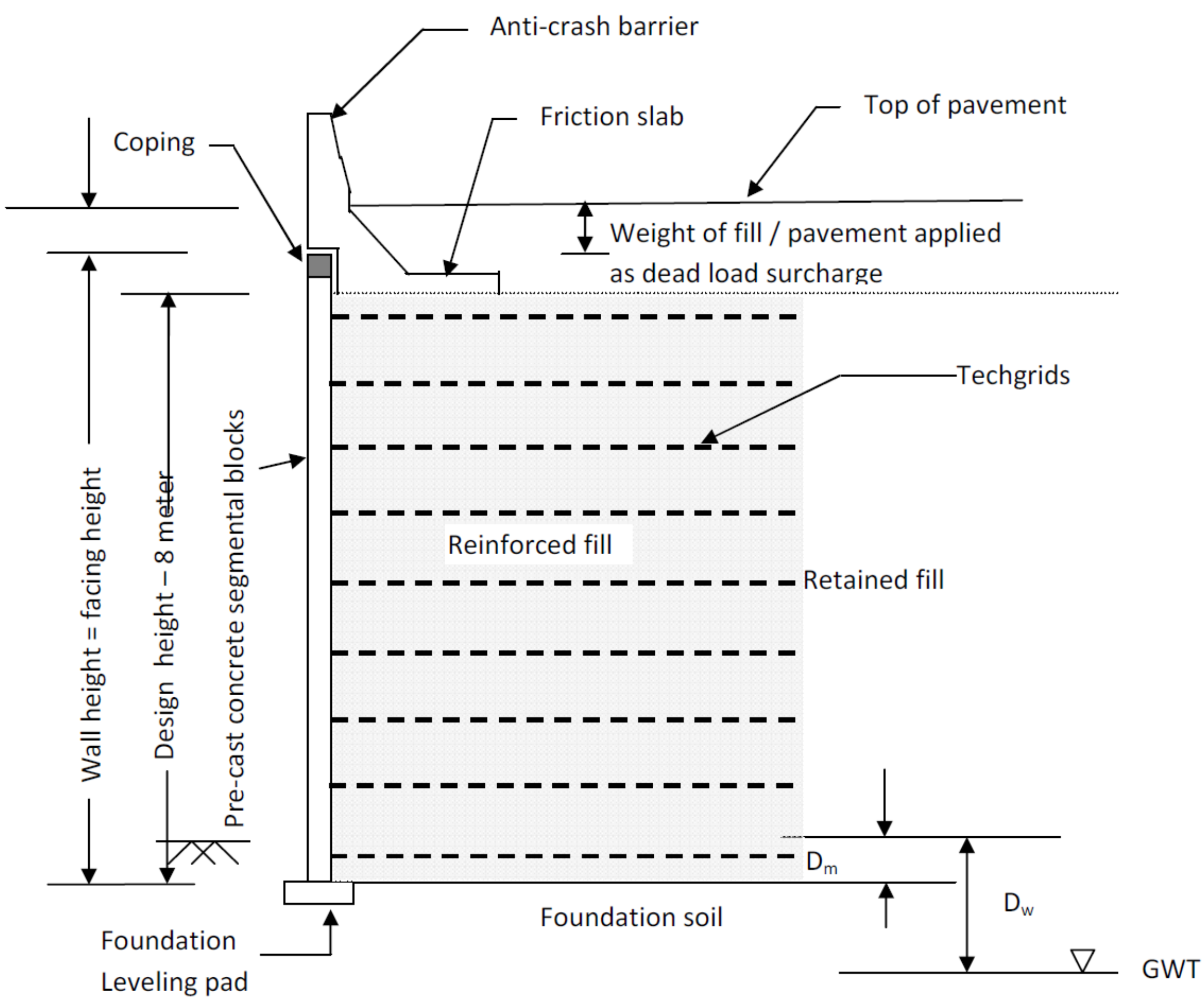


Figure 5.7: Reinforced Soil (RS) Wall cross section

Cost estimation per metre running length of 8m high wall is as follows:

Cost of Geogrids (design and supply) = ₹14,800

Cost for casting and erection of panels = ₹12,000

Total Cost per metre running length for 8m high RS Wall = ₹26,800

Conclusion

The cost benefit from using Reinforced Soil wall vs. Reinforced Cement Concrete wall is:

$$1 - \frac{₹26{,}800}{₹34{,}953} = 23.3\%\ in\ savings$$

This shows the significant upfront cost benefit from the use of Geogrids. Not taken into account is the savings in land cost due to smaller footprint and hence less requirement of area for flyover construction.

5.3.6 Cost Benefit Analysis using Geobags in Coastal/Embankment Protection applications

Historically revetments have been the most common

In a study for the ICID 21st International Congress on Irrigation & Drainage, Geobag Revetments were found to 20-50% cheaper compared to RCC Revetments. A similar study by the BUET (Bangladesh University of Engineering & Technology), BWDB (Bangladesh Water Development Board) & IWM (Institute of Water Modelling) found 40-60% cost reduction.

Type of Structure	Name of River	Agency	Cost Rs/m	Effectiveness
Revetment (Geobags)	Jamuna	Foreign	1.24-1.86 L	On going
Revetment	Jamuna	BWDB	2.36-2.48 L	70-80%
RCC spur	Jamuna/Ganges	BWDB	0.59 L	60-70%

Table 5.10: Geobag installations in Bangladesh used for study

As can be seen there are various techniques to counter the damaging effects of coastal and riverbank erosion apart from revetments. These include the construction of RCC spurs which are column like structures that break the force of the water body undercurrents. An interesting observation as per the same study is that RCC spurs have been found to be 50-80% cheaper than and nearly as effective as revetments. Hence Geobags are susceptible to substitution for coastal and embankment protection works by RCC spurs.

5.3.7 Cost Benefit of Geosynthetic projects based upon IRC cited global & domestic projects

The IRC (Indian Road Congress) is the premier technical body of highway engineers in the country. Case studies and technical papers are regularly contributed to the IRC for publishing and so it is an authenticated source of data on various road building projects around the country. To understand the various design approaches and associated benefits of using

Geosynthetics in road works the IRC membership was availed and its database was accessed for the global examples and their benefits.

These examples also highlight the benefits identified previously in the section in various applications and are quantified in various different forms – reduction in base, course thickness, or increase in TBR (Traffic Benefit Ratio) and BCR. The following table summarizes the various approaches and benefits.

Developer	Geosynthetic Type	Applicability	Distress mode and Design Format	Empirical Support	Maximum Range of Improvement
Giroud and Noiray (1981)	Geotextile	Empirical Method	75 mm rut depth	Quasistatic analysis	30% to 50% reduction in base course thickness
Penner et al. (1985)	Specific geogrid	Based on C.B.R. 4.3 to 5.7%	22 mm rut depth/ Equation and Chart	Lab test	30% to 50% reduction in base course thickness
Burd and Houlsby (1986)	Genetic Geosynthatic	Isotropic elastoplastic	Surface deformation/ FE M Computer Programe	F.E.M.	Improvement after 4 mm surface deformation
Barksdale et al (1989)	Genetic Geosynthatic	Isotropic elastoplastic	surface deformation/ FE M Computer Programe	Field Result	4% to 18% reduction base thickness
Barksdale et al (1989)	Geogrid	C.B.R. 2.4%	Vertical deformation chart , computer programe	Field Test	4% to 18% reduction in base course thickness
Webster (1993)	Specific Geogrid	Based on C.B.R. 3 to 8%	Rut depth (25 mm) /Design charts	Field Test	BCR = 5% to 45%
Tensar (1996)	Specific Geogrid	Based on C.B.R. 1.9 to 8%	20 to 30 mm rut depth/ equations, charts, computers programe	Lab & test track correlate to field test	Traffic Benefit Ratio (TBR) = 1.5 to 10%
J. G. Collin, T. C. Kinney (1996)	Geogrid	Based on C.B.R. 1 to 8%	Surface rutting	Full Scale Lab test	Traffic Benefit Ratio (TBR) = 2 to 10%
Akzo-Nobel (1998)	Specific GG-GT Composite	Not Stated	Bearing capacity/ Equation & Charts	Plate Load Test (Meyer 7 Elias, 1999)	BCR = 32% to 56%
Perkins S.W. (1999)	Geogrid		Permanent surface deformation	Full Scale Lab test	At least 30% reduction in base course thickness.
Giroud & Han (2004)	Geogrid	Theoretical design method	Allowable rut depth, e.g. 75	Empirical test calibrated with	Up to 30% reduction in base course

			mm.	field test	thickness.
Rudolf Hufenus, Rueegger et. at (2005)	Geogrid	C.B.R. 1 to 4%	Rut depth	Full scale Field test	Up to 30% reduction in base course thickness.
Bassam Saad and Hani Mitri (2006)	Geogrid	-	Surface Deformation	3D F.E.M.	Reduction of Rutting strain up to 16 to 34%
Imad L. Al-Qadi et. at (2010)	Geogrid	C.B.R. 4%	Surface rutting	Full Scale test	Reduction in Pavement response up to 23-31%

Table 5.11: Quantifiable benefits of IRC cited projects

Some IRC case studies of projects in India and their qualitative Cost Benefit Analyses can be seen in the following sections:

Study to Prevent Reflecting Cracks on Bituminous Overlay over Cracked Concrete Pavement using Geotextile

Date of start: May 1999
Date of completion: January 2011
Agency: Gujarat Engineering Research Institute (GERI), Vadodara

Findings/ Conclusions/Supporting Data

The careful study of the field data collected during the periodic observations indicated that the deflection, the total distress and the serviceability index over a period of time are minimal in Geotextile test sections as compared to the control panel. Since all the above parameters are measure of the performance and structural capacity of road pavement, the results clearly indicate that the inclusion of a Geotextile can improve the performance of the road pavement possibly due to its ability to reinforce and strengthen the pavement and to control the degradation of structural behaviour of pavement as compared to pavement without Geotextile.

Pilot Project for Construction of PMGSY Roads Using Jute Geotextiles

Date of Start: July 2005
Date of Completion: Continuing
Agencies: Central Road Research Institute (R), Jute Manufactures Development Council (S), National Rural Roads Development Agency (I)

Findings/ Conclusions/Supporting Data:

This project is sponsored by Jute Manufactures Development Council (JMDC) under the aegis of NRRDA. Under this project 5 PMGSY roads in four states (Assam, M.P, Chattisgarh and Orissa), where construction work has been completed, have now been taken up for performance monitoring. The objective of the project is to study efficacy of Jute Geotextile (JGT) for drainage, erosion control, capillary cut-off and subgrade improvement and hence performance monitoring forms an important component of this project. Each of these PMGSY Roads, comprise of several sub-sections in which JGT of different varieties (woven, non-woven and open weave), of different strengths and rot treated as well as non-treated varieties have been laid to study their relative performance. Control sections without JGT have also been constructed. A distinguishing feature of these test roads is the construction of reduced pavement thickness sections where in JGT as drainage improvement layer has been laid above subgrade.

Use of Coir Geotextiles in Road Construction

Date of Start: April 2010
Date of Completion: On-going
Agency: National Transportation Planning and Research Centre (NATPAC) – R

Findings/ Conclusions/Supporting Data:

Laboratory experiments are conducted on weak soil reinforced using natural geotextiles like coir mattings with different mesh size (half inch and one inch), panama weave (commercial name given by manufacturer) and also polymeric geotextile like High Density Poly Ethylene (HDPE). The improvements in soil properties obtained with the use of coir geotextiles were found out. By providing geo-textiles the CBR value of weaker sub grades could be enhanced. Thereby, the pavement layer thickness can be considerably reduced and this facilitates the construction of roads in poor sub-grade soil areas.

Experimental Investigations on Modification of Subgrade Characteristics by Chemical Addictives and Effect of Coir Geotextile on Pavement Distress in Overlays

Date of Start: August 2010.
Date of Completion: August 2011.
Agency: College of Engineering, Trivandrum (R)

In this study, an attempt has been made to study the effects of coir geotextiles reinforcement in asphalt overlays and to study the effect on addition of phosphogypsum on subgrade soil. The objectives of the study are:

- To conduct laboratory experiments in order to determine the effects of coir geotextile, in the behaviour of asphalt overlays.
- To locate the ideal position of Geo textile in overlay for mitigating permanent deformation by experimentation.

Findings/ Conclusions/Supporting Data:

- From experiments, 400 GSM (Gram per Square Meter) woven geotextile placed at bottom position of the overlay specimen showed minimum decrease in stiffness modulus compare to control specimen.
- From experiments, 400 GSM woven geotextile placed at bottom position of the overlay specimen showed maximum decrease in rut deformation compare to control specimen.
- From experiments, Geotextile placed at bottom of overlay performed better than geotextile placed at one-third from bottom in the overlay followed by geotextile placed at middle in the overlay
- From experiments, 400 GSM woven geotextile specimen performed better than 740 GSM woven geotextile specimen followed by 800 GSM non-woven geotextile specimen.
- From analysis, coir geotextile placed in the models showed decrease in stress compare to control model.
- From analysis, coir geotextile placed in the models showed increase in strain compare to control model.
- From analysis, Geotextile placed at bottom of overlay model performed better than geotextile placed at one-third from bottom in the overlay model followed by geotextile placed at middle in the overlay model.
- From result drawn from experiments and analysis it is concluded that geotextiles placed at bottom of overlay performed better than other two positions.

Experimental Investigation of the Influence of Coir Geotextiles on Adherence Property of Bituminous Mixes

Date of Start: January 2011.
Date of Completion: August 2012.
Agency: College of Engineering, Trivandrum (R)

The study was limited to finding the adherence stress between the bituminous concrete mix and coir geotextiles.

The objectives of this study are:

- To determine the optimum tack coat content for obtaining the highest adherence stress
- To determine the maximum improvement in ultimate load of a pavement section when using different types of coir geotextiles
- To determine the type of coir geotextile which gives maximum adherence stress for a particular displacement

Findings/ Conclusions/Supporting Data:

- Adherence stress between pavement layers was improved significantly with the coir geotextiles.

- The coir geotextiles helps to reduce the displacement of overlays compared to control specimen.
- The optimum tack coat content for obtaining the highest adherence stress for all types of coir geotextiles was 0.9Kg/m2
- CCM 700 type coir geotextiles showed maximum improvement in load carrying capacity over control specimen.
- Among the five varieties of coir geotextiles used, CCM 400 was found to be the best choice for a particular displacement.
- The maximum improvement in adherence stress was 8.7 times and the minimum improvement was 3.15 times, control specimen value for a displacement ratio of 0.02.

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6 Analysis of Current Usage of Geosynthetics in India

6.1 Stakeholder Analysis

As mentioned at the beginning of this report, the Geosynthetic industry has four broad groups of stakeholders – manufacturers, contracting agencies, concessionaires/contractors and design consultants, and government bodies & subject matter experts Along with these the government policy-making departments also play a crucial role for industry stimulus.

After Accenture identified key stakeholders and devised the approach and methodology to achieve objectives of this engagement, extensive interviews were conducted to stakeholders. A summary of the stakeholder issues can be seen within the following sections.

The infrastructure industry is unique in the sense that planning and commissioning of various projects is done almost solely by the government. As touched upon previously, Geosynthetics are used primarily in infrastructure projects such as construction of roads, railways, canals, bridges, dams, coastal and river embankments, landfills, etc.

To begin with it is important to understand this group of stakeholders. While mentioned above that the planning and commissioning of project is done by the government, the actual construction and implementation is carried out by concessionaires and contractors upon being selected through a bidding process. This creates a double edged demand side effect as due to the nature of the ecosystem there are two demand centres with regards to Geosynthetics:

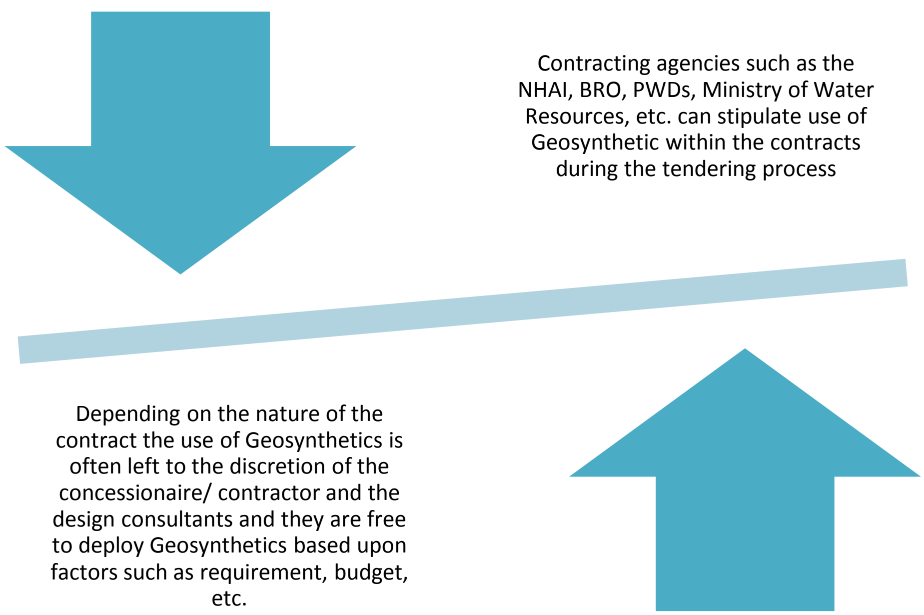


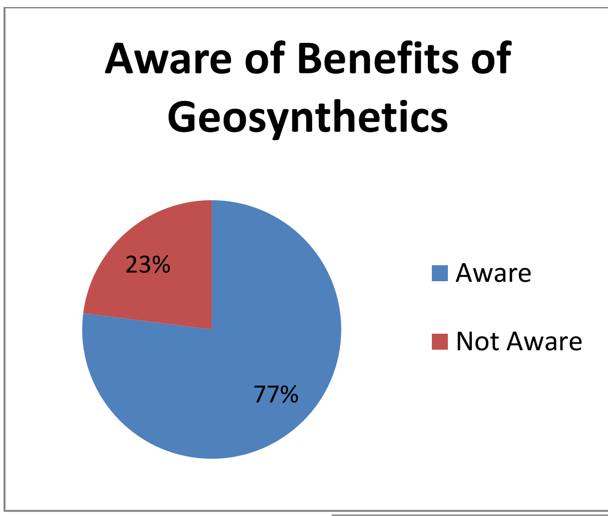
Figure 6.1: Two demand centres

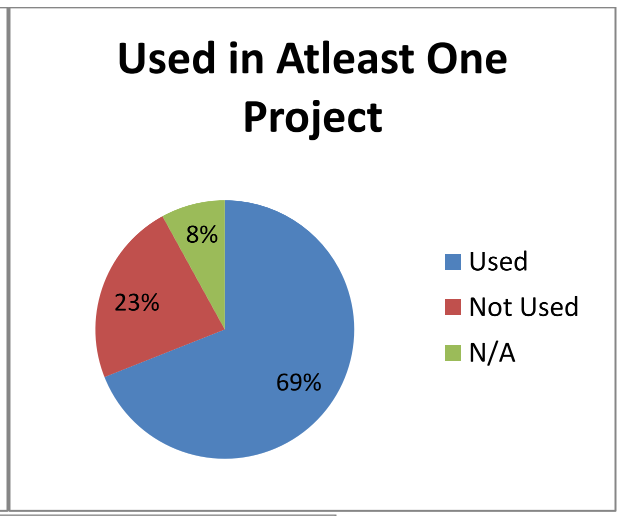
Hence while conducting our primary research it was important to acknowledge the difference in perspective of these two sub-groups and analyse their feedback accordingly.

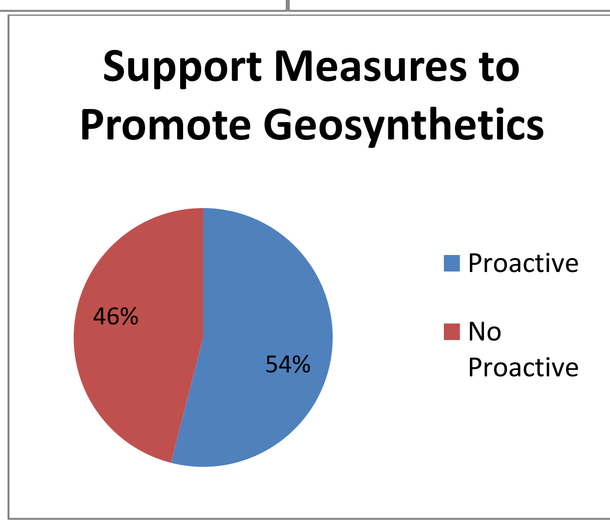
6.1.1 Contracting Agencies

This group of consumer consists of the various government agencies involved in commissioning various public infrastructure works. The NHAI, BRO, various PWDs, Ministry of Water Resources, Railways, etc. are all part of this group. This group is very important and these are the organizations that issue tenders for the work to be carried out in projects such as construction of roads, railways, canals, bridges, dams, coastal and river embankments, landfills, etc. As mentioned above the use of Geosynthetics can gain considerable impetus if these agencies develop mechanisms within their tenders, contracts and guidelines to ensure Geosynthetics are adopted wherever necessary or appropriate.

Hence it is imperative to understand the level of understanding possessed by key personnel within this group of stakeholders with regards to Geosynthetics. A total of 14 personnel ranging from the CEO of the NHAI to the design engineers of various PWDs of the Konkan region, Tripura, as well as chief engineer of the Irrigation department were spoken to. Details of the persons interviewed can be seen in Annexure A.







As you can see above, the level of awareness, especially in senior personnel with regards to Geosynthetics is fairly high. 77% of the respondents displayed working knowledge of the benefits associated with utilizing Geosynthetics. A similar percentage, i.e. 69% also had the experience of deploying Geosynthetics in atleast one infrastructure project.

Despite this only 54% felt that supporting use of Geosynthetics should be part of their agenda. 46% of the respondents felt that their use should be the sole discretion of the concessionaires and contractors. 62% of the respondents did feel that the lack of comprehensive inclusion of Geosynthetics in the various state and regional SoRs is impeding inclusion of Geosynthetics in the design phase of projects. More so the lack of standards and specifications was considered by 50% of the respondents as a reason for this disparity in price and quality from manufacturer to manufacturer.

The key takeaways from interaction with this group are a result of the reluctance to push through measures to place the directives for use of Geosynthetics upon themselves, manifesting themselves as follows:

i. *Awareness* – While officials in these organizations are broadly aware of Geosynthetics, there are few resources with subject matter expertise required to promote and pragmatically incorporate use of Geosynthetics in their projects.

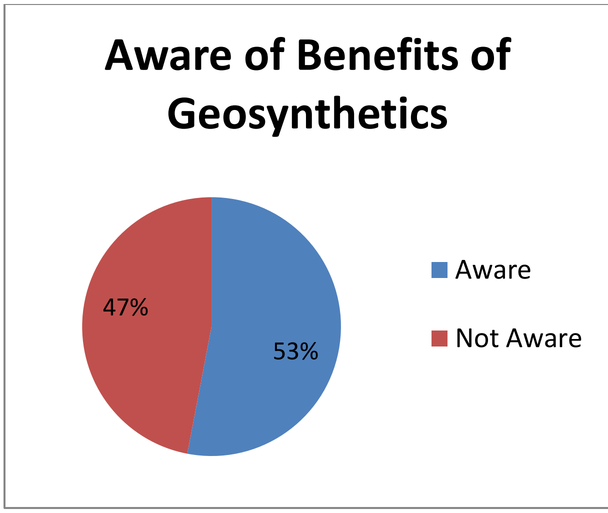
ii. *Usage Policies* – These organizations do not have use of Geosynthetics adequately articulated in their guidelines and tenders and do not have the conviction in the benefits of Geosynthetics to do so.

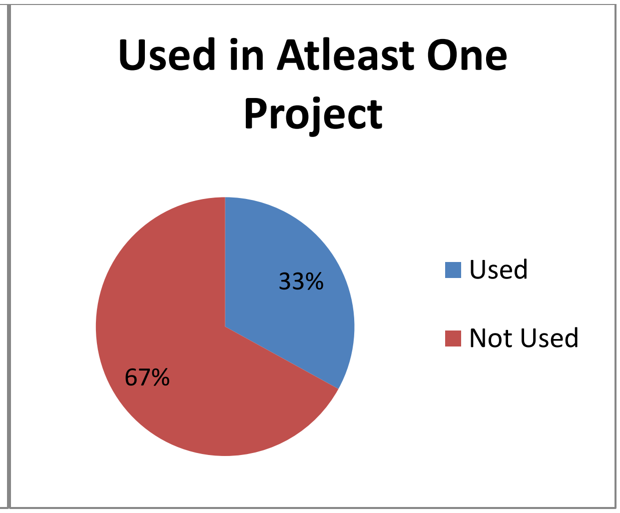
It should be noted objective of this report is qualitative and not quantitative, hence the number of respondents does not satisfy statistical confidence requirements. But the feedback helps give an indicative assessment of reasons behind the lack of growth in the segment.

6.1.2 Concessionaires, Contractors & Design Consultants

This group of stakeholders are the actual implementing agencies and organizations that bid for tenders and execute the various infrastructure projects. As per the current industry dynamics this group is the most crucial, as things stand, in driving the use of Geosynthetics. This is because the tendering process in India still follows the Lowest Bidder or L1 model and hence most tenders are won by the lowest bidder. This coupled with the fact that tenders or usage policies do not stipulate use of Geosynthetics results in lack of uptake for these products.

We initiated discussions with 15 engineers and personnel from various organizations including JMC Infrastructure, STUP Consultants, MERI, IVRCL, J Kumar Consultants, etc. interviewed for this study:





Here one can clearly see the lower awareness and also the conviction in the benefits provided by Geosynthetics resulting in fewer agencies implementing Geosynthetics in their projects. Regardless of level of awareness all respondents referred to the lack of stipulations in the tenders as the reason for them not using Geosynthetics. SoR issues were also mentioned as a deterrent to uptake of Geosynthetics.

The key takeaways from interactions with this group are as follows:

i. *Awareness* – While these organizations are broadly aware of Geosynthetics, there is lack of awareness regarding monetary benefits in certain applications and hence lack of conviction in the effectiveness of Geosynthetics to benefits geotechnical applications.

ii. *Policy* – Only 14 state SoRs include Geosynthetics, and that too not comprehensively, which inhibits inclusion in project design phase and subsequent use. Additionally, usage is not mandatory for applications where the benefits are not monetary but instead environment like in the case of landfills or coastal and riverbank protection.

iii. *Standards & Specifications* – Lack of common industry standards and specifications has led to confusion regarding quality required during procurement and implementation.

iv. *Tenders* – Lowest Bidder or L1 tenders are currently the norm in India and the lack of DBOT and Value Engineering Tenders provides little incentive for concessionaires and contractors to use Geosynthetics. This coupled with the fact that the tenders do not specify use of Geosynthetics specifically and is left to the discretion of the concessionaires and contractors results in stunted uptake of Geosynthetics in infrastructure projects.

It should be noted objective of this report is qualitative and not quantitative, hence the number of respondents does not satisfy statistical confidence requirements. But the feedback helps give an indicative assessment of reasons behind the lack of growth in the segment.

6.1.3 Manufacturers

During the primary research phase something that became apparent is that most Indian users prefer buying Geosynthetics from Indian manufacturers rather than importers. Hence to promote use of Geosynthetics it is important to promote development of Indian manufacturers and understand the key takeaways from discussions with the manufacturers, namely:

i. *High Investment* – The investments required for the various technologies to manufacture Geosynthetics are very high and can go up to INR 80 crore. Lack of policy driven demand and cap-ex policy enablers results in a breakeven period of 7-8 years under optimistic market conditions.

ii. *Awareness and Expertise* – A lack of awareness and expertise on the part of consumers results increased sales and marketing efforts for the manufacturers even in applications where there is a clear-cut cost benefit. This has also resulted in a significant portion of the manufacturers forward integrating into implementation and turn-key style engagements to ensure customers are acquired and the Geosynthetics are implemented correctly. While not desirable it is the result of the nature of the market and the lack of trained personnel.

iii. *Policy* – Various Geosynthetic applications do not have monetary benefits but rather impact the environment and mankind positively. Policies are not in place for various civic entities to ensure use of Geosynthetics in such applications. Similarly various States do not have Geosynthetics included in their SoRs. Even the States that do include Geosynthetics in the SoRs are far from being comprehensive.

iv. *Standards & Specifications* – Lack of common industry standards and specifications has led to lack of a level playing field as the customers are not sophisticated enough in their knowledge of Geosynthetics to be able to cross compare standards from various different organizations. This variation in standards and specifications results in significant variation in quality and hence price affecting the ability of some manufacturers to compete. The dynamics related to standards and specifications are touched upon in further detail in Section 6.4 of this report.

Some keen observations on the part of the manufacturers included areas where regulations may help provide great environment benefit while also providing impetus to the Geosynthetics industry – such as mandatory canal linings and wider prescribed used of silt fences. The various manufacturers were also asked which machines were conspicuous by their absence in the TUFS (Technology Upgradation Fund Scheme) subsidies on capital equipment, but there was lack of consensus and hence a list of machines for subsidy inclusion could not be drafted.

6.1.4 Government Agencies & Subject Matter Experts

The Government of India has recognized the need to provide an impetus to the technical textile industries and has taken certain steps towards promoting these industries. Some of the prominent initiatives are:

- Constitution of Expert Committee on Technical Textiles (ECTT)
- Setting up of a Steering Committee on Growth and Development of Technical Textiles (SCGDTT)
- Launching of the Technology Mission on Technical Textiles (TMTT)
- Coverage of technical textiles under Technology Upgradation Fund Scheme (TUFS)
- 14 Special Economic Zones to attract FDI and duty free imports and domestic procurement for 100 % exports
- Gujarat and Maharashtra are providing 10 % investment subsidy on technical textile projects

While these initiatives have been taken predominantly by the Ministry of Textiles, there has not been much in the way of specific policy changes on behalf of the government in areas such as:

- Incentives for certification / accreditation to international standards
- Incentives for substitution of traditional textiles by technical textiles
- Mandatory use of geotech for efficient utilization of public funds or environmental concerns

Despite these efforts the broader technical textile industry and more specifically the Geosynthetics industry, has yet to gain the momentum that was envisioned while drafting the various government initiatives. Speaking to some officials from various government departments such as the MoRTH, BRO, NHAI, Ministry of Water Resources, Ministry of Railways, etc. in charge of drafting guidelines and regulations related to the infrastructure sectors and Geosynthetics use within, some takeaways include:

i. *Expenditure* – Lack of Geosynthetics use leading to increased expenditure in maintenance of infrastructure and greater exposure to negative environmental impact. There is pressure from the public and the higher authorities to ensure longevity of projects and reduction in maintenance costs, leading to greater interest in Life Cycle Cost Analysis, which is where Geosynthetics come in.

ii. *Schemes to Promote Geosynthetics* – There is difficulty in measuring performance ofexisting schemes and identifying target areas for new schemes.

iii. *Policy Articulation* – Variability of use in applications means greater complexity in articulating usage policies and hence dependence on user discretion for implementation of Geosynthetics.

Centres of Excellence such as BTRA, ATIRA

i. *Standards & Specifications* – Coordination with the BIS and implementation of India specific standards is a tedious process, further compounded by variation in standards and specifications followed by manufacturers and consumers.

ii. *Testing Facilities* – Disconnect between various government departments resulting in delays in implementing testing facilities despite availability of budget.

There is a sense of contentment with the current uptake and an over reliance of natural market forces to generate both demand and supply for the Geosynthetics industry.

6.2 Analysis of Financial Viability of Manufacturing Key Products

The Geosynthetics industry is a capital intensive industry that entails significant investments in machinery. This high barrier to entry has led to approximately 70% of industry capacity residing with the top 10 manufacturers. Another factor is the nascent market where demand is still far from being mature and predictable.

A couple of techniques of fabric production can be used to produce Geotextiles, with each method offering specific advantages for each particular product. The manufacturing feasibility depends upon which technology is being employed. Two of these are woven and non-woven Geotextiles.

Woven and nonwoven have their own merits and demerits. The selection of material has to be based on application. If we compare both the manufacturing processes i.e. woven and nonwoven, then nonwoven manufacturing involves fewer steps. The fibres are aligned in a web like form and then entangled mechanically by using needles. However, the production volumes are bigger per machine for manufacture to be feasible. In the case of a woven geotextiles, the project can be started with minimum number of looms i.e. 4 to 6. Based on initial market response the project can then be expanded further. Therefore the risk factor reduces considerably. To demonstrate the scale of investments and the revenues required for a profitable technical textile unit, certain profiles of manufacturing feasibility have been given below that include assumptions and factors to be taken into account, as well as approximate break even periods. It is important to note that TUFS (Technology Upgradation Fund Scheme) subsidies were recently extended to 2017 and has hence been taken into account in the project financing.

A third method of manufacture is knitted technology where the geosynthetic or geotextile is made by interlooping one or more yarns, fibres, filaments or other elements. Data for manufacturing feasibility of knitted geosynthetics is heavily dependent on type of product and is greatly variable hence has not been provided here.

6.2.1 Manufacturing feasibility for Woven Facility

Woven products are produced by using weaving machines especially Sulzer projectile weaving machines. The range of light to heavy and wide width fabric production is possible with Sulzer projectile weaving machine. Other systems of woven fabric production such as air jet and rapier weaving machines are not preferred for the manufacture of such fabrics, as they do not have required weaving width. Assumptions for setting up a manufacturing facility for woven Geosynthetics are listed below.

ASSUMPTIONS - WOVEN GEOTEXTILE		
1	Shift/day	3
	No. of Working Days / Annum	350
	No. of Working Hours / Shift	8
2	Capacity Utilisation	
	Ist Year	50%
	IInd Year	60%
	IIIrd Year	75%
3	Cost of Power	6
	Cost of Water – Rs per m^3	25
4	Consumable Stores and Spares	
	- % of Machinery Cost	1%
5	Packing & Transport	
	Packing Cost Rs per Kg	4
	Transport Cost Rs per Kg	10
6	Labour Wages - Rs per Day	
	Skilled	240
	Semi Skilled	220
	Un-Skilled	200
	Fringe Benefits - For first 3 Years	36%
	From fourth year onwards	40%
7	Repairs and Maintenance	
	- % Of Machine Cost	2%
	- % Of Building Cost & Utilities	2%
8	Administrative Expenses	
	% of Sales Turnover.	2.0%
9	Interest on Term Loan -	

	- Rupee Loan (Government Bond) @	13.5%
	-Interest on Working Capital @	13.5%
10	Selling Expenses as % of Sales Turnover	
	Selling Expenses	3.0%
	Selling Commission	5.0%
11	Product Development & Sampling	5.0%
12	Exchange Rates - as on 11/10/12	
	1 US $	52.75
	1 Euro	67.95
	1 Pound	84.49
	1 CHF	56.26

Table 6.1: Assumptions for a Woven Textile Facility

Along with the above assumptions the feasibility snapshot below assumes purchase of new machines and not used machines. It is also assumed that the unit will operate at maximum utilization from the 3rd year onwards.

PRODUCTION AND SALES PROJECTIONS - WOVEN GEOTEXTILE			
Sr. #	**Fabric**	**Production Kg. / Day**	**Selling Rate Rs. / Kg**
1	Geo textile - Product 1	3503	216
2	Geo textile - Product 2	3277	216
3	Geo textile - Product 3	7276	227
4	Geo textile - Product 4	6702	227

Table 6.2: Production and Sales assumptions for Woven textile facility

PROJECT AT A GLANCE - WOVEN GEOTEXTILE			
*	Installed Capacity		
	Woven Technical Textiles	No Of Looms	24
*	Basis For Planning		
	Working Days Per Annum		350
	Fabric Processing		DAYS (3 SHIFTS)
	Hours Per Shift		8
*	Project Cost		
	Total	Rs. Lakhs	6955
*	Means Of Finance		

	Promoters Contribution	Rs. Lakhs	2087
	Public Issue / Mutual Funds	Rs. Lakhs	0
	Total Equity	Rs. Lakhs	2087
	Foreign Currency Loan	Rs. Lakhs	0
	Rupee Loan	Rs. Lakhs	4869
	Total	Rs. Lakhs	6955
*	Financial Results		
	Sales Realisation	Rs. Lakhs	12166
	Other Income	Rs. Lakhs	0
	Cost Of Production	Rs. Lakhs	8125
	Gross Operating Profit	Rs. Lakhs	2247
	Net Profit	Rs. Lakhs	703
	Break Even Point		44.96%
	Cash Break Even Point		31.60%
	I.R.R.		23%
	Return On Investment		29.28%
	Breakeven Period		7-8 Years

Table 6.3: Key Numbers – Woven Textile Facility

6.2.2 Manufacturing feasibility for Non-Woven Facility

Warp knitting technique is most widely used compared to weft knitting. Warp knitted protective nets are used in different sectors, which are produced on Raschel machines. The construction or lapping is the way in which individual yarn systems are converted into fabrics.

Nonwovens

There are many techniques to produce Nonwoven fabrics.

- Needle-punched nonwovens
- Stitch-bonded nonwovens
- Thermally bonded nonwovens
- Hydro entangled nonwovens
- Spun bonded nonwovens
- Wet nonwovens

Assumptions for calculating manufacturing feasibility non-woven Geosynthetics are listed below.

ASSUMPTIONS - NONWOVEN GEOTEXTILE		
1	No. of Working Days / Annum	350
	Shifts/Day	3
	No. of Working Hours / Shift	8
2	Capacity Utilisation	

	Ist Year	70%
	IInd Year	80%
	IIIrd Year	90%
3	Cost of Power	6.5
	Cost of Water - Rs. per m^3	15
4	Consumable Stores and Spares	
	- % of Machinery Cost	1%
5	Packing & Transport	
	Packing Cost Rs per Kg	4
	Transport Cost Rs per Kg	10
6	Labour Wages - Rs per Day	
	Skilled	220
	Semi Skilled	200
	Un-Skilled	180
	Fringe Benefits - For first 3 Years	36%
	From fourth year onwards	40%
7	Repairs and Maintenance	
	- % Of Machine Cost	2%
	- % Of Building Cost & Utilities	2%
8	Administrative Expenses	
	% of Sales Turnover.	1.0%
9	Interest on Term Loan -	
	- Rupee Loan @	13.5%
	-Interest on Working Capital @	13.5%
10	Selling Expenses as % of Sales Turnover	
	Selling Expenses	3.0%
	Selling Commission	3.0%
11	Product Development & Sampling	3.0%
12	Exchange Rates - as on 12/10/2012	
	1 US $	55.00
	1 Euro	70.00
	1 Pound	84.49
	1 CHF	56.26

Table 6.4: Assumptions for a Non-Woven Textile Facility

Along with the above assumptions the feasibility snapshot below assumes purchase of new machines and not used machines. It is also assumed that the unit will operate at maximum utilization from the 3rd year onwards.

PRODUCTION AND SALES PROJECTIONS - WOVEN GEOTEXTILE

Sr #	Products	Weight (GSM)	Raw material	Web width (mm)	Output/day (kg)	Output/day (m^2)	Selling rate (Rs/kg)
1	Geotextiles	180	PP	6000	2700	15000	**196**
		300	PP	6000	2250	7500	**187**
2	Filtration	500	PP	6000	1125	2250	**182**
		500	PES	6000	2250	4500	**182**
		650	PP	6000	1125	1731	**176**
		650	PES	6000	1125	1731	**176**
3	Automotive felt	150	PES	6000	2700	18000	**204**

Table 6.5: Production & sales assumptions for a Non-Woven textile facility

PROJECT AT A GLANCE - NONWOVEN GEOTEXTILE			
*	Installed Capacity		
	Needlepunch Products	Tons/Day	13
*	Basis For Planning		
	Working Days Per Annum	350	Days (3 Shifts)
	Hours Per Shift		8
*	Project Cost	Rs. Lakhs	6481
*	Means Of Finance		
	Promoters Contribution	Rs. Lakhs	1371
	TUFS or State Subsidy	Rs. Lakhs	768
	Total Equity	Rs. Lakhs	2139
	Rupee Loan	Rs. Lakhs	4342
	Total	Rs. Lakhs	6481
*	Financial Results		
	Sales Realisation	Rs. Lakhs	7898
	Cost Of Production	Rs. Lakhs	6438
	Gross Operating Profit	Rs. Lakhs	1461
	Net Profit	Rs. Lakhs	505
	Break Even Point		54.25%
	Cash Break Even Point		29.68%
	Average D.S.C.R.		1.77
	I.R.R.		16%
	Return On Investment		21.04%
	Breakeven Period		4 Years

Table 6.5: Key Numbers – Non-Woven Facility

6.3 Analysis of Policy Interventions

6.3.1 Current method of application of geotech products prescribed in the Orange book of MoRTH

The *MoRTH Specifications for Road and Bridge Works*, popularly known as the "Orange Book" is a guidebook authored by the MoRTH (Ministry of Road Transport & Highways) to help civil engineers and contractors find specifications and installation/construction guidelines for various aspects of building roads and highways in India. While drafting tenders the Orange Book is often explicitly or implicitly referred to for directions on installation and specifications to be followed.

While authoring the report the project team met concerned officials from the MoRTH and the IRC (Indian Road Congress) on May 22, 2013 to convey to them proposed shortcomings and changes proposed in this report. The team was informed that the fifth revision[8] had been finalized in April 2013 and was in process of being published. The team was informed that this revision would address some of the shortcomings identified and the balance may be taken up subsequently.

However after reviewing the fifth edition it is observed that the following shortcomings still need to be addressed:

- Apart from dedicated chapter on Geosynthetics (Ch 700) there are 4 other chapters that deal with applications where Geosynthetics should be included:
    - Section 300 – Earthwork, Erosion Control & Damage
        - No mention of Geosynthetics in sections 305.2.1 and 305.3.5 where maintaining CBR (California Bearing Ration)/density/moisture content is discussed.
        - In section 305.4.7 Earthwork for High Embankment use of Geosynthetics as an option is lacking
        - No specific mention of geosynthetic use for Soil Erosion or Sedimentation Control such as silt fences in section 306
    - Section 400 – Sub-Bases, Bases (Non-Bituminous) & Shoulders
        - Clause 404: Water Bound Macadam Sub-Base/Base – If water bound macadam (WBM) is to be laid directly over the subgrade, a layer of screening typically consisting of course sand is laid first. Alternately a Geosynthetic performing separation and drainage functions can be used as an option instead.

[8] The prevalent version of the Orange Book was issued in 2001 and had not been updated since then. The Indian Roads Congress (IRC) issued a supplementary publication in 2002 (IRC:SP 59) that updated the specifications but apart from this no upgrades had been made since.

    - This is the only place where use of a Geosynthetic is mentioned as an option. There is no mention of using Geosynthetics for reinforcement and stabilization of subgrade and sub-base courses.
  - Section 500 – Bases & Surface Courses
    - No mention of Geosynthetic use in base course stabilization or in the surface courses.
  - Section 600 – Concrete Pavement
    - No mention of Geosynthetic use in concrete pavements, especially as a surface course layer.
- Geotextile applications only cover the following:
  - Sub-Surface Drains
  - Reinforced Earth Walls
  - Highway Pavement Overlays
  - Slope Protection Works
  - Reinforced Soil

The current prescribed use of Geosynthetics with detailed verbatim clauses from the Orange Book can be seen in Annexure B.

The IRC (Indian Roads Congress) Special Publication No. 59 contains detailed specifications for only the Geotextile applications, namely – sub-surface drains, highway pavement overlays, separation and erosion control. Applications such as Reinforced Walls as well as other products are not part of the IRC SP:59.

The afore-mentioned shortcomings have been explained in further detail in Section 8.1 of this report. The corresponding updates to the Orange Book have been prescribed in Section 9.2 of this report.

6.3.2 Schedule of Rates for Geosynthetics in Various States

Schedule of Rates (SoR) is a document issued by the various PWDs (Public Works Department) in each state. On the basis of the tenders specifications the concessionaires are supposed to refer to the SoRs to calculate the costs associated with procuring material for the concerned project.

A key impediment to the use of Geosynthetics in infrastructure projects, especially with regards to roads and highways, is the fact that Geosynthetic products are not included in the Schedule of Rates (SoR) for most regions in most States. A more significant impediment is the fact that the items listed in the SoRs vary greatly from state to state and considerably under-represent the various types, sizes and qualities of Geosynthetic products available for the various applications. This is proving to be a major obstacle as planning use of items not present in the SoR is a complex and confusing process and is often not permitted by the contracting agency.

A table showing the SoRs from the fourteen different States can be seen in Annexure C. What is established from studying the existing SoRs is that they need to include an updated list with product type, quality and size as well as rates. We have identified products for use in roads and highways and have discussed the proposed list inclusive of these properties in Section 9.3.

Establishing correlation between SOR and current usage of Geosynthetics

As per the committee's feedback it was felt that it was important to identify relationship between the current inclusion of Geosynthetics in the SoR and sales in those States. While this is not in the scope of work of the engagement, an attempt was made to understand whether the current inclusion has made a positive impact on consumption of Geosynthetics in those States.

To this end various contractors working on World Bank funded projects were contacted as Geosynthetic use is stipulated for these projects and the presence of Geosynthetics in the SORs will aid their procurement. These contractors as well as World Bank officials indicated that overall currently around 10 projects worth $3.48 billion in the transport sector are being deployed, which is expected to lead to Geosynthetic procurement of ₹40-50 crore per year (of total industry size of approx. ₹500 crore and projected to grow at CAGR of 10-12% over the next 5 years).

Further to this demand, a similar effort was made to retrieve Geosynthetic regional usage information from agencies such as CPWD, State PWDs, Manufacturers, Traders, IRC, NHAI, etc. who would make up the balance demand, albeit not of the quantum of the World Bank projects' procurement. After discussions with personnel from the agencies it was understood that there is no single source of data where State wise consumption of Geosynthetics is recorded. This is because:

i. The stakeholders (CPWD, State PWDs, NHAI, World Bank, etc.) do not track their projects on the basis of whether Geosynthetics were used or not, quantity and quality used

ii. Additionally tenders often do not include Geosynthetics within the design specifications.

iii. Manufacturers could have been a source of data, but the difference in State of purchase and State of use would render any data from them meaningless; more so because the manufacturers are mostly concentrated in the western region of the country and do not record location of use in their sales data. (Further, manufacturers were also unwilling to share their sales data)

Since the effort to obtain quantifiable data for use of Geosynthetics within the States from either the IRC database (via membership), or any of the central and State bodies mentioned above, it was apparent that trend would have to be established based upon objective and qualitative feedback. Contractors, the ultimate users, were the best source for identifying the desired trends. Hence, a survey was conducted with a sample size of 15 contractors operating in the

States of Maharashtra & Gujarat to understand the impact of current inclusion of Geosynthetics in SORs on sales of the particular Geosynthetic. The questions asked were:

I. Has inclusion in SoR resulted in you using of geosynthetics in your projects in Maharashtra & Gujarat?
II. If "No" to previous question, then what is the reason? (select one)
    a) Geosynthetics were not specified in RFP/Tender
    b) Geosynthetic use is/was optional and tender was L1 – lowest cost
    c) Geosynthetic material you wanted to use was not present in the SOR
    d) Other

The objective findings of this report based upon the respondents' responses can be seen in the charts below.

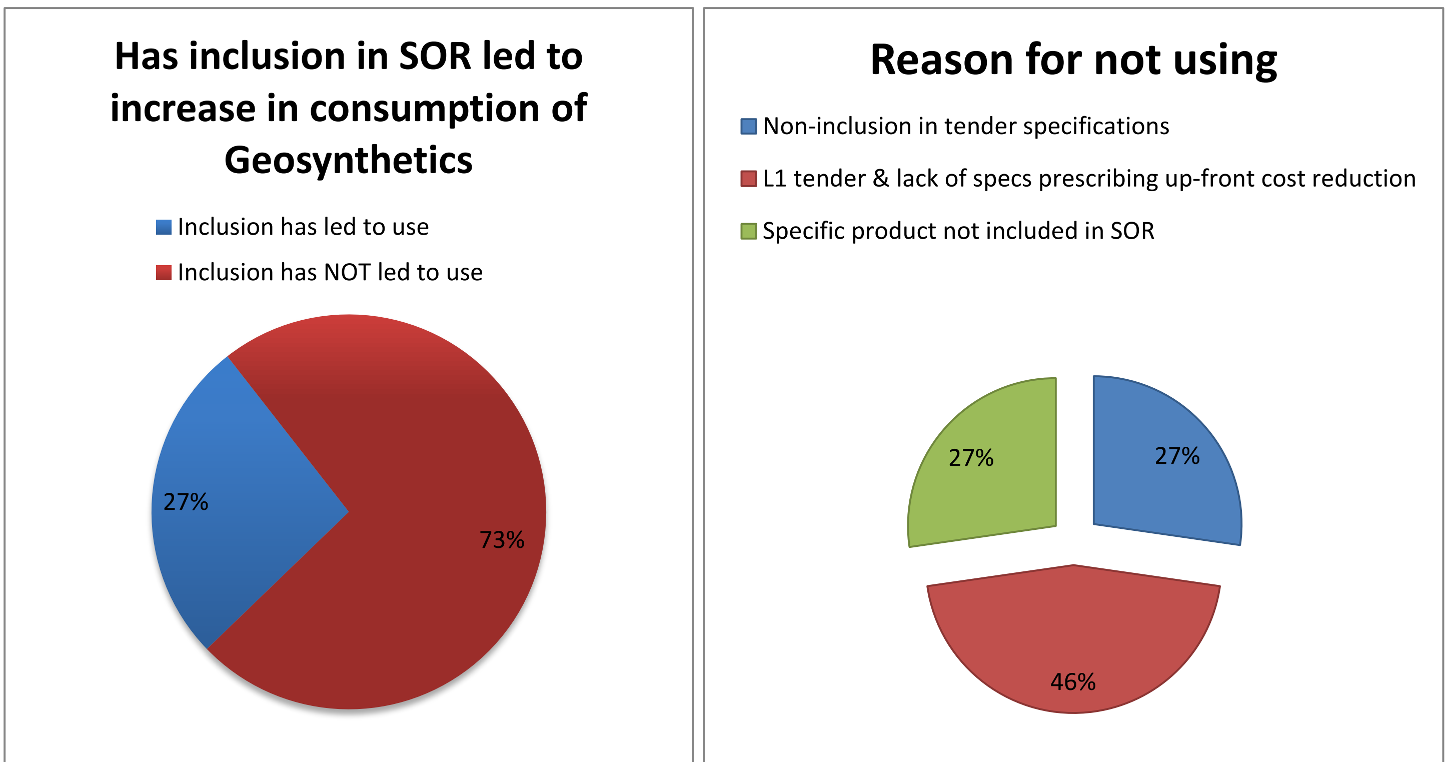


Figure 6.1: Survey of contractors in Maharashtra & Gujarat

From this it can be concluded that it is perceived that inclusion of Geosynthetics in SORs has led to adaption by 27% of respondents for <u>those particular products included</u>. At the same time, non-use can be attributed to a variety of factors in significant proportion that was gleaned from qualitative responses to the survey:

i. Lack of awareness is the reason behind lack of demand by users in the form of non-inclusion in the design specifications.

ii. Non-inclusion of desired products in the SoR - Geosynthetics inclusion in SoRs is limited to 1-2 products per State (mostly Geotextiles only) and does not comprehensively cover the whole segment. Additionally within product types the quality specifications/options (eg. – GSM of material) are limited to 1-2 options only, hence being usable in select tenders only.

iii. The prevalence of L1 (lowest cost) tendering process which dis-incentivises inclusion of Geosynthetics due to assumption of higher up-front costs (in contradiction to Cost Benefit Analysis in section 5.3) as tenders/specifications do not explicitly prescribe corresponding reduction in base courses if Geosynthetics are used for road works.

Hence based on the survey it is concluded that inclusion of Geosynthetics in State Schedule of Rates has had limited utility in improving the uptake of Geosynthetics in India. However it is an important enabler to the process and also a low hanging fruit with regards to actionable recommendations. This report addresses the other reasons for slow uptake in subsequent sections of this report as well the actionable recommendations to mitigate these shortcomings.

6.3.3 Current Regulations Regarding use of Geosynthetics in Landfills

Like most other countries, India in fact does have legislation in place to regulate the management and handling of municipal solid waste (MSW). And as per the "Municipal Solid Wastes (Management and Handling) Rules, 2000", Schedule III "Specifications for Landfill Sites" the section on "Pollution Prevention" states that:

In order to prevent pollution problems from landfill operations, the following provisions shall be made, namely:

a. Diversion of storm water drains to minimize leachate generation and prevent pollution of surface water and also for avoiding flooding and creation of marshy conditions;

b. Construction of a non-permeable lining system at the base and walls of waste disposal area. For landfill receiving residues of waste processing facilities or mixed waste or waste having contamination of hazardous materials (such as aerosols, bleaches, polishes, batteries, waste oils, paint products and pesticides) minimum liner specifications shall be a composite barrier having 1.5 mm high density polyethylene (HDPE) Geomembrane, or equivalent, overlying 90 cm of soil (clay or amended soil) having permeability coefficient not greater than 1 x 10^{7} cm/sec. The highest level of water table shall be at least two meter below the base of clay or amended soil barrier layer;

c. Provisions for management of leachates collection and treatment shall be made. The treated leachates shall meet the standards specified in Schedule- IV;

d. Prevention of run-off from landfill area entering any stream, river, lake or pond.

Conversely, hazardous waste handling rules to be followed as per Rule 8A of the State Pollution Control Boards. However in the case of the SPCBs the design is dependent upon their approval with no stipulations, and information on specifications is not readily available.

While these rule are in place, enforced is an issue over the various municipal corporations around the country responsible for waste disposal, a major reason being the lack of funds for deploying Geomembranes and Geocomposites.

6.4 Lack of Standards and its Impact on the Industry

Standards and specifications stipulating certain product properties and performance are omnipresent for mostly all products encountered on a daily bases – from food to consumer goods to appliances and beyond. Similarly standards and specifications are important in the area of Geosynthetics. Maturity of standards and specifications in this domain is still in a nascent stage and hence the focus of our study was to provide standards from various standard setting organizations abroad and recommend these as benchmarks for the BIS and the industry.

But before embarking upon research into globally prevalent standards it was imperative to understand the dynamics of the Geosynthetics industry ecosystem in India and articulate well defined reasons for the need for standards and specifications in India.

They key stakeholders with directly discernible incentives to establish and adapt a framework for standards and specifications are – Consumers and Manufacturers. Consumers in the Geosynthetics industry can be either Contracting Agencies such as the NHAI, the BRO, PWDs, Municipal Corporations, etc. or the contractors who are executing projects.

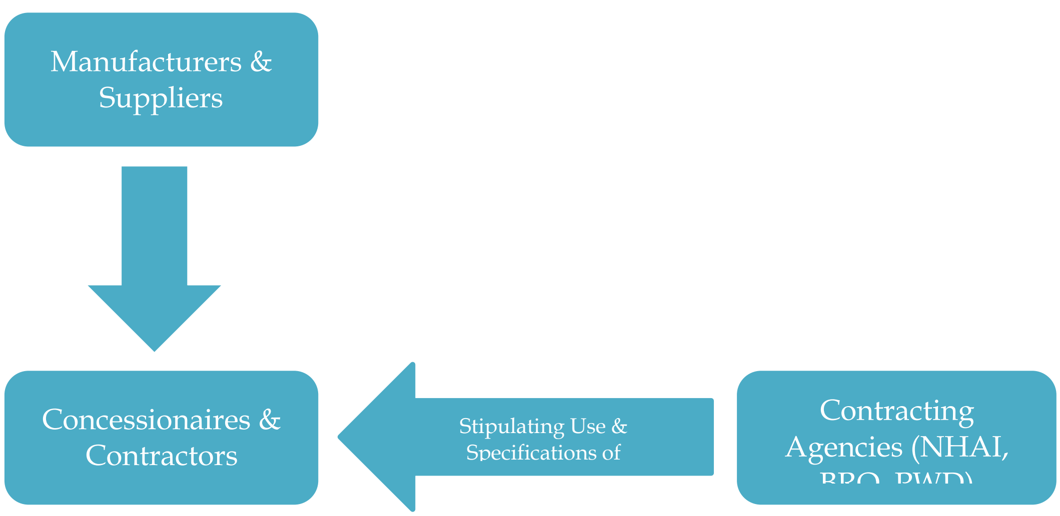


Figure 6.1: Standards stakeholder

This bifurcation in stakeholders is the reason why the Geosynthetics industry ecosystem is unique as there are two different demand sources – the contractor and the contracting agencies.

Either stakeholder can stipulate use of Geosynthetic materials in their projects. This results in 3 different entities with different sets of motivations for established standards and specifications.

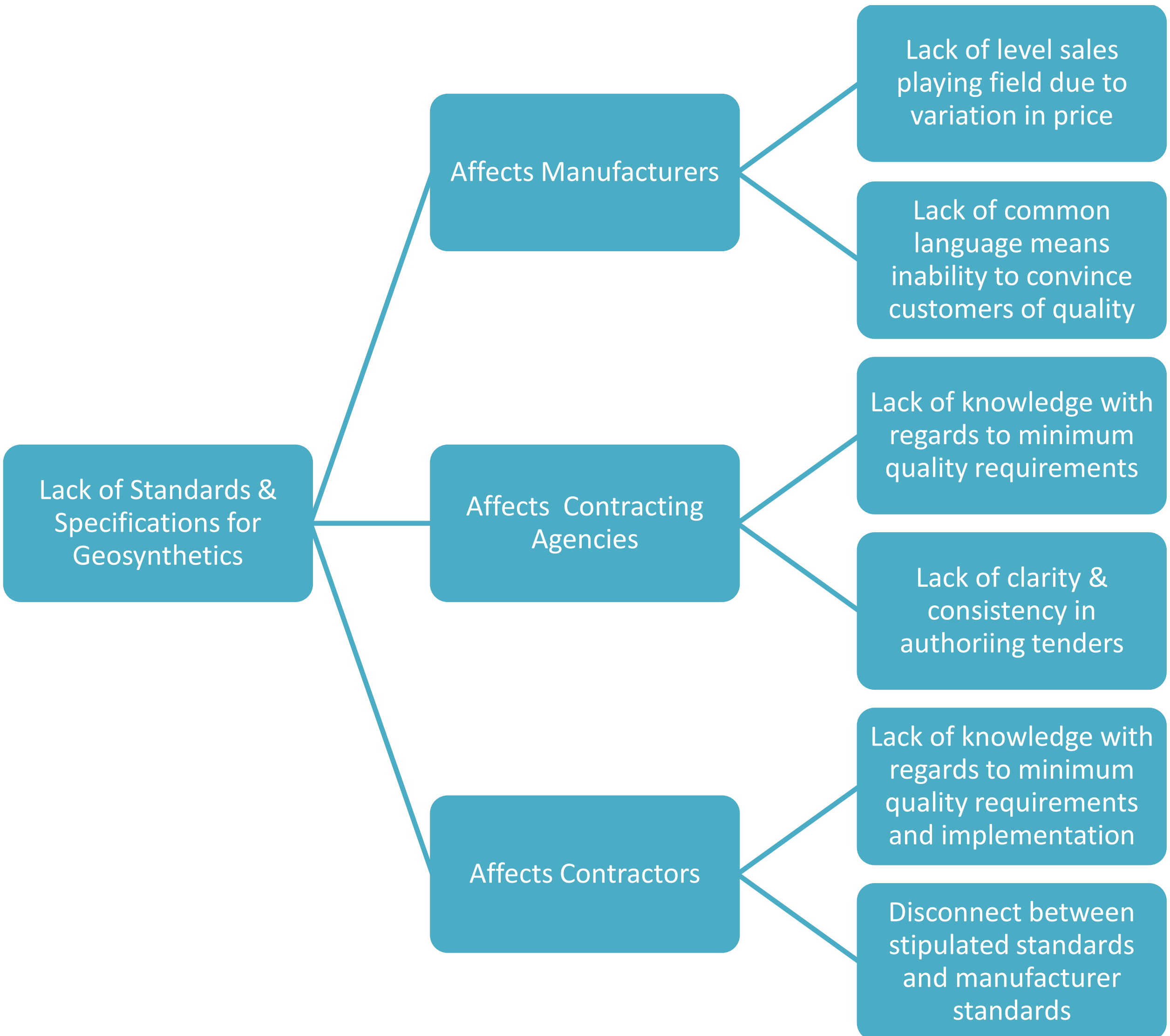


Figure 6.2: Standards issue tree

Summarizing the above listed feedback results in the following key takeaways:

- Product specifications and standards empower consumers to procure a minimum level of quality and ensure satisfactory product/application performance
- Product specifications and standards specified in guidelines for specific applications help overcome lack of knowledge and awareness for consumers
- Product specifications and standards create a level playing field for manufacturers from a sales perspective

The Bureau of Indian Standards (BIS) has devised certain standards in conjunction with the IRC and the BTRA and is continuously developing standards along the lines of the British Standards

Institution (British Standards), Standards Australia (Australian Standards), and obviously the International Organization for Standardization (ISO) and the American Society for Testing and Materials (ASTM). It is important that the Textile Commissioner's office in conjunction with the BTRA continues interaction with the BIS with regards to ensuring standards under development are finalized and approved swiftly. Below is a list of active specifications and standards that have already been developed by the BIS.

Specifications

Sr. No	BIS Standard No.	Description
1	IS 13321 (Part 1):1992	Glossary of terms for geo-synthetics Part : Terms used in materials and properties
2	IS 14715:2000	Woven Jute Geotextiles-Specification
3	IS 15869:2008	Textiles-open weave coir bhoovastra-specification
4	IS 15871:2009	Use of coir Geotextiles (coir Bhoovastra) in unpaved Roads - Guidelines
5	IS 15909:2010	PVC Geo membranes for lining specification
6	IS 15910:2010	Geo-Synthetics For Highways - Specification
7	IS 15872:2009	Application of Coir Geotextiles (Coir Woven Bhoovastra) For Rain Water Erosion Control in Roads, Railway Embankments and Hill Slopes - Guidelines
8	IS 15351:2008	Textiles Laminated High Density Polyethylene (HDPE) Fabric for Canal Lining
9	IS 16090:2013	Geo-Synthetics - Geo-textiles used as protection (or Cushioning) materials – Specification
10	IS 14715(Part 1):2013	Jute Geo-Textiles - Part 1 Strengthening of subgrade in roads-Specification (First revision of IS)

Test Methods (Standards)

Sr. No	BIS Standard No.	Description
1	IS 13162 (Part 2):1991	Geotextiles – Methods of test part 2 Determination of resistance to exposure of ultra-violet light and water (Xenon arc type apparatus)
2	IS 13162 (Part 3):1992	Geotextile - Methods of test Part 3 determination of thickness at specified pressure
3	IS 13162 (Part 4):1992	Geotextiles - Methods of test Part 4 Determination of puncture resistance by falling cone method
4	IS 13162 (Part 5):1992	Geotextiles - Methods of test Part 5 Determination of tensile properties using a wide width strip

5	IS 13325:1992	Determination of Tensile Properties of Extruded Polymer Geogrids Using the Wide Strip - Test Method
6	IS 13326 (Part 1):1992	Method of test for the evaluation of interface friction between Geosynthetics and soil Part 1 modified direct shear technique
7	IS 14293:1995	Geotextiles - Method of test for trapezoid tearing strength
8	IS 14294:1995	Geotextiles - Method for determination of apparent opening size by dry sieving technique
9	IS 14324:1995	Geotextiles - Methods of test for determination of water permeability-permittivity
10	IS 14716:1999	Geotextiles- Determination of mass per unit area
11	IS 14706:1999	Geotextiles - Sampling and Preparation of Test Specimens(BI-LINGUAL)
12	IS 14714:1999	Geotextiles - Determination of Abrasion Resistance
13	IS 14739:1999	Geotextiles - Method for Determination of Creep
14	IS 14986:2001	Jute geo-grid for rain water erosion control in road and railway embankment and hill slopes
15	IS 15060:2001/ ISO 10321:1992	Geotextiles - Tensile Test for Joint/Seams by Wide-Width Method
16	IS 15868(PART 1):2008	Natural Fibre Geotextiles (Jute Geotextiles And Coir Bhoovastra) Methods Of Test - Part 1 Determination Of Mass Per Unit Area
17	IS 15868(PART 2):2008	Part 2 Determination Of Thickness
18	IS 15868(PART 3):2008	Part 3 Determination Of Percentage Of Swell
19	IS 15868(PART 4):2008	Part 4 Determination Of Water Absorption Capacity
20	IS 15868(PART 5):2008	Part 5 Determination Of Smouldering Resistance
21	IS 15868(PART 6):2008	Part 6 Determination Of Mesh Size Of Coir Geotextiles By
22	IS 15891 (Part 1):2011	Textiles Test Methods For Non-Wovens Part 1 Determination Of Mass Per Unit Area
23	IS 15891 (Part 2):2011	Part 2 Determination Of Thickness
24	IS 15891 (Part 6):2011	Test Methods for Nonwovens Part 6 Absorption
25	IS 15891 (Part 7):2012	Part 7 Determination of Bending Length
26	IS 15891 (Part 8):2012	Part 8 Determination of Liquid Strike - Through Time (Simulated Urine)
27	IS 15891 (Part 9):2012	Part 9 Determination of Drapability including Coefficient

For its part the BTRA has been active in benchmarking international standards and pushing for their adoption with the BIS. Below are the draft global standards sent to BIS for wide circulation.

Sr. No	Test Method	Title/ Test	Letter Reference	Date Sent
1	ASTM D 1987	Biological clogging of geotextile	e-mail	Jan.2012
2	ASTM D 4632	Grab breaking strength & elongation		
3	ASTM D 4594	Effect of temperature on stability of		

		geotextile		
4	ASTM D 5322	Chemical resistance of geosynthetics to liquids		
5	ASTM D 6706	Pull out resistance	BTRA / Dir / 70 / 2012	31.03.2012
6	ASTM D 5493	Permeability of Geotextile under Load		
7	ASTM D 6574	Hydraulic Transmissivity		
8	ASTM D 5970	Geotextile deterioration from outdoor exposure		
9	ASTM D 6693	Tensile properties of geomembrane	BTRA / Dir / 104 / 2012	31.05.2012
10	ASTM D 4833	Index puncture		
11	ASTM D 5397	Stress cracking resistance of Geomembrane using notched constant tensile load test		
12	ASTM D 6767	Pore Size Characteristics of Geotextiles by Capillary Flow Test	BTRA / Dir / 112 / 2012	16.06.2012
13	ASTM D 5818	Installation Damage of Geosynthetics		
14	ASTM D 6637	Tensile strength of geogrid	BTRA / Dir / 143/ 2012	23.07.2012
15	ASTM D 5747	Chemical Resistance of Geomembranes to Liquids		
16	ASTM D5494	Pyramid Puncture Resistance of Geomembranes		
17	ASTM D 5596	Dispersion of Carbon Black in Polyolefin Geosynthetics.	BTRA / Dir / 188/ 2012	16.10.2012
18	ASTM D 4885	Performance Strength of Geomembranes by the Wide Strip Tensile Method		
19	In house	Determination of Weld strength of Geocell	BTRA / Dir / 203/ 2012	12.11.12
20	ASTM D 5323	Determination of 2 % Secant Modulus for Polyethylene Geomembranes		
21	ASTM D 6638	Determination of connecting strength between geosynthetic reinforcement and segmental concrete units.	BTRA / Dir / 100/ 2013	18.10.2013
22	ASTM D 7498	Test method for vertical strip drain using a large scale consolidation		

Pursuant to this the BIS has the following standards under process:

Finalised Drafts Under Print

1. DOC.TXD 30(950) - Jute Geo-Textiles - Part 2 Control of bank erosion in rivers and waterways (First revision of IS 14715)
2. DOC.TXD 30(959) - Guidelines for application of coir geotextiles (Coir Woven Bhoovastra) for rail water erosion control in roads, railways embankments and hill slopes

3. DOC.TXD 30(982) - Method of test for determination of California Bearing Ratio.
4. DOC.TXD 30(983) - Textiles-Method of determination of apparent opening size of Geo-Textiles by wet sieving

Draft Standards Finalized But Not Yet Under Print

5. DOC.TXD 30(1025) - Specification for geo-textiles used in subsurface drainage application
6. DOC.TXD 30(1026) - Specification for geo-textiles for permanent erosion control in hard armor systems
7. DOC.TXD 30(1028) - Specification for geo-textiles used in subgrade stabilisation in pavement structures
8. DOC.TXD 30(1029) - Specification for geo-grids used as reinforcement of base and sub-base layers in pavement structures
9. DOC.TXD 30(1030) - Specification for geogrids used as soil reinforcement in mechanically stabilised earth (MSE) retaining structures
10. DOC.TXD 30(1073) - Guidelines for installation of geotextiles as pavement fabric
11. DOC.TXD 30(1076) - Guidelines for installation of geotextiles used in subgrade separation in pavement structures
12. DOC.TXD 30(1077) - Guidelines for installation of geogrids used as reinforcement of base and subbase layers in pavement structures
13. DOC.TXD 30(1078) - Guidelines for installation of geogrids used as soil reinforcement in mechanically stabilized earth (MSE) retaining structures
14. DOC.TXD 30(1122) - Standards Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters
15. DOC.TXD 30(1123) - Standards Test Method for effects of temperature on stability of geotextile
16. DOC.TXD 30(1124) - Standards practice for laboratory immersion procedures for evaluating the chemical resistance of geosynthetics to liquids
17. DOC.TXD 30(1125) - Geotextiles - Method of test for grab breaking load and elongation

Draft Standards Completed Wide Circulation

1. DOC.TXD 30(1027) - Specification for geo-textiles used in subgrade separation in pavement structures
2. DOC.TXD 30(1074) - Guidelines for installation of geotextiles used in subsurface drainage application
3. DOC.TXD 30(1075) - Guidelines for installation of geotextiles for permanent erosion control in Hard Armor Systems
4. DOC.TXD 30(1079) - PVC Geo-membranes for lining - Specification (First revision of IS 15909)

Draft Standards Approved For Wide Circulation

5. DOC.TXD 30(961) - Natural fibre geotextiles (Jute Geo textiles) and Coir Geotextiles (Coir Bhoovastra) - Glossary of terms for erosion control products
6. DOC.TXD 30(1178) - Stress crack resistance of polyolefin geomembranes using notched constant tensile load test
7. DOC.TXD 30(1179) - Pore size characteristics of geotextiles by capillary flow test
8. DOC.TXD 30(1180) - Exposure and retrieval of samples to evaluate installation damage of geosynthetics
9. DOC.TXD 30(1182) - Index puncture resistance of geomembranes
10. DOC.TXD 30(1183) - Determination of weld strength of geocell
11. DOC.TXD 30(1184) - Determination of 2 % secant modulus for polyethylene geomembranes
12. DOC.TXD 30(1185) - Determination of pyramid puncture resistance of unprotected and protected geomembranes
13. DOC.TXD 30(1186) - Tensile properties of geo-grids by the single or multi-rib tensile method
14. DOC.TXD 30(1187) - Performance strength of geomembranes by wide strip method
15. DOC.TXD 30(1188) - Chemical resistance of geomembranes to liquids
16. DOC.TXD 30(1189) - Dispersion of carbon black in polyolefin
17. DOC.TXD 30(1191) - Standard practice for deterioration of geotextiles from outdoor exposure
18. DOC.TXD 30(1192) - Method of test for determination of (in-plane) hydraulic transmissivity of a geo-synthetic by radial flow
19. DOC.TXD 30(1193) - Standard test method for measuring geo-synthetic pull-out resistance in soil
20. DOC.TXD 30(1194) - Standard test method for permittivity of geotextiles under load
21. DOC.TXD 30(1195) - Geosynthetics - Specification for needle punched non-woven geobags for coastal and waterways

As can be seen, specifications and most test methods for Geocells, Geofoam and PVDs (Prefabricated Vertical Drains) have not been formulated. Test methods seem to comprehensively be in the process of update for Geotextiles for use in roads, as well as for filtration purposes. Most importantly, these standards are only helpful if adoption of these as industry norm happens and users as well as manufacturers adhere to them. This will reduce disparity between understanding of requirement and performance.

7 Analysis of Current Usage of Geosynthetics Internationally

7.1 International Bodies Involved in the Promotion of Geosynthetics

Based on feedback received from respondents during our research a list of standard setting organizations was crated whose standards could be studied and used for comparison to the BIS (Bureau of Indian Standards). Additionally details regarding on site audit and quality certification agencies were also received and have been included in the list below as well.

Note: The list of not comprehensive but rather is based on stakeholder feedback of model agencies whose best practices have been analysed for their applicability to the Indian context.

Standard	Organization Name	Geography	Description
ISO	International Organization for Standardization	Global Body	International standard setting body composed of representatives from various national standards organizations.
ASTM	American Society for Testing and Materials International	Global Body	A global organization involved in creating primarily test methods along with specifications and guidelines, but not involved in any sort of certification or enforcement
DIN	German Institute for Standardizations	Germany	German representative in ISO. Primarily possesses test methods.
EN	European Committee for Standardization (CEN)	European Union	Officially recognized as the European standards body by the EU. Signed Vienna Agreement with ISO to avoid duplicity in standards
BS	British Standards Institution (BSI)	UK	British representative in ISO. Primarily possesses test methods, with some specifications.
AS	Standards Australia	Australia	Australian representative in ISO. Primarily possesses test methods.
ASQUAL	ASQUAL Qualification	France	Audit and certification of Geosynthetic applications
NTPEP	NTPEP Audit Program for Geotextiles	US	Audit and Certification program for manufacturer's that was initiated by AASHTO
BBA	British Board of Agrement	UK	Manufacturer quality control specification/accreditation
Geospec	Geospec	UK	Independent UKAS accredited Geosynthetic and Geotechnical testing laboratory dealing mostly with audits
AASHTO	American Association of State Highway and Transportation Officials	USA	Specifications setting body which publishes specifications, test protocols and guidelines focusing mostly on roads and highways and bridges
GSI / GRI	Geosynthetic Institute / Geosynthetic Research Institute	USA	Specifications setting body which publishes specifications, test protocols and guidelines focusing mostly on Geomembranes, as well as road and highways
GMA	Geosynthetic Materials Associations	USA	Lobbyist and enabler for the Geosynthetics industry
IGS	International Geosynthetic Society	Global Body	An association comprising of industry members to exchange information and knowledge and promote the Geosynthetics industry

7.2 Benchmarking of Key Policy Interventions

Understanding what foreign government agencies have done to promote Geosynthetics from a policy perspective is also important. This is especially important as:

a) A lot of demand generation for the Geosynthetic industry relies upon infrastructure projects undertaken or funded by the government.

b) Many applications of Geosynthetics do not have any apparent monetary benefit and hence their use is counter intuitive to contractors' profitability if left to their discretion. An example of this is prevalent in most markets as can be seen below – the mandatory use of Geomembranes in landfills to prevent soil and land water contamination

A list of various government policy initiatives can be seen below and used as a starting point for similar initiatives to be championed by the Office of the Textile Commissioner:

Regulations by foreign governments

- The Department of Water Affairs and Forestry in South Africa made the use of Geomembranes in landfills mandatory under the Minimum Requirements Series not long after 1994.
- In Europe, the Construction Products Directive (89/106/EEC; M/107) has to be followed which made it mandatory to manufacture, test and mark Geosynthetics in accordance with the EN standards. It consequently dictated that product standards and test methods be devised.
- Austria, France, Germany, Hungary, Italy, Switzerland, Japan and the UK have Minimum Requirements in place when it comes to Geomembranes and Geotextiles for MSW landfills.
- The US EPA (Environmental Protection Agency) and the various state and federal highway authorities prescribe use of geosynthetics for the following applications:
  - Since 1984 hazardous waste landfills in the US have been regulated under EPA (Environmental Protection Agency RCRA Subtitle C which mandates the use of two liners and two lateral drainage systems, with leak detection capability. The lower liner system is always a composite liner consisting of a Geomembrane.
  - Municipal Solid Waste (MSW) landfills in the US are regulated under EPA RCRA Subtitle D – non-hazardous solid waste. Since 1993 this has required that all new MSW landfills be lined with a single composite liner consisting of a Geomembrane plus a clay liner (GCL or CCL).
  - In 1992, the US EPA (Environmental Protection Agency) implemented the "National Pollutant Discharge Elimination System" (NPDES) pursuant to the provisions of the Clean Water Act, which consists of rules and permitting requirements for managing storm-water discharges from construction activities including highway construction. Since Geosynthetic silt fences are the most widely used and effective means of

temporary sediment control on construction sites the NPDES indirectly resulted in great increase in Geosynthetics consumption.

- Certain States in the US recommend silt fences for erosion and sediment control during road construction. An excerpt from the "Virginia Erosion and Sediment Control Handbook" regarding silt fences and the use of synthetic filter fibre, either woven or non-woven, can be seen in Annexure J.

Policies and measures followed globally

- The World Bank has stipulated use Geosynthetics in all infrastructure projects it is funding.[9]

- The Geotechnical Design Manual issued by the Washington State DOT discusses Geosynthetic Design in Chapter 16 and again refers to the hand book titled "Geosynthetic Design & Construction Guidelines Participant Notebook" by the National Highway Institute (NHI) (used for the US DOT FHWA courses) for specifications. This handbook has dedicated sections on Geosynthetics in subsurface drainage systems, erosion control systems, roads and pavements, overlays, retaining walls, etc. which include both specifications and usage guidelines. It can be viewed at http://isddc.dot.gov/OLPFiles/FHWA/011431.pdf.

- The California Department of Transportation (Caltrans) specifies a minimum standard of thickness of 0.45 feet for hot mix overlays that includes a stress absorbing membrane interlayer, a.k.a a Geosynthetic layer. This specification can be seen in Annexure I.

- The California Department of Transportation (Caltrans) issued a guide in 2009 titled "Guide for designing Subgrade Enhancement Geotextiles" to assist pavement design engineers in selecting and installing Geotextile layers in road construction.

- In 1999, the Ministry of Water Resources selected 50 hydraulic projects using Geosynthetics as model projects, thus further pushing forward the application and development of Geosynthetics in China.

- Test Procedure of Geosynthetics by the Ministry of Water Resources, and Test Specification for Geosynthetics used in Highway Projects by the Ministry of Communications, China were published successfully to monitor and ensure quality of Geosynthetics used in these applications.

- The implementation of the industry standard, Application Technical Standard for Geosynthetics used in Water Resources and Hydropower Engineering, was started in November 1998. It includes the design methods and key points of construction technology

[9] Penwill-Cook, Frances. "India: Paving Roads the Geotextile Way". March 4, 2010. <http://www.roadtraffic-technology.com/features/feature78297>

using Geosynthetics as filters, for drainage, anti-seepage, bank protection, anti-scour, and soil reinforcement.

7.3 Comparison of Tender Terms & Conditions

The crucial difference between the tendering process in India and abroad with respect to Geosynthetics is the fact that specifications for Geosynthetic use are given in tenders and contracts. So while the contractor has some level of discretion to assess the utilization of Geosynthetics, it is distinctly stated which product and test specifications are to be followed.

- Tender specimen for a contract for the "N.E. 112th Ave. /Gher Rd. Interchange" in Clark County, Washington State, USA was chosen. Their contract specifications clearly stipulate the use of Geotextiles and Geosynthetics and state the applicable standards.
- Tender for the supply and delivery of Geomembrane liner, Geosynthetic clay liner & Geotextile protector for a hazardous waste landfill in Malta.
- Technical specification for the construction of multipurpose Geotextile reefs at Mirya, Maharashtra using Geotextile Tubes and geomats.
- A tender for diversion channel construction in Montana, USA. Specifications for the PP turf reinforcement mats for embankment reinforcement (erosion control) are given

These four tender specimens can be seen in Annexure K.

This is a crucial point in increasing use of Geosynthetics in India as only when their applicability is specified as an option in tenders and contracts by the consumer agencies in India, will contractors start looking at Geosynthetics as an option. This should be an action point for the Textile Commissioner's Office and is a progression from the earlier mentioned strategy of liaising with consumer agencies to garner their buy-in on the use and benefits on Geosynthetics.

7.4. Key Case Studies - Case Studies for Application Based Research for Geosynthetics

During the primary research phase one of the topics of discussion was areas where a lack of application based research in India was affecting adoption of Geosynthetics in infrastructure projects due to low awareness with regards to the associated benefits. Research was also conducted on what some of the newer emerging technologies were in the area of Geosynthetics. The feedback received was extremely insightful which was then used to assemble a few select case studies for applications that have been carried out in various parts of the world showing the extremely promising results. Energies need to be focused towards research in these applications areas (listed below) in India to ensure the untapped potential for Geosynthetics is realised.

7.4.1. Geotextile Tubes for Containment

<u>Sample Case</u>: Amwaj Islands, Bahrain
Geotextile Tubes for containment dykes to create artificial islands

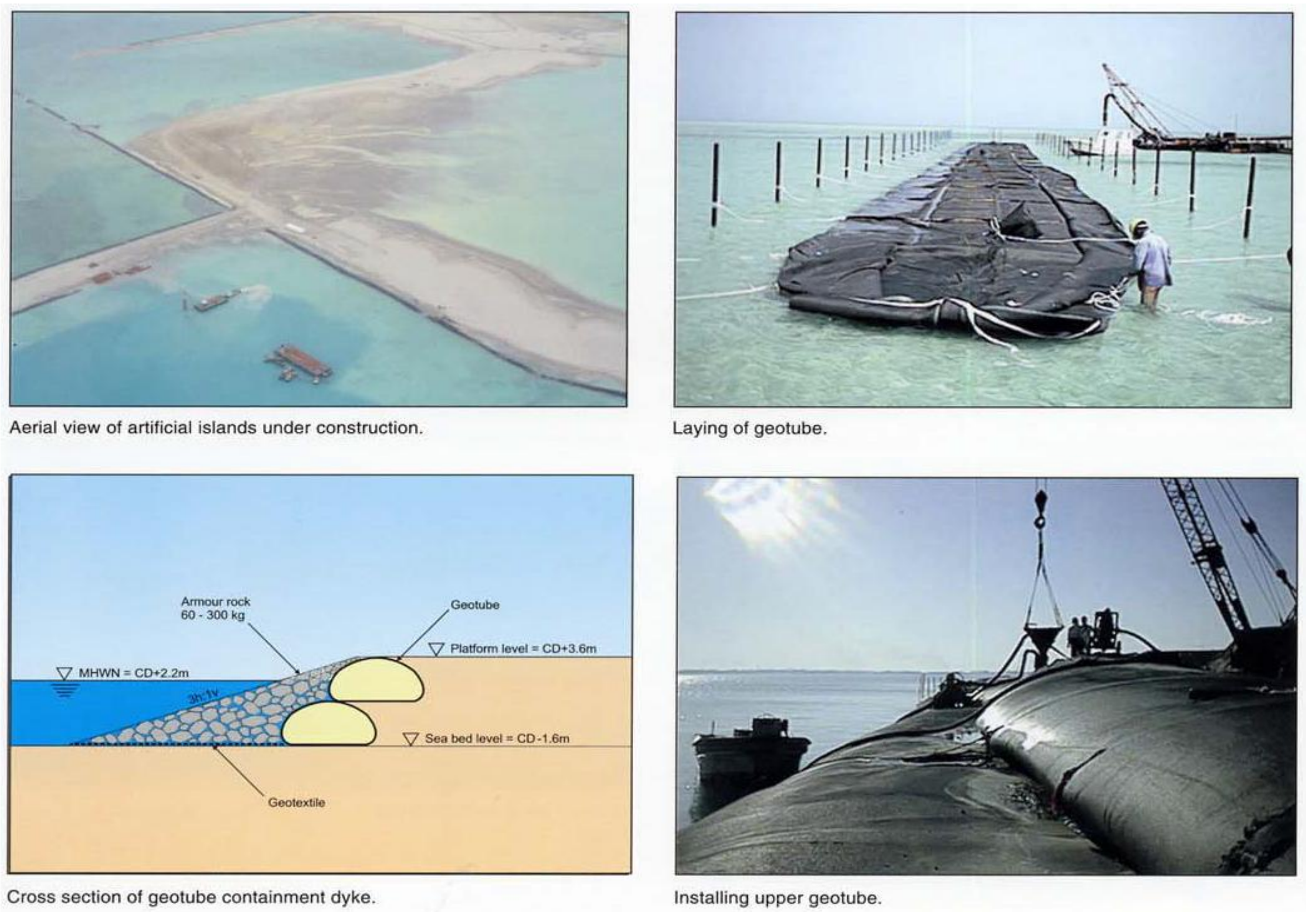


Figure 7.1: Installation of Geotextile tube for coastal containment

Geotextile Tubes were used for containment dykes to create artificial islands for the Amwaj Islands Project in Bahrain. This project is a prestigious housing development site in the Persian Gulf.

Reclamation was carried out in two stages. The first stage involved the installation of a Geotextile Tube of height approximately 2.6m followed by hydraulic filling of sand behind the Geotextile Tube. The second stage involved the installation of another Geotextile Tube, followed by further hydraulic filling of sand to achieve the finished platform level of CD + 3.6m. Upon completion of the reclamation, rock armour of 60-300 kg was placed in front of the Geotextile Tube dyke.

Eventually, submerged reef breakwaters are to be constructed about 300m from the Geotextile Tubes to create perched artificial beaches.

7.4.2. Geotextile Tube Dewatering Containers

<u>Sample Case</u>: Clean-up of the Fox River, Wisconsin, USA

Geotextile Tubes for river clean-up via dewatering dredged contaminated river bottom sediment

In August 2006 the largest ever river cleanup project attempted in North America was underway along a 40-mile stretch of the Fox River in northeast Wisconsin and was using Geotextile Tubes as a key component in the process.

Sediments in the river and bay were contaminated with an estimated 700,000 lbs. of PCB chemicals. This sediment slurry dredged from the riverbed was being piped to a handling facility onshore where it was being pumped into massive, porous Geotextile Tubes that allowed the water to pass but trapped and compacted the solids for easier disposal. The water was treated and returned to the river while the sediment was transferred to landfills.

Figure 7.2: These geotubes are completely filled and are passively dewatering or "aging." Note water-treatment tanks in background

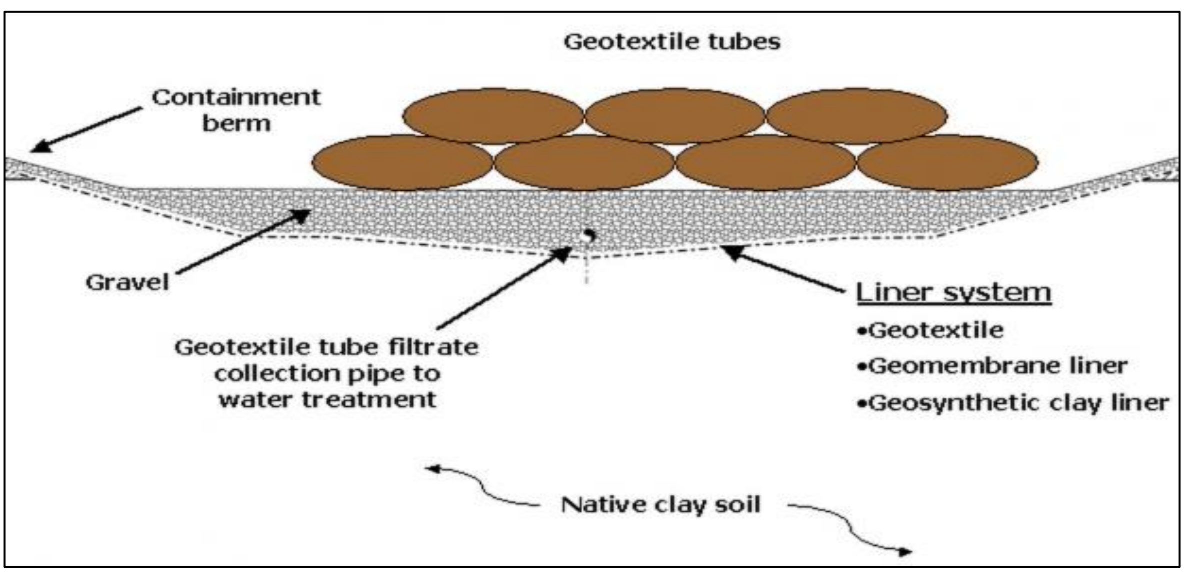


Figure 7.3: Illustration of Geotextile tube application in river clean via dredging and dewatering

7.4.3 Geocells in Road Construction

Sample Case: Institute of Geotechnical Engineering, Technology University of Clausthal
"The use of Geocells in road constructions over soft soil: vertical stress and falling weight deflectometer measurements" by Ansgar Emersleben and Norbert Meyer

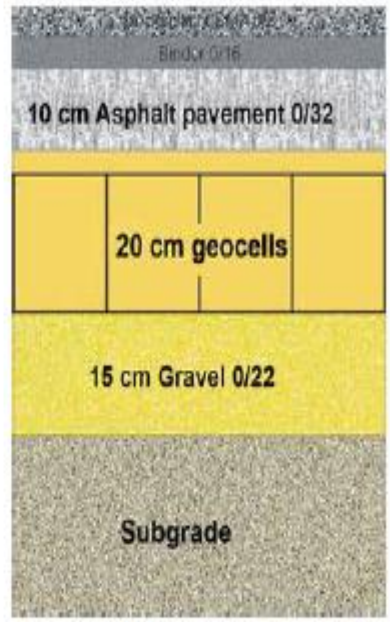


Figure 7.4: Laying and filling of Geocells in road-laying, and illustrative cross section of Geocell installation

Geocells consist of a series of interconnected single cells that are manufactured from different types of polymers. The Geocells are expanded at the construction site and filled with soil. The soil-Geocell layer acts as a stiff mat and distributes the vertical traffic loads over a much larger area of the subgrade soil. Large scale static load tests were carried out to evaluate the influence of a Geocell layer on the load-deformation behaviour of the soil. The test results show that a Geocell layer increases the bearing capacity of the infill materials up to three times compared to an unreinforced soil. The vertical stresses on the soft subgrade, measured by eight earth pressure cells, where also reduced about 30 per cent.

7.4.4. Smart Geosynthetics Enabled with Fibre Optic Sensors

Sample Case: IjkDijk Project carried out by TenCate using their GeoDetect product
Strain detection and system validation at the experimental IjkDijk project site

Since the early 1980 various manufacturers and agencies have been conducting research into instrumenting Geosynthetics for taking measurements in earth's structures. This would help serve multiple purposes – verification of design parameters, monitoring wear and tear, stress and strain detection, movement detection and hence early warning, temperature tracking, etc.
Belgium based global manufacturer TenCate tried out a geo-detection system of theirs at the experimental IjkDijk Project site.

Figure 7.5: Laying of strain detection smart Geosynthetics for predicting failure

The system successfully observed strain into the dyke 2 days before actual failure and was hence validated as an "Early Warning Solution" for strain. The readings below mimic the eventual failure pattern two days in advance.

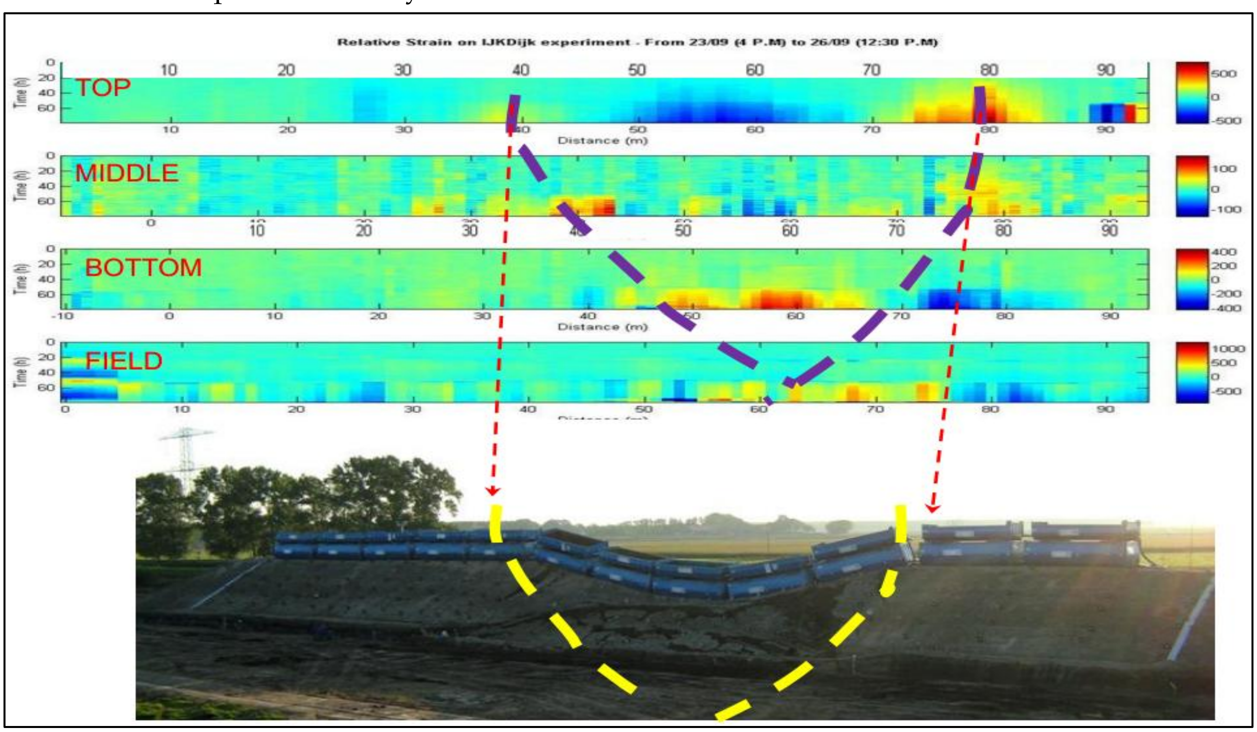


Figure 7.6: Correlation of failure with predictive model

7.4.5. Geosynthetic Clay Liner (GCL) to Contain Wet Process Ash for Powerplant

Location: Southeastern USA

Material Used: Coal Ash Resistant Geosynthetic Clay Liner

Material Supplied by: GSE Inc, USA

Overview:
GSE supplied approximately 1,000,000 square feet of Bentoliner (Coal Ash Resistant) Geosynthetic Clay Liner (GCL) to a 3,520-megawatt Southeastern United States for the containment of wet process ash. The owner insisted that no GCL additives used be toxic or enhance any microbial growth in the surrounding soils and water table.

Solution:
Coal ash resistant Bentoliner was used as part of a composite liner system also comprised of 60 mil textured HDPE Geomembrane and drainage Geocomposite. Bentoliner CAR GCL offered an ideal secondary component to a composite containment system with never-before-seen performance in the presence of coal ash leachate. The GCL offers optimal containment in comparison with a native clay layer.

It also offers a polymer enhanced bentonite formulation that affords outstanding performance under extreme conditions and chemical attack, such as those found in wet and dry coal ash storage impoundments. High ionic solutions containing elevated levels of calcium and sodium have historically been a "no-man's land" for bentonite-based products. Now many of these environments that were once incompatible with a GCL can be managed with Bentoliner CAR.

Result
The owner wanted to construct an impoundment that would conform to any potential rulings from the EPA on coal ash management. Design engineers wanted to achieve the highest possible levels of containment with the greatest margins of safety. Bentoliner CAR GCL addressed both of these needs and at a fractional cost compared to traditional GCLs.

7.4.6. Geocomposites (PVDs) and Geonets for Horizontal Drainage of the Railway Track Bed of the AVE High Speed Train.

Location: New Segovia - Valladolid Railway Access. Sub-Section l: Nava de la Asunción-Coca, Segovia, Spain

Material Used: Geocomposite (Prefab Vertical Drain), Geonet with Geotextile on the surface.

Material Supplied by: Intermas Nets S.A.

Overview:
Between the towns of Coca and Nava de la Asunción (province of Segovia), the Madrid Valladolid High Speed Train runs through slopes made up of schists and clays. In the adjacent land there is an extensive area of irrigated land.

Problem:

Substantial quantities of emerging water were detected while the track bed was being laid. The water came to the surface of the excavation by way of the capillary effect produced in the clays. The presence of the water made the construction work enormously difficult, and failure to act would have meant that, during the useful life of the construction, the water would easily have reached to the structure of the track (the forming and sub-ballast layers), producing deformations in the ground and irreversible damage to the track.

Solution:

The solution to the problem consisted in setting up a drainage system for the track using Geosynthetic materials. The Geocomposites proved to be the most technically and economically effective solution because:

The system consisted of:

1. The placing of the Geocomposite on and along the forming layer.
2. The installation of 2 longitudinal drains in trenches (two edge drains) at the sides of the track bed using the Geonet with Geotextile covering system.

The functions of each Geosynthetic are:

Geocomposites:

- ✓ Intercepts underground and rain water and evacuates it rapidly to both sides of the track bed.

Geonets with Geotextile:

- ✓ Collects the water from the track bed, stops the water coming from the adjacent slopes and drains into a number of sumps prepared for this purpose.

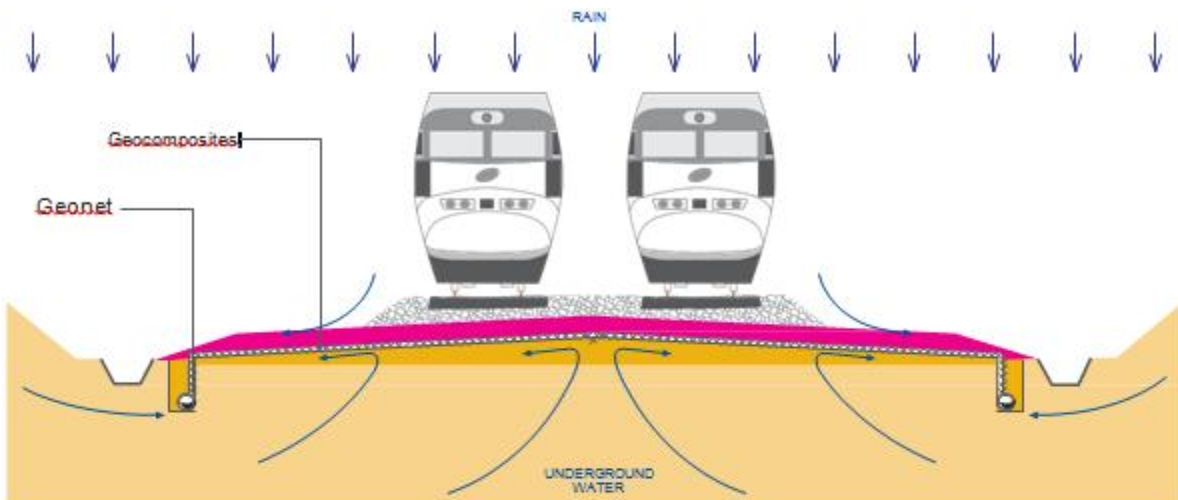


Figure 7.7: Illustration showing sub surface drainage

Result:

The railway track bed drainage system made of Geocomposites (interception and rapid evacuation of water) and Geonet (longitudinal in trench drainage and drain pipes) is the best option for the horizontal drainage of railway track beds because:

A) They are products which are much more economical than traditional solutions and their installation is easy, convenient and fast
B) They have an excellent performance regarding compression and flow-through - characteristics far superior to those required and which the usual competitor products do not satisfy
C) They have a high drainage capacity, even under heavy loads and a minimum slope, with the result that the hydraulic function is guaranteed.

Therefore required results were achieved.

7.4.7. Geogrids and Geotextiles for Floating Foundation

Location: AS Fuessen, between kilometer 124+500 and 122+950, Germany

Material Used: Geogrid, Geotextile

Material Supplied by: Naue, Germany

Overview:

Close by to the interstate exit AS Fuessen, between kilometer 124+500 and 122+950 it was necessary to build a stable foundation for the new interstate on the very weak subsoil.

Figure 7.8: Weak wet subsoil due to water body

Problem:
The subsoil of the new interstate contained major areas of weak peat, chalk and sediments in various thicknesses. Due to several metres of thick weak subsoil the foundation bearing dams needed to be stabilised to minimise settlements.

Solution:
The designer selected for this purpose a floating foundation with crushed material from 2 – 150 mm, which should additionally be Geosynthetic reinforced.

The selected cross section of the floating foundation was as follows:

- The bottom reinforcement layer of the floating dam foundation was a high tensile woven Geotextile and was laid over the entire base and slope areas.
- After installation and compaction of a 50 cm thick first layer, the main uniaxial reinforcing Geogrid was installed under tension.

- Then the final base course material was placed over Geogrid until the final level was achieved.

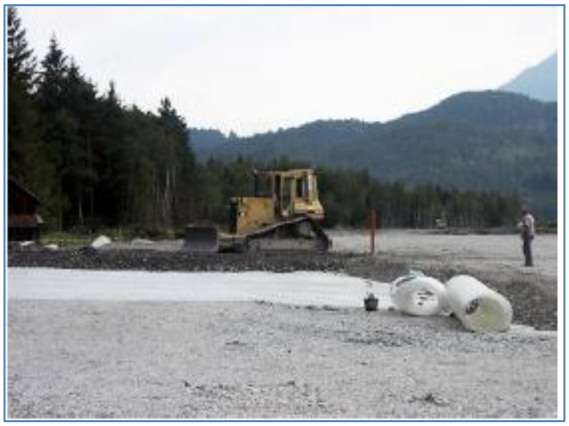



Figure 7.9: Geotextile being placed over Geogrid

Selecting Geogrid material as the main reinforcement in the floating dam foundation was explained by the facts, that the Geogrid

- Has extraordinary low long term creep behaviour,
- Shows an extreme efficient interlocking, and therefore force transfer, with the selected fill material and
- Is a very economical solution

Results:
Construction was completed in 2003 and desired results are achieved

7.4.8. Geofoam in Highway reconstruction on soft soils

Location: Interstate-80/94—Interstate-65 Interchange Borman Expressway—Gary, Indiana

Material Used: Geofoam

Design & engineering: Indiana Department of Transportation

Project site manager: Gary Walsh, Walsh Construction Co.

Installation: Walsh Construction, Chicago

Figure 7.10: Geofoam being installation for road stabilization

Overview:
Once a thriving industrial suburb of Chicago that was sometimes called the Steel City, Gary, Ind., has seen a gradual decline in its industrial base and population. Indiana's fifth-largest city was hard hit by the decline in steel mill employment but has recently found an economic boon in the light manufacturing and tourist industries. Its location on the south shore of Lake Michigan is ideal for casino boats and provides a place for Chicagoans who are looking for weekend getaway s. The increase in industry and tourism led to a growing number of vehicles using the highways surrounding Gary. Most of the highway system was constructed in the 1950s and clearly was not aging well or able to withstand the increase in traffic. The Indiana Department of Transportation (INDOT) recognized the need for major improvements to the highway system and approved the reconstruction of the Borman Expressway (I-80/I-94) from Gary westward to the Illinois state line, a project that has been under way since 2004. The last element of the project is the $189 million Major Moves New Construction Interchange Modification that included the reconstruction and widening of the I-80/94–I-65 interchange.

Problem:
Gary's location at the southern tip of Lake Michigan contributes to its extremely soft soils and presents a challenge for road projects, which must withstand the constant vehicle traffic.

Solution:

The Federal Highway Administration (FHWA) recommended the use of expanded polyethylene (EPS) Geofoam as a soil stabilizer for this project because of the soft soils adjacent to the existing roadway. INDOT followed the FHWA's recommendation and placed the project out for bid with a specification to use Geofoam. Geofoam is a lightweight, rigid foam plastic that has been used worldwide as a fill for more than 30 y ears. It's approximately 100 times lighter than most soil and at least 20-30 times lighter than other lightweight fill alternatives. Because it is a soil alternative, Geofoam embankments can be covered to look like normal sloped embankments or finished to look like a wall. Since this was the general contractor's first experience using Geofoam, the knowledge of the salespeople and the available technical support was critical for them. They provided shop drawings and technical support from the initial design phase through the project's completion.

Figure 7.11: Geofoam being installation for road stabilization

A partnering workshop 10 months before the start of this project offered a Geofoam educational presentation for the engineers and project managers. Geofoam representatives were at the jobsite on the first day to coordinate truck deliveries and to review the lay out and installation techniques with the on-site crews.

The INDOT project specifications called for a blend of sand and shredded tires with the Geofoam. This was put in place first and mechanically stabilized earth (MSE) wall sections with metal straps were sandwiched between the blend of the sand and shredded tires to further reduce the overburden loads on top of the soft soils. The Geofoam installation began with 32 flatbed trucks delivering 1 1 5 cubic yards of Geofoam per truck that were unloaded by a heavy equipment operator using a retrofitted forklift. The trucks pulled up beside the concrete construction barriers and were unloaded from one side. The volume of Geofoam delivered on the 32 flatbed trucks was equivalent to more than 400 dump truck loads of traditional earth fill. The reduction in deliveries in the tightly congested jobsite area allowed for fewer disruptions and a close adherence to the construction schedule.

The Geofoam blocks were initially placed in a staging area before they were unloaded into the work area. They were then hand placed by workers to prevent vertical or horizontal joints in the stack. Barbed metal plates were used to prevent the layers from shifting prior to covering with the overburden. The lightweight nature of the Geofoam blocks contributed to the speed and ease of installation, according to the contractor, with each block maneuverer into place by two workers. "For as much Geofoam as we put down, the project went really quick," said Gary Walsh, the general contractor. "There's really no comparison to using traditional fill. There are no lifts needed. We just unloaded the blocks and got it installed fast."
Each of the large blocks weighed less than a standard bag of ready -mix concrete and a crew of six was able to install 700 cubic yards working four to five hours a day during a one-week period. Using Geofoam reduced the total overburden weight on the soft soils by more than 10.3 million pounds. The installation crew overcame the challenge of cutting around stormwater drainage penetrations by using a hot-wire cutter. Though the crew had assorted thicknesses of Geofoam, including some tapered pieces, maintaining the grade change required some curved and tapered field fabrication that was simplified by using the hot-wire cutter. After the Geofoam was in place, a course of levelling sand was installed to smooth out stair-stepped areas. A load distribution slab, 28-mil Geomembrane, road base, and concrete paving slab were then placed over the Geofoam.

Results:
After the Geofoam was in place, a course of levelling sand was installed to smooth out stair-stepped areas. A load distribution slab, 28-mil Geomembrane, road base, and concrete paving slab were then placed over the Geofoam.
The completion of this project brings Gary , Ind., one step closer to providing the transportation infrastructure necessary to support its existing industrial base and to accommodate its growing tourism industry . As this city reinvents and revitalizes itself, its major thoroughfares can now carry the burden of an increased traffic load.

7.4.9. Geotextile Tubes as Reclamation Dykes for Bridge/Elevated Highway

Location: Incheon, South Korea

Engineering & design: Seil Engineering Co. Ltd. in collaboration with a geotechnical team from the University of Incheon

Project Manager: Korea Expressway Corp.

Installation: Daelim Engineering & Construction

Geosynthetics & fabrication: Geotextile Tube, Geosynthetics

Overview: The new Incheon Grand Bridge — or simply the Incheon Bridge — is a 18.4km (11 .4mi), six -lane toll bridge in the city of Incheon, South Korea. The project was constructed in the metropolitan city of Incheon (pop. more than 2.7 million), the major seaport city on Korea's western coast and home to the country's largest international airport. With three bridge lanes in each direction, the bridge now connects Songdo City and Incheon International Airport located on Yeongjong Island. It is now Korea's longest bridge and currently the fifth-longest cable-stayed bridge in the world. Design and construction was undertaken by Samsung Construction Joint Venture, which consisted of seven major Korean contractors. The complete project costs totalled more than $1 .4 billion.

Geotextile Tubes

A Geotextile Tube is a close-ended fabric tube with filling ports. Sand is hydraulically pumped in through the filling ports during site installation to effectively form a partially flattened "sand sausage" that acts as a reclamation dike unit. Reclamation dikes up to 3m (10ft) high and 60m (200ft) long were constructed within a few hours using the Geotextile Tube application. A total of more than 14km (8.7 mi) of Geotextile Tubes with diameters ranging from 3–5m (10–13ft) were supplied to the Incheon Grand Bridge Project as reclamation dike units to form a 1.6km (1mi) long artificial island strip that rises about 7–9m (23–30ft) above the sloping seabed.

Figure 7.12: Geotextile tubes as reclaimed dyke

The artificial island had to be functional and well-maintained during the entire construction period. This Geotextile Tube supply contract was valued at more than $2 million. Geotextile Tubes were used successfully as reclamation dikes to construct the artificial island that facilitated construction of the foundation and superstructure for the Incheon Bridge project within the construction time frame. The Geotextile Tube solution resulted in significant cost savings over conventional reclamation dike construction methods. This Geotextile Tube project is currently the largest of its kind in Korea in terms of quantity and project value. The Geotextile Tube diameter of 5m (16.5ft) used in this project also represents the largest dimension currently installed in Korea.

Figure 7.13: Bridge being constructed on Geotextile tube dyke

Construction:

Incheon Bridge construction was accomplished using barges in deep waters and land-based construction in shallower waters along the bridge's route. It was more cost-effective and time-efficient to use land-based construction in shallow water areas. But this decision required creation of an artificial island platform to allow the use of land-based equipment. Reclamation dikes were constructed before fill was placed within the confines of the dikes to raise the platform to the design level. Many options for the construction of the reclamation dikes were evaluated and the solution using Geotextile Tubes was adopted because it was more economical and satisfied the client's technical requirements as well as construction time constraints.

The primary 1 2.3km (7 .6mi) centre bridge section was constructed in an area of soft marine and estuarial deposits in waters of varying depth and a maximum tidal range exceeding 9m (30ft). The Geotextile Tube application allowed construction of the perimeter reclamation dike within a tight construction schedule as well as difficult tidal, wave, and foundation conditions. The sand-filled Geotextile Tube dikes adapted to the large foundation deformations and withstood wave onslaught from the sea during the entire bridge construction period.

Results:

Project was completed successfully in 2009.

7.4.10. Geomembrane for Canal Lining

Background

GSE was called upon to line the newly constructed Pasto Grande Umarzo Canal project in the mountains of Peru. The concrete-lined canal measures 59,000 feet (18 km) and supplies drinking and irrigation water to an agricultural community.

Solution

Geosynthetic cushion and textured HDPE waterproofing Geomembrane to line the canal. A steel-reinforced, cast-in-place concrete protective covering was later installed over the Geomembrane to minimize the cost of the surface preparation and to protect the HDPE. Forms were utilized on the steep side slopes.

The Result

Geomembrane was an excellent choice for this difficult and demanding canal lining installation. It proved able to withstand the installation of the protective concrete layer and continues to hold up well under traffic.

7.6 Implications of International Benchmarking for India

The various sections above have served to provide international benchmarks and best practices which can be adapted for India. Based upon the current usage in India and abroad the following focus areas have been identified to classify the issues and base our recommendations on:

- Policy
- Standards & Specifications
- Awareness
- Tendering Process

Within these four focus areas international benchmarks and best practices have been used to form a basis of some of the recommendations. These are

Policy

Usage policies and regulations in other countries have been studies for the suitability for the Indian industry. Most stipulations abroad deal with applications where monetary benefits are negligible and hence there is lack of incentive for contractors and concessionaires to use Geosynthetics at their own discretion. Examples of such instances are primarily in the case of Geomembranes and Geosynthetic clay liners (GCLs) for landfills. Since environmental benefits from prevention of contamination are further exacerbated in India where potable water is still not available for a significant portion of the population, such a regulation in India is well justified.

Standards & Specifications

Another area where global practices were closely studies is the standards and specifications framework prevalent. Logically standards and specifications should vary from country to country and region to region which would limit applicability to India. But in the case of specifications observed such as AASHTO, GRI and ASTM, there is allowance for variation built in as countries such as the US (where AASHTO was devised and is applicable) experience a spectrum of terrain and climatic conditions. Standards for test methods are merely methods of testing the critical properties as outlined in specifications and are fairly similar globally. Hence both standards and specifications used as benchmarks were transferrable to India.

Awareness

One of the motivations behind this engagement is ensuring our use of Geosynthetics is at par with the use globally so that India can avail or the economic and social benefits as well. Hence globally prevalent material for promotion of usage such as handbooks used by the GMA (Geosynthetic Materials Association) and the FHWA (Federal Highway Authority) has been referred to in drafting the handbook in Annexure H, as well as prescription of use in section 9. This philosophy has also been used in identifying applications for research in section 9.7 which were based upon case studies for various products and applications prevalent globally that have been highlighted in section 7.4.

Tendering Process

It was observed that countries abroad have Geosynthetic use and specifications built into tenders issued for works to be carried out. While exact language has not been used, a similar format has been prescribed for inclusion in tenders issued in India.

Keeping these factors in mind certain interventions have been identified in section 9.

8 Key Interventions Required

The previous chapters have served to highlight various areas where usage and regulatory policies need to be updated, modified, or created. While analyzing the scenario domestically various aspects have been studied:

- Geosynthetic products and their applications in India, including case studies for the same showing specific scenarios where Geosynthetics were used to solve peculiar problems.
- It is important that monetary benefits be highlighted to spur growth of Geosynthetics, and to this end a couple of options for the Life Cycle Cost method have been presented here, as well as the cost benefit analysis for key impact applications.
- Feedback has been gathered from the various key stakeholders in the Geosynthetics industry ecosystem – manufacturers, contracting agencies, concessionaires and contractors, as well as policy makers and subject matter experts. This feedback has been used to narrow down upon the core pain points as highlighted in the chart below.
- Snapshots for manufacturing feasibility have been presented highlighting the high capital expenditure and long break even periods.
- The standards and specifications being developed for India have also been listed.

A representation of the various issues and their reasons summarized from our interactions above can be seen in the diagram below:

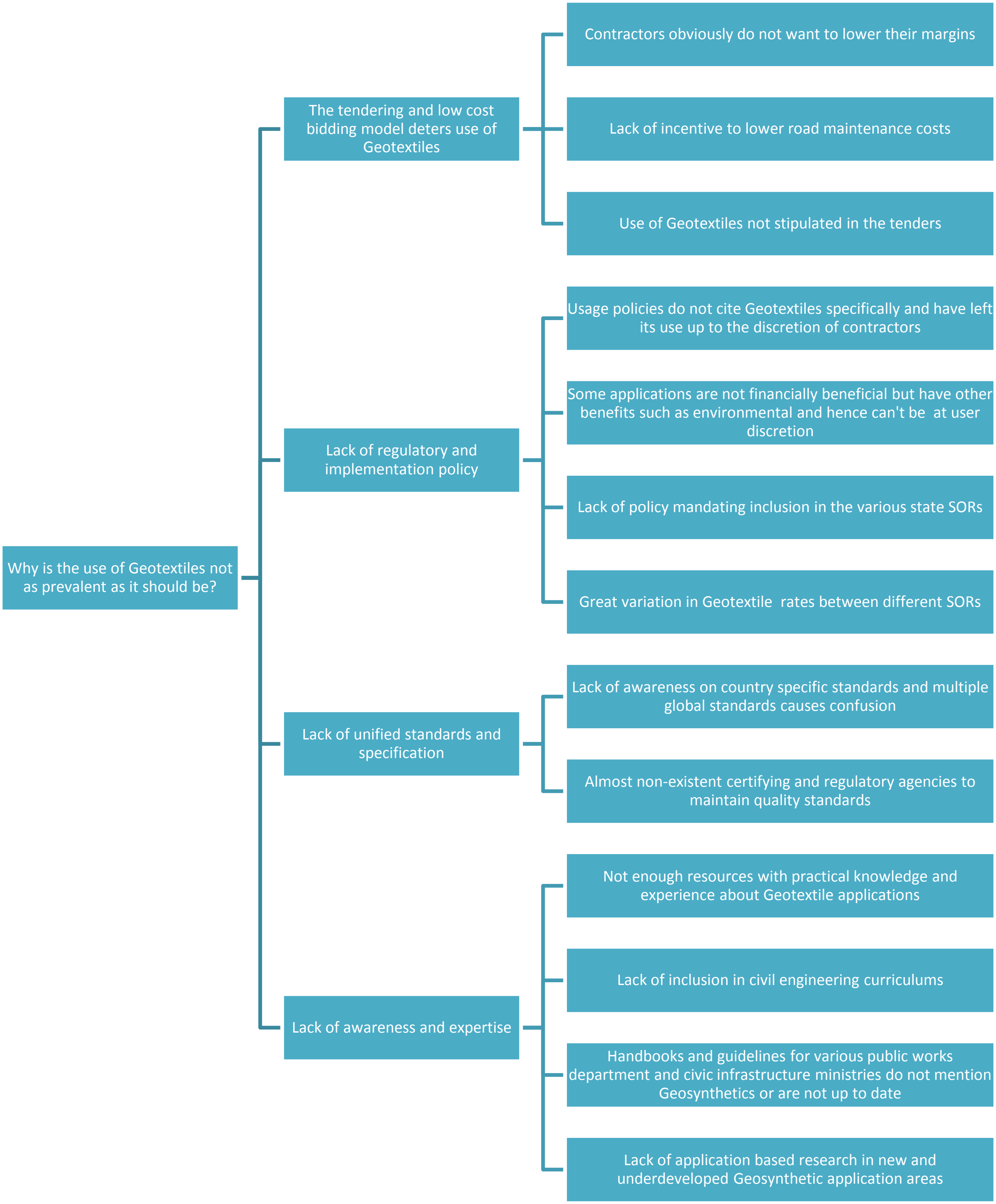


Figure 8.1: Intervention issue tree

The key question which is the genesis of this assignment is:

"Why is the use of Geotextiles not as prevalent as it should be?"

As per stakeholder feedback these are some of the issues to address along with the respective reasons:

Policy

- Propose regulatory changes to stipulate use
- Addition to Schedule of Rates in different states

Standards Framework

- Propose standards and specifications to be followed based upon global benchmarking
- Upgradation of testing framework

Awareness

- Addition to government departmental usage guidelines
- Greater inclusion in engineering curriculums
- New areas for application based research

Tendering Process

- Propose tender templates and promote DBOT and Value Engineering bids

A. Lack of regulatory and implementation policy
   - Usage policies do not cite Geotextiles specifically and have left its use up to the discretion of contractors
   - Some applications are not financially beneficial but have other benefits such as environmental and hence can't be at user discretion
   - Lack of policy mandating inclusion in the various state SORs
   - Great variation in Geotextile rates between different SORs

B. Lack of awareness and expertise
   - Not enough resources with practical knowledge and experience about Geotextile applications
   - Lack of inclusion in civil engineering curriculums
   - Handbooks and guidelines for various public works department and civic infrastructure ministries do not mention Geosynthetics or are not up to date
   - Lack of application based research in new and underdeveloped Geosynthetic application areas

C. The tendering and low cost bidding model deters use of Geotextiles
   - Contractors obviously do not want to lower their margins

- Lack of incentive to lower road maintenance costs
- Use of Geotextiles not stipulated in the tenders

A, B &C represent a vicious circle where confluence of factors is having a domino effect leading to non-use. This can be illustrated in the following manner:

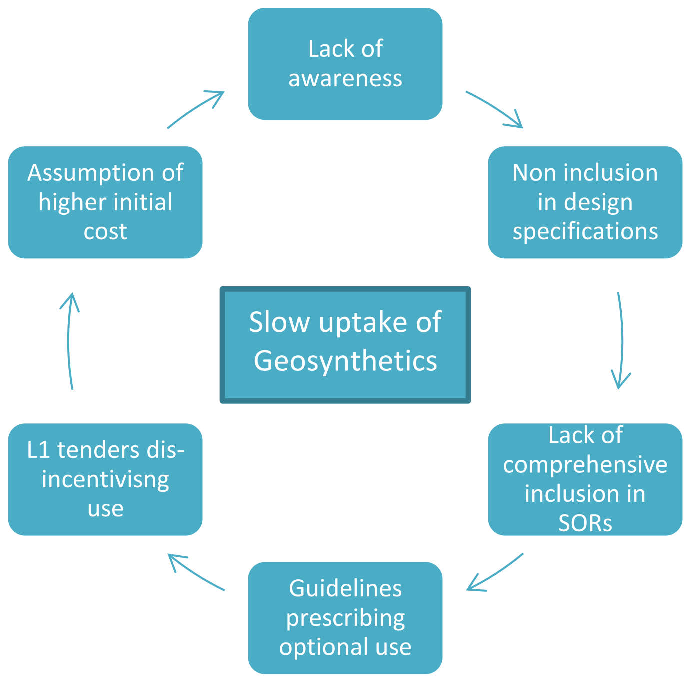


Figure 8.1: Various interrelated factors need to be addressed

D. Lack of unified standards and specification
   - Lack of awareness on country specific standards and multiple global standards causes confusion
   - Almost non-existent certifying and regulatory agencies to maintain quality standards

In the following chapters certain interventions will be identified that should help stimulate the growth of the Geosynthetics sector in India.

8.1 Shortcomings in the current MoRTH Orange Book for Geosynthetics

In section 6.3.1 the current usage policy of Geosynthetics in the MoRTH (Ministry of Road Transport & Highways) was highlighted and some of the shortcomings pointed out. Simultaneously the FHWA (Federal Highway Authority) guidebook issued by the US Department of Transportation referred to in section 7.2 helped identify areas where the MoRTH Orange Book needs to be updated to into account all products under Geosynthetics that can be used for roads and highways. The following areas were identified:

- Only 5 Geosynthetic products have been identified in the Orange Book for use in road and highway construction applications. 3 more Geosynthetic products have been identified for inclusion within the Orange Book.
- Apart from Section 700 that is dedicated to Geosynthetics, 4 other chapters within the Orange deal with the various stages of constructing roads. Geosynthetics can be used in these stages depending on site specific conditions. These chapters are:
  1. Section 300 – Earthwork, Erosion Control & Damage
  2. Section 400 – Sub-Bases, Bases (Non-Bituminous) & Shoulders
  3. Section 500 – Bases & Surface Courses
  4. Section 600 – Concrete Pavement

  Within these sections five clauses have been identified which should mention the use of Geosynthetics as an alternative solution along with the scenario for usage.
- In the Orange Book for some applications or products specifications have not been mentioned or are extremely generic. Wherever specifications are given they are detailed and do not mention a designated standard specification by the BIS (or international body if BIS specification unavailable) to be followed. These specifications have been proposed in section 9.6 of this report.

8.2 Absence of Life Cycle Cost Analysis method of calculating benefits

The Orange Book also does not contain the Life Cycle Cost Analysis method of calculating benefits for a project due to geosynthetic use. Issues with the SoRs (Schedule of Rates) for Geosynthetics in various States

Section 6.3.2 of this report explains how the SoRs are used in India and how they form an important link in tendering and use of Geosynthetic material for road construction. The following issues were identified:

- Only 14 States or regions within States include Geosynthetics in any form within their SoRs and there is a need to ensure all status and regions do the same.
- 5 Geosynthetic products is the maximum any state includes – Geogrids, Geonets, Geomembranes, Geotextiles, Geotextile filter fabric. Only 4 States include these five products. The rest of the States/regions include only 1-2 products. All the remaining applicable Geosynthetic products need to be included.
- Even where included the entire permutations and combinations regarding product type, size and quality are not given, and neither is a standard specification indicated.

8.3 Shortcomings in the tendering and financial bid evaluation processes

In section 6.1 one of the primary reasons for non-use of Geosynthetics was the fact that tendering process in India does nothing to incentivise use of Geosynthetics because:

- Tenders do not specify the use of Geosynthetics or mention it as an alternative with respective specification standards and this was identified as an impediment to awareness and use.
- L1 or Lowest Bidder model for tendering results to cost cutting on the part of concessionaires and contractor to maintain profitability. Instead of DBOT (Design, Build, Operate and Transfer) or Value Based Engineering Contract Bids would incentivise concessionaires to include Geosynthetics at the design stage.

Annexure K provides a few tender specimens for development of a template to be adopted for Geosynthetic procurement or deployment in India.

8.4 Disadvantages of not having common or India specific specifications and standards that can be followed and adopted by the entire industry

Discussions with the various industry stakeholders in section 6.1, especially the contracting agencies, concessionaires, contractors and manufacturers brought to the forefront the disconnect between buyer and seller with regards to quality, consequently affecting pricing and resulting in a non-level playing field. This was augmented by the fact that globally specifications followed mostly differ depending on application – AASHTO is preferred for road construction applications as they possess comprehensive specifications for the same; similarly the Geosynthetics Research Institute (GRI) specifications are most followed for Geomembrane applications, etc.

8.5 Lack of awareness due to non-inclusion of Geosynthetics in handbooks or guidelines of other civic infrastructure government departments

Feedback received from various stakeholders in section 6.1, international practices as mentioned in section 7.2 and the exercise involving upgradation of the MoRTH Orange Book led to the conclusion that apart from road construction there is great potential for use of Geosynthetics in other applications such as railways, landfills and canal linings. Guidelines and specifications for inclusion of Geosynthetics in these applications is lacking and inclusion similar to that in the Orange Book will go a long way in harnessing said potential.

8.6 Areas for application based research that are untapped or unexplored

Chapter 4 of this report gives various cases where Geosynthetics were used as solutions for field level problems. These cases are indicative of the fact that certain applications such as reinforced soil walls, tanks and reservoir lining, embankment stabilization, pavement reinforcement and erosion control have been used in various instances in India and their effectiveness has been proven.

But there are certain applications that are prevalent abroad which are extremely effective but for which there is extremely low awareness in India or that are new from a technology standpoint and hence have not been explored in India. These applications areas which can be seen in Chapter 7.4 of this report need to be focused upon for research and pilot studies going forward.

8.7 Lack of quality framework in India

As per manufacturer feedback in section 6.1.3 of the report there is lack of many testing facilities. BTRA is the only GSI accredited lab and not all tests are available even with the BTRA. More labs need to be established and the status of tests with BTRA needs to be ascertained and tests offered need to be updated to be all inclusive. Additionally a framework needs to be established that checks not only quality of the products but also production control as well as on-site installation.

8.8 Lack of basic information on Geosynthetics in civil engineering courses

As per stakeholder feedback in section 6.1, most civil engineering colleges do not include Geosynthetics/polymers/plastics as part of the curriculum. So graduates from civil engineering courses do not possess even basic knowledge regarding Geosynthetics when they enter the industry. This is unlike courses in textiles engineering which cover Geosynthetics and Geotextiles. This is a serious gap that is hindering the growth of the Geosynthetics industry and should be addressed by steps towards incorporating Geosynthetics into the curriculum.

8.9 Sparse regulations stipulating use of Geosynthetics in various applications

Based upon stakeholder feedback in section 6.1, as well as international policies covered in section 7.2 there are multiple application areas where regulations and laws stipulate use abroad and where there are no monetary incentives for elective use by contractors and concessionaires. This is present especially in instances where environmental benefits are paramount. Such measures have played a big role in providing an impetus to the Geosynthetics industry in other parts of the world.

Unfortunately such regulatory policies have not permeated into the regulatory framework in India and thus it has impacted the environmental, social and economic benefits to be gained from using Geosynthetics. Areas for such measures need to be identified and proposed.

9 Recommendations

9.1 Regulatory and Policy Changes

Based on the benchmarking study undertaken in section 7.2 and 7.5, it has been established that no regulatory changes are required to mandate the use of Geosynthetics abroad. Moreover the justification of use and promotion is based upon financial benefits accruing to the users.

The changes which can catalyse the use of Geosynthetics in India pertain largely to awareness building and inclusion of Geosynthetics in various manuals & schedule of rates. The same has been detailed out in subsequent sections along with other steps required to build an ecosystem which would promote the use of Geosynthetics.

9.2 Inclusion of Geosynthetics & Detailing of the Usage Policy in the MoRTH Orange Book

As highlighted in Chapter 6.3.1, the usage policy for Geosynthetics in the MoRTH had not been updated for over a decade and hence did not include all Geosynthetic products or applications.

After extensively going through the fourth edition of the Orange Book the following highlighted areas should incorporate Geosynthetics as an option:

a) In Clause 305 "Embankment Construction" there is no mention of use of Geosynthetics apart from for support of heavy construction equipment during embankment construction. After looking at various case studies and going through information on the Geosynthetics products that can be used in various capacities in road construction:

   - Geocells, Geofoam, and Prefabricated Vertical Drains (PVD) should be included for stabilization and reinforcement in Clause 305 as an alternative in conditions where soft soil is prevalent. PVDs specifically should be mentioned in Clause 305.3.3 "Dewatering". The specifications can be according to those mentioned in Section 9.6 of this report and the installation guidelines and design considerations can be according to those mentioned in the handbook in Annexure H.
   - In addition to this separate sub-clauses under Clause 700 for Geofoam should be incorporated.

b) Similarly in Clause 401.4.1 "Preparation of Subgrade" there is no mention of the role Geosynthetics can play in reinforcement and stabilization. Incorporate according to the previous point.

c) In Clause 306 "Soil Erosion and Sedimentation Control" no Geosynthetics are mentioned. Geocells and Geogrids should be incorporated as an alternative under "construction options"

d) In Clause 309 "Surface/Sub-Surface Drains" the specifications should be updated according to those mentioned in Section 9.6 of this report and the installation guidelines and design considerations can be according to those mentioned in the handbook in Annexure H.

e) In Clause 313 "Rockfill Embankment" there is no mention of Geosynthetics for separation. Geotextiles should be incorporated here.

f) Similarly in the Clause 700 "Geosynthetics" for applications for Geosynthetics in roads only overlays are focused upon, and separation functionality has not been incorporated. This should be added along with specifications according to those mentioned in Section 9.6 of this report and the installation guidelines and design considerations can be according to those mentioned in the handbook in Annexure H.

- <u>Proposed change to be discussed</u>: In Clause 700 under "Sub-surface Drains" point (c) should be changed to – *Water permittivity in either direction at a <u>rate of less than 10 litres/m2/sec</u>. under a constant head of water of 100 mm, determined in accordance with BS:6906 (Part 3) or ASTM D4491 or as stated in the design drawing. The flow rate determined in the test shall be corrected to that applicable to a temperature of 15°C using published data on variation in viscosity of water with temperature.*

g) The Life Cycle Cost Analysis method, specifically for roads given in section 5.1.1 and 5.2.2 should be incorporated as a separate chapter under Section 700 to equip project managers and engineers with a handy method of calculating benefits of geosynthetic use over the life of a project.

In June 2013 the fifth revision of the Orange Book was published. This edition was studied for updates to Geosynthetic inclusions that were proposed by ITTA and its members, as well as cross checked against short comings listed in this report. The following updates were noted:

- The Geosynthetic products with dedicated section in Clause 700 were increased from five to include Geocells for Slope Protection, Paving Fabrics & Glass Grids (Geocomposite varieties), Natural Geotextiles for erosion control, Geosynthetic Mats for erosion control, Geocells for slope protection, Geocomposite Drains (Prefabricated Vertical Drains & Fin Drains) for soil consolidation, Geogrids for slope protection and sub-base reinforcement, and Geotextiles for drainage, separation and erosion control.

- Geosynthetics have been prescribed in more of the particular application sections as compared to the fourth edition, which was highlighted as an important area of improvement so that engineers know exactly which application areas Geosynthetics can be used in. The additional clauses are:
    - Clause 314: Geosynthetic PVDs (Prefabricated Vertical Drains) – Use of PVDs is prescribed for weak embankment foundation and BIS standard IS:15284 (Part 2) as

well as ASTM D 4873 are referenced. Properties in section 700 (Table 700-3) also specified.

- Clause 404: Water Bound Macadam Sub-Base/Base – If water bound macadam (WBM) is to be laid directly over the subgrade, a layer of screening typically consisting of course sand is laid first. Alternately a Geosynthetic performing separation and drainage functions can be used as an option instead.
- Clause 505.4.3: Geosynthetics are prescribed as an option for use in the DBM (Dense Bituminous Macadam) course in accordance with Clause 703
- Clause 507.4.3: Geosynthetics are prescribed as an option for use in the BC (Bituminous Concrete) course in accordance with Clause 703
- Clause 517.2.4: Geosynthetics are prescribed as an option for use in the Crack Prevention Courses layer in accordance with Clause 703.3
- Clause 601: Section on Dry Lean Cement Concrete Sub-Base cites installation of drainage layer as per Clause 401, and base courses construction also mirrors method cited in previous chapters. Hence use of geosynthetics is similarly prescribed
- Clause 3103.7: Geotextile, Geogrids and other Geosynthetics for use as reinforcing elements within section 3100 "Reinforced Soil".

There are some areas that still need to be addressed in the fifth revision which have been identified below:

a. Inclusion of Geosynthetics in embankment construction applications within section 305
b. Geofoam for road for subgrade reinforcement
c. Geocells for roads for subgrade reinforcement
d. Use of Geobags for use in revetments in section 2504
e. Inclusion of Geotextiles in section 2700 "Wearing Coat and Appurtenances" and section 2811 "Repair and Replacement of Wearing Coat"

These should be taken up with the MoRTH and IRC for incorporation via steps outlined in section 10 of this report.

9.3 Publishing of Standard SoR (Schedule of Rates) for Geosynthetics

To rectify the glaring lack of Geosynthetics representation in the various SoRs it was most important to assess what items should be included. All the stakeholders felt that the list of items should be comprehensive when it comes to:

a. *Products* – The SoRs should contain all 8 Geosynthetic products applicable to road construction

b. *Sizes* – Each product should have multiple common sizes listed

c. *Quality* – Each product should be accompanied by a standard specification and a basic description of the specifications

Based on the feedback from various industry representatives and subject matter experts, such a list for inclusion of Geosynthetics in SoRs is provided Annexure D. *Price given here is purely be indicative* as with so many regions within so many States there is significant variation from state to state and region to region due to logistics and taxation.

9.4 Inclusion of Geosynthetics in handbooks and guidelines of other Government departments

During the primary research phase it was discovered that no other public works organization or department has handbooks or guidebooks specifying use of Geosynthetics as an alternative solution is certain applications. It is recommended that the following departments be approached for inclusion of Geosynthetics as solutions along with specifications in their guidelines:

1. Railways – Feedback from Konkan Railways brought to light the fact that some Geosynthetic products such as jute Geosynthetics are included in their SoR, but there are no guidelines or handbooks explaining where Geosynthetics can be incorporated in railway construction. Geosynthetics can be included in the Railway Works Manual or with the Track Design Directorate.

2. Canals – As per feedback from the Kolhapur Irrigation Department the state government supplies a handbook titled "Water Treatment for Hydraulic Structures" for canal and dam building but there is no mention of Geosynthetics. Rather if they come across peculiar situations where need for Geosynthetics is felt, then an external design consultant from MERI, Nashik is called in who studies the situation and then designs and implements the Geosynthetics accordingly. Hence geosynthetic products to be used for canal linings such as geotextiles and geomembranes should be included in the handbook titled "Water Treatment for Hydraulic Structures" according to information given in the handbook in Annexure H as well as the accompanying specifications and standards given in section 9.4.

3. Landfills – Another untapped market for Geosynthetics is in landfill applications dictating the use of Geomembranes and GCLs (Geosynthetic Clay Lining). Municipal Corporations handle sewage disposal and follow their local guides/manuals. These local guides and manuals do not contain guidelines and specifications for Geosynthetic use, though use of Geomembranes is mandatory as per the Ministry of Environment and Forests, highlighted in section 6.3.3.

9.5 Introduce Changes in the Procurement Process: Tender Evaluation Criterion & Inclusion of Standard Specifications

Tenders, as mentioned earlier, are the main driver in the process of civil construction as it is the first document that links the contracting agency with the concessionaire. The merits of the project and consequently inclusion of Geosynthetics within it depends entirely upon the terms and conditions laid out in this tender. Stakeholder holder feedback narrowed down upon two key proposals:

1. A major impediment to the use of Geosynthetics in civil and public works is the non-inclusion of Geosynthetics within tenders. After researching various tender formats used globally the tenders as attached in Annexure K were identified to be used as a template for India.

   A sample format of the specification sheet for Geosynthetic procurement in a tender for landfill construction is given below. This specification will be part of the larger tender issued for the road works, landfill construction, etc.

GEOMEMBRANE LINER SPECIFICATION				
Property	**Test Method**	**Value**	**Units**	**Specification**
Thickness			mm	
Carbon Black Content	ASTM D1603(3)		% by mass	
Density			Kg/m^3	
Tensile Properties				
Stress at yield	ASTM D6693 Type IV		N/mm	
Stress at break	ASTM D6693 Type IV		N/mm	
Elongation at yield	ASTM D6693 Type IV		%	
Elongation at break	ASTM D6693 Type IV		%	
Puncture Resistance	ASTM D4833		N	
Stress crack resistance	ASTM D5397		Hours	
Comments/Special Instructions:				

2. Inclusion of Geosynthetics in tenders will ensure usage, but if discretionary use of Geosynthetics by concessionaires and contractors is to be promoted then two further tender options as followed globally should be considered:

   a. *Tenders inviting DBFOT (Design Build Finance Operate Transfer) bids* - DBFOT finds extensive application in the infrastructure projects and in PPP (public–private partnership). In the DBFOT framework a third party, for example the public administration, delegates to a private sector entity to design and build infrastructure and to operate and maintain these facilities for a certain period. During this period the private party has the responsibility to raise the finance for the project and is entitled to retain all revenues generated by the project and is the owner of the regarded facility. The facility will be then transferred to the public administration at the end of the concession agreement. Since the responsibility to design and maintain the project rests with the concessionaire, they will ensure their profitability is high over the lifetime of the project and hence be more inclined to use Geosynthetics to reduce maintenance costs.

b. *Value Engineering contracts* – PPP (public–private partnership) contracts providing incentives to encourage contractors to submit proposals that identify ways the government can save costs are called "value engineering contracts". In the US value engineering is prescribed for construction contracts in section 48.202 of the Federal Acquisition Regulations. The contract clause concerning value engineering for construction is found in FAR 52.248-3. All fixed-price construction contracts over $100,000 are to provide for value engineering, unless the head of an agency has elected to exempt his agency or a particular contract from the value engineering requirements. Participation by the construction contractor is normally voluntary. If the government accepts a value engineering proposal, a construction contractor is entitled to a share of up to 55% of the savings under his contract.

9.6 Adopting and Developing Standards Suitable for Indian Context

It is important to segregate product specifications and standards while benchmarking the standards available with the BIS and listed in section 6.4 of this report. It is recommended that these standards are to be followed by the Indian industry (including the Government) and used as guide by the BIS (Bureau of Indian Standards) in developing Indian standards. This is based upon feedback from experts stating the suitability of these standards for the Indian context, i.e. these standards account for Indian climactic and geological conditions.

It is important to note that the customer is at his own discretion when it comes to the quality they desire. The aim is to create an ecosystem where common standards are followed and all stakeholders are comfortable and well versed in them.

Till comprehensive standards are developed by the BIS the ASTM standards can be used wherever BIS standards are not available.

9.6.1 Product Specifications

Ideal product specifications have not yet been developed comprehensively by a single standard setting organization globally. Based upon feedback from stakeholders around the world, standards for particular applications or products were studied and finalized accordingly. These specifications were selected on the basis of the following parameters:

a) Popularity of standard across various geographies

b) Technical comprehensiveness with respect to products that can be deployed for various conditions of use

Based on the above evaluation criteria it is recommended that AASHTO be adopted for roads and pavement applications, GRI for landfill and other filtration applications and the rest can be adopted from ASTM. Specifications to be adapted on priority (or verified for completeness if already developed by BIS) have been marked in **bold**. These are based upon important applications as identified in section 5.3representing greatest cost benefit to the economy.

I. For roads and highways the AASHTO (American Association of State Highway and Transportation Officials) specifications are the mostly widely followed. These include the following:

Sl. No.	Standard	Descriptions
1	R 50-09	**Geosynthetics Reinforcement of the Aggregate Base Course of Flexible Pavement Structures**
2	M 288-06 (2011)	**Geotextile Specification for Highway Applications**

M288-06 covers six Geotextile applications: Subsurface Drainage, Separation, Stabilization, Permanent Erosion Control, Sediment Control and Paving Fabrics. However, AASHTO M288-06 is not a design guideline. It is the engineer's responsibility to choose a Geotextile for the application that takes into consideration site-specific soil and water conditions.

When site conditions are unknown, engineers can refer to AASHTO M288-06 Survivability Default Classes for guidance. The survivability default classes specification in GRI GT13 (a), which augments the AASTHO M 288-06 specification, can be seen in Annexure L.

II. Similar to AASTHO for roads and highways, the GRI (Geosynthetic Research Institute) that develops specifications and standards primarily for Geomembranes. The GRI standards applicable include:

Sl. No.	Standard	Descriptions
1	GRI GM10	The stress crack resistance of HDPE Geomembrane Sheet
2	GRO GCL5	**Design Considerations for Geosynthetic Clay Liners (GCLs) in various applications**
3	GRI GN2 & GRI GC13	**Joining and Attaching Geonets and Drainage Components (not to be followed for drainage applications with Geomat Core)**
4	GRI GT13(a) & (b)	**Test method and properties for Geotextiles used as separation between subgrade soil and aggregate**

III. The ASTM has the most developed collection of product specifications. Their standards for Geosynthetics are as follows:

Sl. No.	Standard	Descriptions
1	D7008-08 -	Standard Specification for Geosynthetic Alternate Daily Covers
2	D7239-06(2011) -	**Standard Specification for Hybrid Geosynthetic Paving Mat for Highway Applications**
3	D6707-06(2011)	**Standard Specification for Circular-Knit Geotextile for Use in Subsurface Drainage Applications**
4	D2643-08	Standard Specification for Prefabricated Bituminous Geomembrane Used as Canal and Ditch Liner (Exposed Type)
5	D7176-06(2011) -	Standard Specification for Non-Reinforced Polyvinyl Chloride (PVC)

		Geomembranes Used in Buried Applications
6	D7177-05(2010) -	Standard Specification for Air Channel Evaluation of Polyvinyl Chloride (PVC) Dual Track Seamed Geomembranes
7	D7408-08 -	**Standard Specification for Non Reinforced PVC (Polyvinyl Chloride) Geomembrane Seams**
8	D7465-08 -	Standard Specification for Ethylene Propylene Diene Terpolymer (EPDM) Sheet Used In Geomembrane Applications
9	D7613-10	Standard Specification for Flexible Polypropylene Reinforced (fPP-R) and Non-reinforced (fPP) Geomembranes
10	D6817-11	Standard Specification for Rigid Cellular Polystyrene Geofoam
11	D6826-05(2009)	Standard Specification for Sprayed Slurries, Foams and Indigenous Materials Used As Alternative Daily Cover for Municipal Solid Waste Landfills
12	D7001-06(2011)	**Standard Specification for Geocomposites for Pavement Edge Drains and Other High-Flow Applications**

9.6.2 Performance Standards/Test Methods

While there are not many detailed product specifications prevalent, as can be seen above, there are a considerable number of performance standards or test methods in existence to check the various properties of Geosynthetics. The premier organization with regards to test methods is ASTM, while ISO and EN are also organizations with test methods in place. The industry almost universally follows ASTM standards and it is proposed that they be followed till the BIS can develop India specific standards.

The list of applicable ASTM standards is given in Annexure E.

9.7 Investing in research for newer applications and exploring cross cutting applications

Chapter 4 shows in great detail the applications that have been carried out within India and gives a good impression of the various pilot studies and research projects they have been a part of. The objective here is to ensure that research energies are focused upon incumbent technologies that have never been trialled at length in India or newer emerging technologies that need to be explored further. Using the cases given in section 7.4 the following application areas have been identified for further research and pilot studies:

1. Geotextile Tubes/Geobags dewatering containers that can be used for river bed clean-up. Some projects using Geotextile Tubes for coastal and embankment protection have already been carried out in India. This has resulted in some familiarity with Geotextile Tubes amongst stakeholders in India and is an advantage.
2. Smart Geosynthetics enabled with fibre optic sensors to aid in - verification of design parameters, monitoring wear and tear, stress and strain detection, movement detection and hence early warning, temperature tracking, etc.
3. Geocomposites and Geonets for horizontal drainage of the railway track bed.
4. Geotextile Tubes as reclamation dykes.

5. Geofoam in highway reinforcement and stabilization on soft soil, especially in cases where time if paramount and quick turnaround is required. This is because Geofoam is extremely light compared to subgrade/sub-base gravel and easy to transport.
6. Pre-fabricated Vertical Drains (PVDs) in road applications for drainage
7. Geonets for slope stabilization and preventing fall of debris
8. Geotextiles in pavement overlays to resuscitate potholed roads and reduce maintenance costs
9. Slope stabilization using Geogrids/Geocells

Impact Resistance Bags or Impact Control Bags were also suggested as an area for research but these were adjudged to be Protech industry products and hence were included in list of cross cutting applications below.

It has been observed that typically the machinery and equipment to manufacture Geosynthetics can be used for various cross cutting applications. Consequently most Geosynthetics manufacturers offer products that are not limited to the Agrotextile industry but also belong to various other technical textile industries such as Geotech, Packtech, Sporttech, Indutech, etc. Some of the most popular cross cutting products/applications are:

- Agrotextiles such as Shade Nets and Mulch Mats
- Indutech Fabrics for Seed Processing Plants
- Protective textiles such as scaffolding and netting for construction and site maintenance
- Turf for sporting applications such as golf
- Impact Resistance Bags/Impact Control Bags

9.8 Upgrading existing and creating new testing facilities for Quality Control

Feedback from stakeholders as well as observations from systems in place abroad dictate that there is need of a three step system of quality-assurance-tests for geosynthetic materials in civic works:

1. Basic product quality assurance tests by an approved body
2. Control tests on site or of specimens taken from the site
3. Manufacturer accreditation for production quality control by an approved body

1. Tests for Quality Assurance

Properties to be tested	Standards	Basic tests S P F R	Production control S P F R	Site control S P F R

Mass Per Unit Area	BS EN ISO 965 ASTM D 5261	+ + + +	+ + + +	+ + + +
Thickness	BS EN ISO 964/1-2 ASTM D 5199	+ + + +	+ + + +	+ + + +
Tensile Strength & Elongation	BS EN ISO 10319 ASTM D 4595	+ + + +	+ + + +	g g g g
Tensile Creep & Creep Rupture Compressive Creep	ISO 13431, ASTM D 5262	+ d		
Static Puncture	EN-ISO 12236 ASTM D 6241	n n n n	n n n n	n n n n
Installation Damage		+ + + +		
Chemical Resistance	ENV 12447	x x x x		
Weather Resistance	ASTM D 4355 DIN EN 12224	+ + + +		
Friction Soil/ Product	ISO 12957, ASTM D 5262	x x x +		
Friction Product/ Product	ISO 12957, ASTM D 5262	+		
Pullout Force	ASTM D 6706, DIN EN 13738	+		
Opening Size O90,W	ASTM D 4751 ENV ISO 12956	+ + + x	+	
Water Permeability Vertical Kv	ASTM D 4491 DIN EN ISO 11058	+ + + x	+	
Water Flow Capacity In Plane Kh	ISO 12958, ASTM D 4716	d		

<u>Key</u>

- Standards:
  - ISO: Standards of the International Standard Organisation
  - EN: European Standard
  - ENV: Provisional European Standard
  - ASTM: American Standard
- Functions:
  - S = Separation
  - P = Protection
  - F = Filter & Drainage

- R = Reinforcement
- + = Test Necessary
- x = Applicable in some cases/for some products
- g = For Wovens, Grids and some Knitted Fabrics
- d = For Drains only
- n = For Nonwovens only

On Site Inspection

On site quality control may consist of:

- The evaluation of compliance of a delivered product with the specification
- The evaluation of the compliance of site-conditions with specification
- The inspection of handling and conditions of storage
- The inspection of placing the product on site
- Taking samples for evaluation of compliance with the specification
- Placing and extracting control samples to check damage during installation
- Placing of control samples to check the behavior with time

The number of samples required is a function of:

- The importance of the product for the safety of the work
- The area of product used in the work.

The contractor has to execute quality control testing of products delivered on site. The specimens for site control need to be taken by the client or an institute under contract with the client, together with a representative of the producer or/and of the contractor. The result decides the acceptance or rejection of the product. If the product is already installed a negative test result will give reason for a deduction from the project fees.

Manufacturer Quality Accreditation

If the product is certified on basis of a factory production control with continuous inspection and audit-testing of product by an approved body then entry control is not demanded. The manufacturers need to install a system with production control and accreditation with a quality – mark on the product.

The inspirations for such a quality mechanism are programs abroad such as the NTPEP Audit Program in the US which is a system of central Audit and Acceptance without which manufacturers are unable to bid and provide geosynthetics for certain projects.

Status of Testing Labs in India

As mentioned earlier, BTRA is the only GSI (Geosynthetics Institute) accredited lab in India.
Feedback from manufacturers showed that:

- There is a requirement for more labs in India for testing Geosynthetic material and ensuring conformance to standards
- The existing lab at the BTRA (Bombay Textile Research Association) does not have all tests available and hence needs to be updated as soon as possible

To evaluate progress of the BTRA in upgrading their testing facilities the following information was gathered:

Tests Available

While tests are by default offered to verify ASTM standards, the process of testing against other test methods like ISO, EN, etc. is not too complicated and can be accommodated by BTRA.

Standard	Description	Corresponding Standards
ASTM D792	Test Method for Specific Gravity (Relative Density) and Density of Plastics by Displacement	ISO 1183
ASTM D1004	Test Method for Initial Tear Resistance of Plastic Film & Sheeting	
ASTM D1238	Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer (Melt Flow Index)	ISO 1133
ASTM D1388	Test Method for Stiffness of Fabrics	
ASTM D1603	Test Method for Carbon Black in Olefin Plastics	
ASTM D1693	Environmental Stress-Cracking of Ethylene Plastics	
ASTM D1777	Test Method for Measuring Thickness of Textile Materials	
ASTM D3776	Test Method for Mass Per Unit Area (Weight) or Woven Fabric	
ASTM D4218	Test Method for Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique	
ASTM D4437	Determination of the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes, peel, shear	
ASTM D4491	Water Permeability of Geotextiles by Permittivity	ISO 11058
ASTM D4545	Determination of the Integrity of Factory Seams used in Joining Manufactured Flexible Sheet Geomembranes, peel, shear	
ASTM D4594	Effects of Temperature on Stability of Geotextiles	
ASTM D4595	Tensile Properties of Geotextiles by the Wide-Width Strip Method	ISO 10319
ASTM D4632	Grab Breaking Load and Elongation of Geotextiles	
ASTM D4751	Apparent Opening Size of a Geotextile	ISO 12956
ASTM D4833	Index Puncture Resistance of Geotextiles, Geomembranes and Related Products	
ASTM D4884	Test Method for Seam Strength of Sewn Geotextiles	ISO 10321
ASTM D4885	Test Method for Determining Performance Tensile Strength of Geomembranes Using Wide Strip Testing	
ASTM D4886	Test Method for Abrasion Resistance of Geotextiles (Sand Paper/Sliding Block Method)	
ASTM D5034	Breaking Strength and Elongation of Textile Fabrics (GrabMethod)	ISO 13934
ASTM D5035	Breaking Strength and Elongation of Textile Fabrics (StripMethod)	
ASTM D5199	Nominal Thickness of Geotextiles and Geomembranes	
ASTM D5261	Test Method for Measuring Mass per Unit Area of Geotextiles	ISO 9864
ASTM D5323	2% Secant Modulus for Polyethylene Geomembranes	
	Thermal Conductivity	
ASTM E 96	Water Vapour Transmission rate	
ASTM D 6706	Horizontal Pull out	
	Particle size analysis	
ASTM D 4716	Hydraulic Transmissivity	
ASTM D	Soil Geotextile Clogging potential	
ASTM D 5397	Stress Cracking Resistance	
ASTM D 5494	Pyramid puncture resistance	

Status of New Testing Equipment Procurement

To upgrade facilities and expand upon tests offered BTRA has identified 31 machines to be procured, out of which the in-principle approval has been granted for 13 machines. These 31 machines can be seen below:

Out of these 31 the 13 in process of being procured under the COE (Centre of Excellence) upgradation are:

THE BOMBAY TEXTILE RESEARCH ASSOCIATION PROGRESS ON PROCUREMENT OF EQUIPMENTS/MACHINEY UNDER CENTRE OF EXECELLENCE (COE) - UPGRADATION	
S.NO.	**NAME OF THE EQUIPMENT**
1	Water permeability under load tester
2	Dry Powder Particles Analyser
3	Hydraulic Transmissivity Tester
4	Vertical Strip Drain Tester
5	Geosynthetic Pull out Resistance (in soil) Tester
6	Outdoor Exposure Tester for Geotextiles
7	Carbon Black Dispersion Tester
8	Soil Geotextile Clogging Potential Tester
9	Online Mass & Thickness Measurement
10	Filtration Efficiency Tester
11	Abrasion Tester for Geotextiles
12	DTA / TGA
13	`Multi Axial Tension Tester for Geosynthetics

The BTRA should ensure that it pursues the equipment procurement to expedite delivery of the same.

9.9 Inclusion of Geosynthetics in educational curriculums

In a recent survey conducted by ITTA (Indian Technical Textile Association) while 9 out of 20 colleges have electives pertaining to Geosynthetics, none have Geosynthetics included as a chapter within soil mechanics in core courses for civil engineering. Effort should be made by the Ministry of Textiles to approach various autonomous universities to facilitate the incorporation of Geosynthetics/plastics/polymers within the civil engineering curriculum within soil mechanics, along with offering of elective courses if not already available. The curriculum can cover basic information from the handbook in Annexure H. This would contain chapters on:

- Products – A list of the 13 Geosynthetic products
- Functions – A description of the 6 functions Geosynthetics perform and a chart displaying the multi-functionality of the various products

- Applications – Common applications where Geosynthetics are used, showing the functionality and the products in use
- Advantages - A brief idea of the benefits associated with using Geosynthetics including cost benefit analysis

Leading universities/colleges in India that can lead research and develop courses for geosynthetics have been identified after discussions with industry stakeholders based upon their faculty as well as research conducted in this area. The list is as follows:

1. National Institute of Technology (NIT's)
2. NIRMA university, Gujarat
3. GIIT, Gujarat
4. BITS Pilani
5. Delhi College of Engineering, Delhi

The various industry stakeholders have also highlighted the dearth of instructors and academicians with detailed knowledge of geosynthetics who can aid in improving knowledge and awareness of these materials within engineering curriculums.

The strategy to mitigate this is to include only generic information regarding geosynthetics as given in the list above that can serve as just an introductory chapter within soil mechanics with the aim of familiarising students with this family of geotechnical products.

Secondly, manufacturers can be invited as guest speakers to conduct sessions on geosynthetics that will help mitigate any tutorial shortcomings on the subject of geosynthetics. Apart from encouraging engineers to use geosynthetics in geotechnical projects via the educational awareness efforts listed above, capacity building is important for manufacture, and implementation of geosynthetics. In this regard the ITIs (Industrial Training Institutes) in India should provide instruction and impart skills for manufacture and real world implementation of geosynthetics.

Further to this NSDC (National Skill Development Council) has a mandate to train about 30% of the overall target of 500 million informal sector workers in India by 2022. It has identified Construction Skill Development as one of the priority sectors amongst the 21 focus areas and is working with private training providers on a PPP (Public Private Partnership) model. The details of these training providers are available at http://nscsindia.org/NSCSTrainingPartners.aspx.

Lastly, given that geosynthetics applications are a relatively new development, working professionals have inadequate knowledge, skills or experience in this field. Taking into account the benefits of geosynthetics, any initiatives taken without the capacity building of existing professionals will not prove to be effective. Accordingly it is proposed that the capacity building of various professionals in the government and the private sector (across entry and mid levels at the minimum) should be taken up. These customized trainings should be implemented in conjunction with institutes with a focus on highway engineering and construction management such as:

- National Institute for Training of Highway Engineers (NITHE), Noida
- National Institute of Construction Management and Research (NICMAR), Pune
- Central Institute of Road Transport (CIRT), Pune
- Central Road Research Institute (CRRI), New Delhi
- Various IITs/NITs

The programs conducted by these institutes are typically 3-5 days in duration.

Various steps have been outlined in section 10 for the Ministry of Textiles via its COEs to initiate the inclusion of geosynthetics in various curriculums and training programs as outline above.

9.10 Introduce stipulations to make certain products mandatory for certain applications

It is imperative to devise stipulations for applications where an environmental or social benefit is being realized and there is no apparent monetary benefit to motivate private players into using Geosynthetics. Using data from practices prevalent internationally as well as stakeholder feedback the two areas where such a stipulation could be feasible in India are:

- Mandatory use of Geomembranes and Geosynthetic clay liners (GCL) in landfills

  Urban India generates 188,500 tonnes per day (68.8 million tonnes per year) of Municipal Solid Waste (MSW)[10]. In 2011 India required 380 km^2 of area for landfills. Needless to say it is imperative that modern and recoverable landfills be employed to handle our waste management.

  Just like the forty countries that have legislation concerning disposal of Municipal Solid Waste (MSW) and Hazardous Waste, India too has certain regulations established as mentioned in section 6.3.3. Enforcement of these regulations needs to be overseen, and the Ministry of Textiles may even consider a fund to subsidize the costs of setting up landfills lined with Geosynthetics for the various municipal corporations.

- Mandatory use of Geomembranes and Geocomposites in canal lining

  India is still an agriculture based economy which relies on nature for irrigation. Over the past century cyclical efforts have been made to improve the canal network in India to

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[10] Annepu, Ranjith Kharvel. "Sustainable Solid Waste Management in India". Columbia University. January 10, 2012. <http://www.seas.columbia.edu/earth/wtert/sofos/Sustainable%20Solid%20Waste%20Management%20in%20India_Final.pdf>

provide irrigation to as much farm land as possible. As per the CWC (Central Water Commission) there were 31.3 million hectares of irrigated land in 2001-02, out of which 18 million hectares were covered by all government schemes for canals. Efficiency of canals can be as low as 40% and is often around the 60% mark – this results in loss of water through seepage due to leakages in the existing canals linings. Geomembranes can resolve these issues and prolong the life of canals by preventing leakage.

- Mandatory use of Silt Fences to prevent soil erosion during highway construction

  As has been touched upon in section 7.2 of this report, silt fences have seen widespread application over the world due to anti-erosion regulations for which Geotextile filter fabrics are the best material available. Similar legislation in India which would lead to indirect use of Geosynthetics like silt fences should be implemented to prevent erosion and soil and minerals into water streams accompanied by sedimentation.

- Mandatory use of Geotextiles for pavement overlay applications

  In section 7.2 the mandatory use of geotextiles for pavement overlay applications in the state of California in the US has been cited as a stimulant for the geotextiles industry in that country.

  Overlays are more relevant in today's world where roads are already constructed and need regular maintenance to ensure they can be driven upon. Typical road construction without the use of geotextiles in the base courses requires at least two overlays over the 15 year assumed life of roads in India. This involves relaying the top layer of the road and is a significant component of lifetime maintenance costs for roads.

  A layer of geotextiles while carrying out overlays significantly improves wear and tear of the road and reduces need for another overlay during the 15 year assumed life of the road. To understand the impact and potential savings to the country, if the 71,000 kilometres of national highways in India adopt geotextiles for overlays the corresponding reduction in overlay maintenance costs will be in the region of 8000 crore! To achieve such significant savings the NHAI should make the use of geotextiles mandatory for pavement overlays.

- Inclusion of Geosynthetics within the Special Focus Products Scheme (FPS)

  The DGFT's (Directorate General of Foreign Trade) Focus Product Scheme (FPS) serves the role of incentivising export of specific goods which have high export intensity / employment potential, so as to offset infrastructure inefficiencies and other associated costs involved in marketing of these products. Export of notified products as notified within Appendix 37D of the Hand Book of Procedures Vol. 1 shall be entitled for Duty Credit Scrip @ 2% of FOB (Freight on Board) value of exports in free foreign exchange. However, Special Focus Product(s) /sector(s), covered under Table 2 and Table 5 of Appendix 37D, shall be granted Duty Credit Scrip equivalent to 5% of FOB value of exports (in free foreign exchange).

As highlighted by stakeholder as well as ITTA, there is some unused capacity in India due to the recent increase in manufacturers entering the market. This spare capacity should be leveraged along with India's advantage as a low cost manufacturing country to promote exports of Geosynthetics. Hence, Geosynthetics products if included under Special Focus Product(s)/sector(s), covered under Tables 2 and 5 of Appendix 37D, will be eligible for Duty Credit Scrip equivalent to 5% of FOB value of exports in free foreign exchange.

- Inclusion of Geosynthetics within the Focus Market Scheme (FMS) for exports

  For the Focus Market Scheme Objective is to offset high freight cost and other externalities to select international markets with a view to enhance India's export competitiveness in these countries.

  Exporters of all products to notified countries (as in Table I and 2 of Appendix 37C of Hand Book of Procedures Vol. 1) shall be entitled for Duty Credit Scrip equivalent to 3% of FOB value of exports for exports made from 27.8 2009 onwards.

  For exports to countries notified in Table 3 of Appendix 37C (Special Focus Markets) are eligible for duty credit scrip @ 4% of FOB value, made w.e.f. 01.04.2011, 5-6-2012 , 01-01-2013, or 01-05-2013, as the case may be.

  The following categories of export products / sectors shall be ineligible for Duty Credit Scrip, under FMS scheme: a) Supplies made to SEZ units; b) Service Exports; among others categories of exports.

  These additional incentives will help invigorate Geosynthetic exports from India thereby ensuring manufacturers have additional demand for the supply they generate.

10 Next Steps and Approach

Based upon recommendations listed above, certain steps and measure will have to be initiated by the Textile Commissioners Office to facilitate implementation of these recommendations and ensure there is buy-in on the part of the concerned departments.

1. Inclusion of Geosynthetics and detailing of usage policy in the MoRTH Orange Book
    a. BTRA (Bombay Textile Research Association) should finalize and approve specifications suggested in section 9.6.1
    b. Proposal to be sent to the MoRTH (Ministry of Road Transport and Highways) to include specifications in the Orange Book as per section 9.2 where chapters for inclusion have been highlighted
    c. Proposal to also be sent to IRC (Indian Roads Congress) to ensure Special Publication No. 59 be updated accordingly
2. Publishing of standard SoR for Geosynthetics
    a. The list of geosynthetics drawn up in section 9.3 and Annexure D should be included in a proposal and sent to the MoRTH for approval
    b. Subsequent to the approval from the MoRTH, the proposal shall then be sent to the PWDs (Public Works Department) of each region in each state with endorsement of the MoRTH for inclusion in their individual Schedule of Rates
    c. The individual PWDs should then approach manufacturers for quotations (landed cost) for each of the geosynthetic items as per the list and include the same within the SoRs
3. Introduce Changes in the Procurement Process: Tender Evaluation Criteria & Inclusion of Standard Specifications
    a. Since there are multiple bodies issuing tenders, this is a tedious process, but the focus should be on providing geosynthetics tender sample to PWDs (Public Works Departments), NHAI (National Highway Authority of India), Municipal Corporations and Water Works Departments
    b. Help can be sought from the MoRTH, Ministry of Water Resources and the Ministry of Environment and Forests to propagate the tender specification format amongst individual state, regional and city bodies through circulars
4. Adopting and developing standards
    a. The Textile Commissioner's Office should include standards applicable to geosynthetics in their promotional material and reach out to the various user agencies such as the NHAI, PWDs, etc. to promote uptake of the suggested standards and specifications as per section 9.6

b. The BTRA has the required expertise and has already spent considerable time developing standards in collaboration with the BIS (Bureau of Indian Standards). They should continue with proposing standards to the BIS that they deem appropriate for the Indian context augmenting those in section 9.6.

c. The key with standards and specifications is voluntary uptake by stakeholders; hence efforts must be taken by the BTRA to spread awareness on standards being adopted (like AASHTO) as well as when newer BIS standards are released

5. <u>Inclusion of Geosynthetics in handbooks and guidelines of other government departments</u>

a. As per the recommendations in section 9.4 the Ministry of Water Resources should be approached with a proposal for inclusion of geosynthetics use in canal linings and embankment protection in guidebooks such as the "Water Treatment for Hydraulic Structures" handbook

b. Similarly the Ministry of Railways should be approached with a proposal for inclusion of geosynthetics in the Railway Works Manual or with the Track Design Directorate.

c. Local municipal corporations should be approached to include geomembranes and GCLs (geosynthetic clay liners) within their local guides/manuals. Help should be sought from the Ministry of Environment and Forests to propagate the inclusion of the same via circulars

6. <u>Investing in research for newer applications and exploring cross cutting applications</u>

a. The Textile Commissioner's Office should take a proactive role in sponsoring pilot projects in conjunction with manufacturers and the various Ministries highlighted such as the Ministry of Water Resources, Ministry of Railways, Municipal Corporations and the MoRTH for applications highlighted in section 9.7.

7. <u>Updating existing and creating new testing facilities for quality control</u>

a. The Textile Commissioner's Office should extend support to the BTRA in gaining approvals and purchase of machinery required as given in section 9.8 to offer complete testing services.

b. Support should also be extended to other COEs such as ATIRA (Ahmedabad Textile Industry's Research Association) to develop their testing facilities to obtain NABL (National Accreditation Board For Testing and Calibration Laboratories) as well as GSI (Geosynthetics Institute) accreditation.

c. A three pronged quality framework has been proposed in section 9.8 that will address manufacturer production accreditation, product quality certification, as well as onsite side as well as the site of use. The BTRA should be the starting point for this effort and can help decide nodal agencies for each quality parameter.

8. Inclusion of relevant chapters in educational curriculums

    a. The universities identified should be approached with a proposal to change civil engineering core curriculum to include geosynthetics, plastics and polymers within the broader scope of soil mechanics.

    b. The syllabus or matter to be included should be as per section 9.9.

    c. The agencies identified for upskilling of the unorganized work force should be approached to include instruction on geosynthetic implementation. The trainings should be centred around applications detailed in the handbook, but the medium of instruction should be in local language supported by practical demonstrations to cater to the target audience.

    d. The institutes identified in section 9.9 for working professional courses where entry to mid level professionals can update their skills and knowledge with regards to geosynthetics should be approached for introduction of courses on geosynthetics with material from the report as reference. The material in these courses will be dependent on time allotted within the 3-5 day duration and will include topics as highlighted in sections 1, 3, 4 & 5 of the report. The aim is to familiarise participants with geosynthetics and highlight their quantitative and qualitative benefits.

9. Introduce stipulations to make certain products mandatory for certain applications

    a. The Ministry of Environment and Forests should be approached with proposal to update the regulation on "Municipal Solid Wastes (Management and Handling) Rules, 2000", Schedule III "Specifications for Landfill Sites", specifically the section on "Pollution Prevention" to include clear and distinct regulations for both Municipal Solid Waste (MSW) and Hazardous Waste

    b. The Ministry of Water Resources should be approached with a proposal to include regulation on use of geomembranes in canal lining as part of the National Water Policy 2012 draft revision

    c. The MoRTH (Ministry of Road Transport and Highways) should be approached with a proposal to include silt fences as part of the Orange Book stipulating mandatory use. Concurrently the Ministry of Environment and Forests can be approached for inclusion of mandatory use of silt fences in their rules on erosion control

    d. The MoRTH (Ministry of Road Transport and Highways) as well as the CPWD should be approached to discuss the mandatory use of Pavement Overlays which will drastically reduce maintenance costs.

    e. The DGFT (Directorate General Foreign Trade) to be approached for inclusion of Geosynthetics within Special Focus Product(s)/Sector(s) classification to avail 5% duty credit scrip. An application along with justification for inclusion of Geosynthetics should be drafted to take the process forward.

Sr No	Recommendation	Champion
1	Inclusion of Geosynthetics & Detailing of the Usage Policy in the MoRTH Orange Book	Ministry of Textiles and ITTA to follow up with Shri K C Varkeyachan (Chief Engineer, MoRTH) and Shri S K Nirmal (Sup. Engineer, MoRTH) for further changes to the Orange Book
2	Publishing of standard SoR for Geosynthetics	• Ministry of Textiles and ITTA to follow up with Shri K C Varkeyachan (Chief Engineer, MoRTH) and Shri S K Nirmal (Sup. Engineer, MoRTH) to request communication to states for inclusion of Geosynthetics in SoRs. Contact No. 9650126245 • Also follow up with Shri Bhatia (ADG CPWD) – Contact PA Mr Ashok Kumar at 011-23061196
3	Introduce changes in the Procurement process: Tender Evaluation criterion & inclusion of standard specifications	Ministry of Textiles to contact various contracting agencies such as the MoRTH, CPWDs, BRO, NHAI, Railways, etc. and take tender specimens to said agencies.
4	Adopting Standards and Specifications	BTRA to follow up with the BIS on development of specifications based on suggested international standards. Contact Shri J K Gupta, Director (Textiles).
5	Inclusion of Geosynthetics in handbooks and guidebooks for other public works departments	• Ministry of Textiles and ITTA to contact Shri S K Jain (Member Engineering) and Shri Alok Kumar (Executive Director, Civil Engineering) with Ministry of Railways for inclusion of Geosynthetics in the Railway Works Manual. • Ministry of Textiles and ITTA to contact Shri Pradeep Kumar (Commissioner, SPR & CADWM) for inclusion of Geosynthetics for Canal Linings in the Hydraulic Works Manual. Contact PA – DS Rawat at 9971795043/011-2370107.
6	Investing in Research for newer applications	ITTA and BTRA to coordinate with manufacturers for pilot programmes
7	Updating existing and creating new testing facilities for Quality Control	Ministry of Textiles to ensure BTRA is able to procure machines required for testing. Also to follow up with ATIRA on promoting testing facilities.
8	Inclusion of Geosynthetics in educational curriculums	Relevant universities have been identified in Ch. 9.8. The Ministry of Textiles as well as ITTA should contact these universities and initiate process of standardized inclusion of geosynthetics within Soil Mechanics subject area within their respective curriculums.
9	Introduce stipulations to make geosynthetic use mandatory for certain applications	The Ministry of Textiles to approach the MoRTH (Shri Rohit Kumar singh – JS Highways, MoRTH), CPWD (Mr Bhatia – ADG), MoWR (Shri Pradeep Kumar - Commissioner, SPR & CADWM), MoEF, DGFT (Director General Shri Anup K Pujari) to enact various stipulations as outlined in section 9.10.

Annexure A – List of Stakeholder Interviewed for Geosynthetics

Sr. No.	Company Name	Concerned Person	Designation	Date of Visit
1	Terram Geosynthetics Pvt. Ltd.	Mr. Parimal Parekh	Managing Director	21st June 2012
2	ATIRA	Dr. A.K. Sharma	Director	21st June 2012
3	Venkateshwara Traders	Mr. Raju	Proprietor	22nd June 2012
4	SVM Nonwovens Pvt. Ltd.	Mr. Siva Kumar	Director	25th June 2012
5	Charminar Nonwovens Ltd.	Mr. Siva Kumar	Director	26th June 2012
6	R & B, Rural Roads, Hyderabad	Mr. G. V. S. N. Raju	Chief Engineer	26th June 2012
7	A.T.E. Enterprises Pvt. Ltd.	Mr. G. V. Aras	Director	3rd July 2012
8	BTRA	Dr. Ashok N. Desai	Director	4th July 2012
9	Capatex – UK			6th July 2012
10	Indian Roads Congress	Mr. R. V. Patil	Asstt. Director (Tech.)	11th July 2012
11	IIT Delhi	Dr. V. K. Kothari	Professor	11th July 2012
12	Everest International	Mr. Maheshwari		12th July 2012
13	IGS	Mr. Uday Chander	Sr. Manager (Technical)	12th July 2012
14	Aanchal International	Mr. Ramkumar Gupta	Director	12th July 2012
15	VJTI	Dr. Deepa Raisinghani	Lecturer	12th July 2012
16	Marfatia Brothers	Mr. Baluni	Manager	12th July 2012
17	Garware Wall Ropes Ltd.	Mr. S. H. Bamne	Vice President – Corporate	16th July 2012
18	Shri Ambica Polymer Pvt. Ltd.	Ms. Jyotika Agarwal	Director – Marketing	16th July 2012
19	Yanpai, China			17th July 2012
20	Tex Delta, Spain			17th July 2012
21	Maccaferri India	Ms. Annapoorni Iyer		18th July 2012
22	Pacific Harish Industries Ltd.	Mr. Venkatesh	Director - Nonwovens	19th July 2012
23	ACE Geosynthetics, Taiwan			20th July 2012
24	Excel Nonwovens	Mr. Sawant	Marketing Head	23rd July 2012
25	Geosynthetic Materials Association, USA	Mr. Andrew M Aho	Managing Director	27th July 2012
26	International Association of Geosynthetics Installers, USA	Laurie Honnigford	Managing Director	27th July 2012
27	Weisman-Friedman Industry Development Ltd	Mr. Amnon Moller		30th July 2012
28	Geo Synthetic Institute	Dr. George R Koerner	Director	3rd August 2012

	(GSI), USA			
29	MoRTH and IRC	Mr. A K Sharma	Chief Engineer	7th Aug 2012
30	Reliance Industries Limited	Mr. M S Verma	VP-RIL (ex Bureau of Indian Standards)	7th Aug 2012
31	National Highway Authority of India	Mr. Jaswant Kumar	CGM	8th Aug 2012
32	Techfab India Industries Ltd.	Mr. Anant Kanoi	Managing Director	10th August 2012
33	Supreme Nonwovens Industries	Mr. Amit Kavrie	Managing Director	10th August 2012
34	Bansal Industries	Mr. Manoj Bansal	Proprietor	
35	Tripura PWD	Mr. Indrajeet Debbarma	Asst Engineer	8th October 2012
36	National Highway Commission	Mr. M. Chandrashekhar	Chief Executive Officer	9th October 2012
37	National Highway Commission	Dr. Ram Kumar	Chief General Manager	9th October 2012
38	SMC Infrastructure	Mr. Mahagaonkar	Contractor	10th October 2012
39	Soham Engg Foundation	Mr. Vittal Vaishampayam	Contractor	10th October 2012
40	Oriental Structural Engineers	Mr. J.P.Gupta	Civil Engg	10th October 2012
41	JMC Infrastructures	Mr. Tiwari	Civil Engg	10th October 2012
42	L & T Infrastructure	Mr. T. Ravikumar	Chief Engineer	10th October 2012
43	National Highway Commission	Mr. D.O. Tawade	Chief Executive Officer	10th October 2012
44	PWD Dept attached with TMC	Mr. Pramod Nimbalkar	Executive Engineer	10th October 2012
45	Irrigation Department	Mr. A.D. More	Chief Engineer	11th October 2012
46	Laxmi Civil Engg Services Pvt ltd	Mr. Hemant Shah	Chief Engineer	12th October 2012
47	IVRCL Pvt. Ltd.	Mr. Dhyaneshwar	Purchase Manager	11th October 2012
48	PWD Dept, Pune	Mr. Jayendra Randive	Chief Engineer	11th October 2012
49	J Kumar Constructions Pvt Ltd	Mr. Rajesh	Purchase Manager	12th October 2012
50	PMK and Associates	Mr. P.M.Kanekar	Managing Director	12th October 2012
51		Mr. Rajendra Rokade	Civil Contractor	12th October 2012
52	STUP Consultants	Mr. Pravin	Senior Design Engineer	15th October 2012
53	Central Design organization, Maharashtra	Mr. P.L. Nikumb	Deputy Engineer	17th October 2012
54	Earthen Dam Departments, CDO	Mr. Chandwadkar	Design Engineer	17th October 2012

55	Maharashtra Engineers Research Institute	Mr. N.B.Nakhil	Chief Research Officer	17th October 2012
56	Highway Research Department, MERI	Mr. Pahade	Executive Engineer	18th October 2012
57	Design and Reseach Department, MERI	Mr.M.N.Ranganekar	Assistant Engineer	18th October 2012
58	Maharashtra Engineers Research Institute	Mr. Anil Dhake	Sectional Engineer	18th October 2012
59	Maharashtra Engineers Research Institute	Mr. Salunkhe	Deputy Engineer	18th October 2012
60	Garware Wall Ropes Limited	Mr. Satya Kumar Sunkavalli	Asst Manager-Designs (Geo Synthetic Division)	19th October 2012
61	CPWD, Pune	Mr. Padbhanabham	Asst Engineer	19th October 2012
62	PWD Designs Department	Mr. Vikas Ramgude	Chief Executive officer	23rd October 2012
63	PWD, Konkan Region	Mr. Natesh	Executive Engg	29th October 2012, 19th November 2012
64	Konkan Railways	Mr. Shinde	Asst. Executive Engg	29th October 2012, 31th October 2012
65	Garware Wall Ropes Ltd	Mr. Tiru Kulkarni	VP – Geosynthetics Division	31st October 2012
66	Garware Wall Ropes Ltd	Mr. Siddheshwar Wankhede	AGM West – Geosynthetics Division	31st October 2012
67	National Jute Board	Mr. T. Sanyal	Chief Consultant	6th November 2012
68	K.K. Envirotech Pvt Ltd	Mr. Ketan Shah	Managing Partner	6th November, 7th November 2012
69	Garware Wall Ropes Ltd	Mr. M. Venkatraman	Design Consultant	6th November 2012
70	Strata Geosystems (India)	Mr. Shahrokh Bagli	Chief Technology Officer	7th November 2012
71	California DOT, USA	Mr. Imad Basheer	O/o Pavement Design	8th November 2012
72	Kusumgar Corporate	Dr Talukdar		12th December, 2012
73	Ministry of Railways	Mr. S. K. Jain	Member Engineering	22nd May 2013
74	Ministry of Railways	Mr. Alok Kumar	Exec Director, Civil Engineering	22nd May 2013
75	Ministry of Road Transport and Highways	Mr. Rohit Kumar Singh	Joint Secretary, Highways	22nd May 2013
76	Ministry of Road Transport and Highways	Mr. K C Varkeyachan	Chief Engineer	22nd May 2013
77	Ministry of Road Transport and Highways	Mr. S K Nirmal	Superintendent Engineer	22nd May 2013

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Annexure B – Orange Book References for Geosynthetic Use

Under the chapter on "Geosynthetics" (Clause 700) the following products and applications are covered:

A. **Geotextiles** – The important properties highlighted are cross-plane permeability/ permittivity and apparent opening size or equivalent opening size. The applications for which details such as specifications and installation instructions are given include:

- *Sub-Surface Drains* – The Geotextile can be woven or non-woven and should be treated with carbon black to provide short term resistance to UV light. The specifications given for this application are:
    a. Sustain a load of not less than 10 kN/m at break and have a minimum failure strain of 10 per cent when determined in accordance with BS:6906 (Part 1) or shall have a grab tensile strength more than 0.4 kN/m and grab elongation corresponding to this limit in accordance with ASTM D 4632.

    b. The Apparent opening size, shall satisfy the following

        i. Soil with 50 per cent or less particles by weight passing IS sieve 75 microns, apparent opening size less than 0.6 mm.

        ii. Soil more than 50 per cent particles by weight passing IS sieve 75 microns, apparent opening size less than 0.927 mm.

        iii. The test should be as per TF 25 # 6

    c. Water permittivity in either direction at a rate of not less than 10 litres/m2/sec. under a constant head of water of 100 mm, determined in accordance with BS:6906 (Part 3) or ASTM D4491 or as stated in the design drawing. The flow rate determined in the test shall be corrected to that applicable to a temperature of 15°C using published data on variation in viscosity of water with temperature.

    d. Have minimum puncture resistance of 200 N when determined in accordance with BS:6906 (Part 4) or ASTM D 4833.

    e. Have minimum tear resistance of ISO N when determined in accordance with ASTM Standard D 4533.

- *Reinforced Earth* – Geotextiles is just one of the options for reinforcing elements along with aluminium alloy, copper, carbon steel, metal mats, synthetic grids, or any proprietary material approved by the engineer and indicated on the drawings. Geosynthetics shall be tested in accordance with tests prescribed by BIS. In absence of IS

Codes, tests prescribed either by ASTM or British Standards or International Standards Organisation, shall be conducted.

No other specifications are given.

- *Highway Pavements* – For road applications only pavement overlays are discussed and this includes laying and implementation of Geotextiles over existing bituminous surface to provide a water resistant membrane and crack retarding layer. The specifications discussed are:

  a. The paving fabric will be a nonwoven heat set material consisting of at least 85 per cent by weight polyolefins, polyesters or polyamides.

  b. The fabric shall be specifically designed for pavement applications and be heat bonded only on one side to reduce bleed-through of tack coat during installation.

  c. Specifications for paving fabrics

Property	Standard Requirements	Test Method
Tensile Strength	36.3 kg	ASTM D 4632
Elongation	50%	ASTM D 4632
Asphalt Retention	10 kg/10 sq. m.	Texas DOT 3099
Melting Point	150 °C	ASTM D 276
Surface Texture	Heat bonded on one side only	Visual Inspection

  d. Certification of conformance from paving fabric manufacturer may be required.

  e. All numerical values represent minimum average roll values (average of test results from any sampled roll in a lot shall meet or exceed the minimum values) in weaker principal direction. Lot shall be sampled according to ASTM D 4354, "Practice for Sampling of Geosynthetics for Testing".

  f. Conformance of paving fabrics to specification property requirements shall be determined as per ASTM D 4759, "Practice for Determining the Specification Conformance of Geosynthetics".

- *Slope Protection Works* – Geotextiles are used for prevention of migration of fine soil particles. No specifications are given.

B. **Geogrids –** The important properties highlighted are that Geogrids can be mono or bi-directional y oriented, for use as a tensile member or for reinforcement. Characteristic strength of Geogrids varies from 40 kN/m to 200 kN/m peak strength at a maximum elongation of 15% in the direction of the length of the roll. The applications for which details such as specifications and installation instructions are given include:

1) *Reinforced Earth* - Geogrids are just one of the options for reinforcing elements along with aluminium alloy, copper, carbon steel, metal mats, or any proprietary material approved by the engineer and indicated on the drawings. Geosynthetics shall be tested in accordance with tests prescribed by BIS. In absence of IS Codes, tests prescribed either by ASTM or British Standards or International Standards Organisation, shall be conducted. The standards and specifications given are:

   a. The supply of Geogrids shall carry a certification of BIS or ISO 9002 for all works. While the reinforcing element for wall or slope portion shall be with mono oriented Geogrid, the reinforcement for the foundation of a reinforced earth wall or slope shall be with bi-directionally oriented Geogrid. For mono-oriented Geogrid, the characteristic design tensile strength at a strain not exceeding 10 per cent in 100 years shall be at least 40 kN/m when measured as per GR1:GG3. The strength for bi-directionally oriented Geogrid in the longitudinal direction shall be at least 40 kN/m at a maximum elongation of 15 per cent. The Geogrid shall be inert to all naturally occurring chemicals, minerals and salts found in soil.

2) *Slope Protection Works* – Boulder gabions/mattresses are laid in Geogrid wraps resulting in bolsters to be placed along slopes of embankments or in aprons. Aperture size and tensile strength are the key properties. Key standards and specifications are. Mattresses constructed with Geogrids or Geonets shall be used for thickness of 300 mm or above as shown in the drawings. The mesh opening may vary depending on functional requirement but shall have aperture between 35 mm and 100 mm. Standards and specifications are:

   a. Aperture: Rectangular, square or oval shaped (and not in diamond, round or polygonal shape)

   b. Colour: Black

   c. Mechanical Properties: Peak strength not less than 10 kN/m at maximum elongation of 15 per cent. Not more than 5 per cent elongation at half peak load.

   d. Strands/Fabric Form: Integral joints with junction strength of 100 per cent of plain strands as measured by GRI-GG3 standards. Material shall have ISO 9002 certification.

   e. Life: Atleast 8 years in case of continuous exposure and 5 years for buried applications (defined as capable of retaining atleast 75% of its original strength after the life span stated)

C. **Geonets** - Geonet shall be made from a single extruded un-oriented process from polyethylene or polypropylene or similar polymer. They shall not be used as soil reinforcement due to high creep characteristics, neither as a slope reinforcement or soil retaining wall or asphaltic reinforcement.

1) *Slope Protection Works* – Boulder gabions/mattresses are laid in Geonet wraps resulting in bolsters to be placed along slopes of embankments or in aprons. Aperture size and tensile strength are the key properties. Key standards and specifications are. Mattresses constructed with Geonets shall be used for thickness of 300 mm or above as shown in the drawings. The mesh opening may vary depending on functional requirement but shall have aperture between 35 mm and 100 mm. Standards and specifications are:

a. Aperture: Square or rectangular net shape for protective applications, and polygonal aperture for separation

b. Geonets used in protective works for highway structures shall be atleast 650 gm/sq.m. in unit weight.

c. Colour: Black

d. Mechanical Properties: Peak strength not less than 10 kN/m at maximum elongation of 15 per cent. Not more than 5 per cent elongation at half peak load.

e. Strands/Fabric Form: Integral joints with junction strength of 100 per cent of plain strands as measured by GRI-GG3 standards. Material shall have ISO 9002 certification.

f. Life: Atleast 8 years in case of continuous exposure and 5 years for buried applications (defined as capable of retaining atleast 75% of its original strength after the life span stated)

D. **Geomembrane** - Geomembrane shall be made from PVC or polyethylene sheets. The joints of these sheets are heatbonded or seamed for effective permeation cutoff. Geomembranes are used primarily in landfills, along with other containment applications such as canal lining and embankment protection. Specifications given are:

a. PVC of Polyethylene sheets of 0.8mm thickness

b. Protected from UV exposure by 2.5% carbon black

c. Colour: Black

d. Supplied in roll form with 3m width

E. **Geocomposite -** Geocomposites shall be made from combination of Geonets, Geogrids or Geomembranes of above description using heat bonded, seamed stitched or wrap techniques. Their principal use shall be to regulate drainage in cross-plane or in-plane directions. Minimum unit weight of such material shall conform to the special provisions or as per contract drawing.

Geosynthetics are also referred to in the following instances of the fifth edition of the Orange Book:

- Clause 305: Embankment Construction – Geosynthetic material use is advised to increase bearing capacity of foundation where embankment is to be constructed but which cannot support the weight of repeated heavy load of construction equipment.
- Clause 308: Seeding and Mulching – Use of jute nets or Geonets is prescribed in detail here. Specifications given for jute netting dictates undyed jute yam woven into a uniform open weave with approximate 2.5 cm square openings. In case of Geonets they shall be made of uniformly extruded rectangular mesh having mesh opening of 2 cm x 2 cm. The colour may be black or green. They shall weigh not less than 3.8 kg per 1000 sq. m. The jute/Geonets shall be used post the seeding and mulching phase.
- Clause 309: Sub-Surface Drains – Under the broad scope the use of Geosynthetic sub-surface drain designs is mentioned as an option provided it is approved by the design engineer. This is expanded upon in section 309.3.5 where some installation guidelines are given. Readers should then refer to Clause 700 for further details on Geosynthetic sub-surface drains.
- Clause 2504.2.1: Geosynthetics are prescribed as an option in pitching for slope protection.

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Annexure C – Comparison of SoRs in the 14 different States

Sr #	State	Specifications	Geogrid (Rs/sq m)	Geomembrane (Rs/sq m)	Geonets (Rs/sq m)	Geotextile (Rs/sq m)	Geotextile Filter (Rs/sq m)	Geobags (Rs/sq m)	Geocomposites (Rs/sq m)
1	Arunachal Pradesh		Input	Input	Input	25	Input		
2	Bihar		Input	Input	68.75	53.75	53.75		
3	Chhattisgarh	Bitumen Impregnated Geotextile: (Providing and laying a bitumen impregnated Geotextile layer after cleaning the road surface, Geotextile conforming to requirements of clause 704.3, laid over a tack coat with 1.05 kg per sqm of paving grade bitumen 80 - 100 penetration and constructed to the requirement of clause 704.4.5) as per section 522				230			
4	CPWD	Geotextile 120 gsm membrane				32			
		Extra for covering top of membrane with Geotextile, 120 gsm nonwoven, 100% polyester of thickness 1 to 1.25 mm bonded to the membrane with intermittent touch by heating the membrane by Butane Torch as per manufactures recommendation				53.85			
5	Jharkhand		68.75	68.75	68.75	53.75	53.75		
6	Karnataka	Geo-textile (filter fabric) 200 gsm					150		
		Geo-textile (filter fabric) 250 gsm					180		
7	Kerala	Coir Geotextiles - 400 gsm				18			
		Coir Geotextiles - 700 gsm				29			
		Coir Geotextiles - 740 gsm				30			
		Coir Geotextiles - 900 gsm				40			
		Geotextiles -Synthetic				59			
		Cost per m3	300						

8	Madhya Pradesh	Bitumen Impregnated Geotextile: (Providing and laying a bitumen impregnated Geotextile layer after cleaning the road surface, Geotextile conforming to requirements of clause 704.3, laid over a tack coat with 1.05 kg per sqm of paving grade bitumen 80 - 100 penetration and constructed to the requirement of clause 704.4.5) as per section 522	204			236			
		Laying of a Geotextile filter between pitching and embankment slopes on which pitching is laid to prevent escape of the embankment material through the voids of the stone pitching/cement concrete blocks as well as to allow free movement of water without creating any uplift head on the pitching					224		
9	Maharashtra - Mumbai	Polypropylene multifilament woven Geotextile fabric for filter layer (approved opening size 0.075 mm and water permeability 9.00 L/sqm/S)					70.5		
	Maharashtra - Pune		270	510	190	89	89		
10	Rajasthan	Bitumen Impregnated Geotextile: (Providing and laying a bitumen impregnated Geotextile layer after cleaning the road surface, Geotextile conforming to requirements of clause 704.3, laid over a tack coat with 1.05 kg per sqm of paving grade bitumen 80 - 100 penetration and constructed to the requirement of clause 704.4.5) as per section 522	500	750	450	300	250		
11	Sikkim		200	400	200	250	200		
12	Uttar Pradesh	Supplying high performance woven Geotextile bags of size 1.09m x0.69m (outer to outer) fabricated from "Engineered textile" manufactured from 100 %						116.5	

		PP multifilament yarn in machine and cross direction , which are woven into stable network such that the yarn retains their relative position. The fabric used for manufacturing of bags shall be (200 GSM) TFI 1200 or equivalent and meet the criteria given under technical specification and have high UV resistance , inert to biological degradation and resistant to naturally encountered chemicals like acids and alkalis including excise duty but excluding VAT, toll tax and contractor's profit.							
		Supplying pillow type Geotextile bags of size 1.03m x 0.7 m to (outer to outer) be filled with specified fill. The nonwoven fabric used for manufacturing of bags shall be 400 GSM 100 % PP Geotextile made of staple fibre bonded into stable network through needle-punching and meeting the technical specification. The Geotextile used for manufacturing of bags should be Tech-geo PN40 OR equivalent and have minimum 70% resistance against UV exposure , 80-% Abrasion resistance as per BAW of Germany and should be inert to biological degradation and resistant to naturally occurring acids and alkalis. Including excise duty but excluding VAT, toll tax and contractor's profit.						155	

		Supplying 150 GSM Non-woven Geotextile made of 100 % Polypropylene staple fibre (continuous filament not allowed) bonded into stable network through needle-punching meeting the technical specifications and qualification criteria in the tender. The Geotextile should be Tech-geo PR 15 OR equivalent and have minimum 70% resistance against UV exposure and should be inert to biological degradation and resistant to naturally occurring acids and alkalis including excise duty but excluding VAT, toll tax and contractor's profit.				40			
		Supplying 200 GSM Non-woven Geotextile made of 100 % Polypropylene staple fibre (continuous filament not allowed) bonded into stable network through needle-punching meeting the technical specifications and qualification criteria in the tender. The Geotextile should be Tech-geo PR 20 OR equivalent and have minimum 70% resistance against UV exposure and should be inert to biological degradation and resistant to naturally occurring acids and alkalis including excise duty but excluding VAT, toll tax and contractor's profit.	54			54			
		Supplying 250 GSM Non-woven Geotextile made of 100 % Polypropylene staple fibre (continuous filament not allowed)				67			

		bonded into stable network through needle-punching meeting the technical specifications and qualification criteria in the tender. The Geotextile should be Tech-geo PR 25 OR equivalent and have minimum 70% resistance against UV exposure and should be inert to biological degradation and resistant to naturally occurring acids and alkalis including excise duty but excluding VAT, toll tax and contractor's profit.							
		Supplying 300 GSM Non-woven Geotextile made of 100 % Polypropylene staple fibre (continuous filament not allowed) bonded into stable network through needle-punching meeting the technical specifications and qualification criteria in the tender. The Geotextile should be Tech-geo PR 30 OR equivalent and have minimum 70% resistance against UV exposure and should be inert to biological degradation and resistant to naturally occurring acids and alkalis including excise duty but excluding VAT, toll tax and contractor's profit.				80			
		Supplying 400 GSM Non-woven Geotextile made of 100 % Polypropylene staple fibre (continuous filament not allowed) bonded into stable network through needle-punching meeting the technical specifications and qualification criteria				102			

		in the tender. The Geotextile should be Tech-geo PR 40 OR equivalent and have minimum 70% resistance against UV exposure and should be inert to biological degradation and resistant to naturally occurring acids and alkalis including excise duty but excluding VAT, toll tax and contractor's profit.							
		Supplying 500 GSM Non-woven Geotextile made of 100 % Polypropylene staple fibre (continuous filament not allowed) bonded into stable network through needle punching meeting the technical specifications and qualification criteria in the tender. The Geotextile should be Tech-geo PR 50 OR equivalent and have minimum 70% resistance against UV exposure and should be inert to biological degradation and resistant to naturally occurring acids and alkalis including excise duty but excluding VAT, toll tax and contractor's profit.				133			
13	Assam	Sub surface drain with Geotextiles: Construction of sub surface drain 200mm dia using Geotextiles treated with carbon black with physical properties as given in clause 702.2.3 formed in to a stable network and a planer Geocomposite structure, joints wrapped with Geotextile to prevent ingress of soil all as per clause 702 and approved							1037

		drawing including excavation and track filling							
		Narrow filter Sub-Surface Drain: Construction of a narrow filter sub drain consisting of porous of perforated pipe laid in narrow trench surrounded by a Geotextile filter fabric with a minimum of 450 mm overlap of fabric and installed as per clause 702.3 and 309.3.3 including excavation and backfilling					743		
		Laying paving fabric beneath a pavement overlay: Providing and laying paving fabric with physical requirement as per table 704-2 over a tack cost of paving grade bitumen 80-100 penetration, laid at a rate of 1kg per sqm over thoroughly cleaned and repaired surface to provide a water resistant membrane and crack retarding layer. Paver fabric to be free of wrinkling and folding to be laid before cooling of tack coat brooming and rolling of surfaces with pneumatic roller to maximize paving fabric contact with pavement surfaces	361						
		Laying boulder apron in crates of synthetic Geogrid: proving, preparing and laying of Geogrid crated apron 1m x 5m, 600 mm thick including excavation and backfilling with baffles at 1 meter interval made with Geogrid having characteristics as per	927						

		clause 704.2, joining sides with connecting staples, top corners to be tensioned placing of suitable cross interval ties in layer of 300 mm connecting opposite side with lateral braces end bed with polymer braids to avoid building constructed as per clause 704.3 filled with stone minimum size of 200mm and specific gravity not less than 2.85 packed with spalls keyed to the foundation recess in case of sloping ground and laid over a layer of Geotextile to prevent migration of fines all as per clause and 704 and laid as per clause 2503.3 and appropriate design							
		subgrade stabilization: providing and laying one layer of non-woven Geotextile of minimum mass per unit area of 200 gms/sqm having minimum roll width of 5.0m treated with carbon black with physical properties as given in clause no 702.2.3 over 25mm thick compacted sand layer on a prepared sub grade as a filter media with necessary overlaps as per drawing and technical specification and as directed by the Engineer in charge.				136			
		Providing and laying one layer of biaxial PVC knitted coated polyester Geogrid of unit roll width of 5.0m having minimum tensile strength of 40KN/m in both direction at a maximum elongation	190						

		of 15% in the direction of the length of the roll and satisfying all requirements of IS Code BIS Code of practice and test prescribed in ASTM or British standards or ISO on prepared sub grade as a separator cum reinforcing agent with necessary overlaps as per drawing and technical specification and as directed by the Executive Engineer in charge complete							
14	West Bengal	Supplying Geotextile/Geofabric/Geo synthetic (non-woven) used as a filter in Anti-erosion as per specification given below including carriage of material to work site complete (This rate is inclusive of all taxes and transportation charges as applicable) Specifications: 1. Physical properties: i) Mass per unit area (ASTMD 5261)- 280gsm/m² ii) Thickness (ASTM D5199) - 2.50 mm 2. Mechanical Properties: i) Tensile strength (wide width) (ASTM D4595 - 19KN/m ii) Grab tensile strength (ASTM D4632) - 445 N iii) Trapezoidal tear resistance (ASTM D4533) - 550 N 3. Hydraulic Properties:- i) Permeability (ASTMD 4491) - 0.03mm/sec ii) Apparent opening size (ASTMD 4751) - 0.09 mm iii) Permittivity (ASTMD 4491) - 0.012/sec				82			

		Supply of geo-bags of dimension 1.0 m x 1.5 m (laid flat) properly stitched at two ends with polypropylene or equivalent yarn for use in bank protective works in the district of Nadia and Murshidabad including all cost of transportation to departmental godowns in the respective districts, taxes duties and other incidental charges. (the rate is inclusive of all taxes and transportation charges as applicable) Specifications: i) Material: Non-woven, staple fibre needle punched/PET/PP ii) Tensile Strength: MD-12 KN/m, XD-23 KN/m (ASTM D 4595 (MARV) iii) CBR Puncture resistance: 3200 N (ASTM D 6241) (MARV) iv) Trapezoidal tear resistance: MD-100%, XD-680 N (ASTM D 4533) (MARV) v) Wide strip tensile elongation: MD-100%, XD-100% (ASTM D 4595) (MARV) vi) Apparent opening size: 130 micron or lower (ASTM D 4571) vii) Mass: 350 gms/m2 or higher (ASTM D 5261) viii) Thickness: 4.6 mm or higher (ASTM D 5199						272.50 (Each)	
		labour for filling Geosynthetic bags (capacity = 0.406 Cum/bag) with fine sand, machine stitching the open end of the bag as per design and thread and as directed by engineer in charge including carriage and hire charges of all						150.60 (each bag)	

		materials and equipment including cost of sand within initial lead of 150m and all lifts							
		Extra rate of above item for every additional lead of 60 meters or part thereof over the initial lead of 150 meters. A) Each additional lead						12.20 (Each Bag)	

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Annexure D – Proposed SoR Item List and Indicative Rates

Note: Prices given here are purely indicative and are included solely for guidance based upon opinion of the report review committee on Feb 16, 2013. States will have to set their own prices.

Geogrid

Specifications	Property Value	Test Method	Indicative Rate
Ultimate tensile strength (kN/m)	30.0	ASTM D 6637	Rs 130 per m^2
Elongation at maximum load (%)	14.0		
Tensile strength at 2 % elongation (kN/m)	6.0		
Tensile strength at 5 % elongation (kN/m)	10.5		
Aperture size (mm) (± 2 mm)	26 x 26		
Ultimate tensile strength (kN/m)	40.0	ASTM D 6637	Rs 160 per m^2
Elongation at maximum load (%)	15.0		
Tensile strength at 2 % elongation (kN/m)	7.5		
Tensile strength at 5 % elongation (kN/m)	14.0		
Aperture size (mm) (± 2 mm)	25 x 25		
Ultimate tensile strength(kN/m)	60.0	ASTM D 6637	Rs 200 per m^2
Elongation at maximum load (%)	15.0		
Tensile strength at 2 % elongation (kN/m)	9.0		
Tensile strength at 5 % elongation (kN/m)	16.0		
Aperture size (mm) (± 2 mm)	25 x 25		
Ultimate tensile strength (kN/m)	90.0	ASTM D 6637	Rs 250 per m^2
Elongation at maximum load (%)	15.0		
Tensile strength at 2 % elongation (kN/m)	11.0		
Tensile strength at 5 % elongation (kN/m)	25.0		
Aperture size (mm) (± 2 mm)	23 x 23		

Nonwoven Geotextile

Parameters	Test Method	Type 1	Type 2	Type 3
Thickness (mm)	ISO 9863	1 – 1.9	2 – 2.9	3 – 4
Grab Breaking/ Tensile Strength (N)	ASTM D-4632	Min. 500	Min. 900	Min. 1500
CBR Puncture Strength (N)	ISO 12236, ASTM D4833	Min. 1300	Min. 2200	Min. 3700
Apparent Opening Size (micron)	ASTM D4751	Max 280	Max 200	Max 180
Permittivity (s^{-1})	ASTM D 4491	Max 3.0	Max 2.0	Max 1.7
UV Resistance @ 500 hrs	ASTM D 4355	70 %	70 %	70 %
Indicative Rate (Rs/m^2)		Rs 115	Rs 150	Rs 180

`Woven Geotextile

Specifications	Property Value	Standard	Rate
Grab Tensile Strength (kN/m)	0.890	ASTM D 4632	Rs 50 per m^2
Grab Elongation (%)	15		
Mullen Burst (kPa)	2750	ASTM D 3786	
Puncture Strength (kN)	0.422	ASTM D 4833	
Trapezoid Tear Strength (kN)	0.330	ASTM D 4533	
Ultra violet resistance	70 % for 500 hrs	ASTM D 4355	
Apparent opening size (mm)	0.425	ASTM D 4751	
Permittivity (sec-1)	0.05	ASTM D 4491	
Flow rate (l/m2/s)	160		
Grab Tensile Strength (kN/m)	1.11	ASTM D 4632	Rs 65 per m^2
Grab Elongation (%)	15		
Mullen Burst (kPa)	3450	ASTM D 3786	
Puncture Strength (kN)	0.489	ASTM D 4833	
Trapezoid Tear Strength (kN)	0.4	ASTM D 4533	
Ultra violet resistance	70 % for 500 hrs	ASTM D 4355	
Apparent opening size (mm)	0.425	ASTM D 4751	
Permittivity (sec-1)	0.05	ASTM D 4491	
Flow rate (l/m2/s)	160		
Grab Tensile Strength (kN/m)	1.40	ASTM D 4632	Rs 80 per m^2
Grab Elongation (%)	15		
Mullen Burst (kPa)	4130	ASTM D 3786	
Puncture Strength (kN)	0.645	ASTM D 4833	
Trapezoid Tear Strength (kN)	0.530	ASTM D 4533	
Ultra violet resistance	70 % for 500 hrs	ASTM D 4355	
Apparent opening size (mm)	0.425	ASTM D 4751	
Permittivity (sec-1)	0.05	ASTM D 4491	
Flow rate (l/m2/s)	160		

Jute Geotextiles

Sr. No	Specification	Indicative Rate
1	Woven Jute Geotextile (For separation and filtration purpose) 724 GSM	Rs 61.50 per m^2
2	Open weave Jute Geotextile (For control of surficial soil) 500 GSM	Rs 30 per m^2
3	Woven Jute Geotextile with eco-friendly additive for longer durability 627 GSM	Rs 71 per m^2
4	Non-woven Jute Geotextile 500 GSM	Rs 26.50 per m^2

Geocomposites

Sr	Specifications	Property Value	Test Method	Indicative Rate
1	Tensile strength	60 kN/m	ASTM D 4595	Rs 210 per m^2
	Elongation at	12 %		
	Load at 2 % elongation	12 kN/m		
	Load at 5 % elongation	25 kN/m		
	Apparent opening size	150 micro meter	ASTM D 4751	
	Water permeability (flow rate) normal to the plane	70 ltrs/ m^2/s	ASTM D 4491	
	Asphalt retention	1.15 ltrs/ m^2	ASTM D 6140	

2	Tensile strength	90 kN/m	ASTM D 4595	Rs 265 per m^2
	Elongation at	13 %		
	Load at 2 % elongation	20 kN/m		
	Load at 5 % elongation	40 kN/m		
	Apparent opening size	150 micro meter	ASTM D 4751	
	Water permeability (flow rate) normal to the plane	70 ltrs/ m^2/s	ASTM D 4491	
	Asphalt retention	1.15 ltrs/ m^2	ASTM D 6140	

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Annexure E – ASTM Test Methods & Specifications for Geosynthetics

Standard	Description
Geosynthetics	
D4354-99(2009)	Standard Practice for Sampling of Geosynthetics for Testing
D4439-11	Standard Terminology for Geosynthetics
D4716-08	Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
X`D4759-11	Standard Practice for Determining the Specification Conformance of Geosynthetics
D4873-02(2009)	Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
D5199-12	Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
D5262-07	Standard Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behaviour of Geosynthetics
D5321-08	Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method
D5322-98(2009)	Standard Practice for Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids
D5496-98(2009)	Standard Practice for In Field Immersion Testing of Geosynthetics
D5514-06(2011)	Standard Test Method for Large Scale Hydrostatic Puncture Testing of Geosynthetics
D5596-03(2009)	Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D5617-04(2010)	Standard Test Method for Multi-Axial Tension Test for Geosynthetics
D5818-11	Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics
D5819-05	Standard Guide for Selecting Test Methods for Experimental Evaluation of Geosynthetic Durability
D5885-06	Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry
D5887-09	Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter
D5888-06(2011)	Standard Guide for Storage and Handling of Geosynthetic Clay Liners
D5889-11	Standard Practice for Quality Control of Geosynthetic Clay Liners
D5890-11	Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners
D5891-02(2009)	Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners
D5993-99(2009)	Standard Test Method for Measuring Mass Per Unit of Geosynthetic Clay Liners
D6072/D6072M-09	Standard Practice for Obtaining Samples of Geosynthetic Clay Liners

D6102-06	Standard Guide for Installation of Geosynthetic Clay Liners
D6141-09	Standard Guide for Screening Clay Portion of Geosynthetic Clay Liner (GCL) for Chemical Compatibility to Liquids
D6243-09	Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method
D6364-06(2011)	Standard Test Method for Determining Short-Term Compression Behaviour of Geosynthetics
D6495-09	Standard Guide for Acceptance Testing Requirements for Geosynthetic Clay Liners
D6496-04a(2009)	Standard Test Method for Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners
D6574-00(2011)	Standard Test Method for Determining the (In-Plane) Hydraulic Transmissivity of a Geosynthetic by Radial Flow
D6575-00(2006)	Standard Test Method for Determining Stiffness of Geosynthetics Used as Turf Reinforcement Mats (TRMs)
D6638-11	Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)
D6706-01(2007)	Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil
D6766-09	Standard Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners Permeated with Potentially Incompatible Liquids
D6768-04(2009)	Standard Test Method for Tensile Strength of Geosynthetic Clay Liners
D7008-08 -	Standard Specification for Geosynthetic Alternate Daily Covers
D7361-07 -	Standard Test Method for Accelerated Compressive Creep of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method
D7406-07 -	Standard Test Method for Time-Dependent (Creep) Deformation Under Constant Pressure for Geosynthetic Drainage Products
D7499/D7499M-09	Standard Test Method for Measuring Geosynthetic-Soil Resilient Interface Shear Stiffness
D7702-11	Standard Guide for Considerations When Evaluating Direct Shear Results Involving Geosynthetics
Geotextiles	
D1987-07	Standard Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters
D4355-07	Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus
D4491-99a(2009)	Standard Test Methods for Water Permeability of Geotextiles by Permittivity
D4533-11	Standard Test Method for Trapezoid Tearing Strength of Geotextiles
D4594-96(2009)	Standard Test Method for Effects of Temperature on Stability of Geotextiles

D4595-11	Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
D4632-08	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
D4751-04	Standard Test Method for Determining Apparent Opening Size of a Geotextile
D4884-09e1	Standard Test Method for Strength of Sewn or Thermally Bonded Seams of Geotextiles
D4886-10	Standard Test Method for Abrasion Resistance of Geotextiles (Sand Paper/Sliding Block Method)
D5101-01(2006)	Standard Test Method for Measuring the Soil-Geotextile System Clogging Potential by the Gradient Ratio
D5261-10	Standard Test Method for Measuring Mass per Unit Area of Geotextiles
D5493-06(2011)	Standard Test Method for Permittivity of Geotextiles Under Load
D5567-94(2011)	Standard Test Method for Hydraulic Conductivity Ratio (HCR) Testing of Soil/Geotextile Systems
D5970-09	Standard Test Method for Deterioration of Geotextiles from Outdoor Exposure
D6241-04(2009)	Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe
D6389-99(2005)	Standard Practice for Tests to Evaluate the Chemical Resistance of Geotextiles to Liquids
D6767-11	Standard Test Method for Pore Size Characteristics of Geotextiles by Capillary Flow Test
D7178-06(2011) -	Standard Practice for Determining the Number of Constrictions "m" of Non-Woven Geotextiles as a Complementary Filtration Property
D7701-11	Standard Test Method for Determining the Flow Rate of Water and Suspended Solids from a Geotextile Bag
Geomembranes	
D4437-08	Standard Practice for Non-destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes
D4833-07	Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products
D4885-01(2011)	Standard Test Method for Determining Performance Strength of Geomembranes by the Wide Strip Tensile Method
D5323-92(2011)	Standard Practice for Determination of 2 % Secant Modulus for Polyethylene Geomembranes
D5397-07	Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
D5494-93(2011)	Standard Test Method for the Determination of Pyramid Puncture Resistance of Unprotected and Protected Geomembranes
D5641-94(2011)	Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber
D5721-08	Standard Practice for Air-Oven Aging of Polyolefin Geomembranes

D5747-08	Standard Practice for Tests to Evaluate the Chemical Resistance of Geomembranes to Liquids
D5820-95(2011)	Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes
D5884-04a(2010)	Standard Test Method for Determining Tearing Strength of Internally Reinforced Geomembranes
D5886-95(2011)	Standard Guide for Selection of Test Methods to Determine Rate of Fluid Permeation Through Geomembranes for Specific Applications
D5994-10	Standard Test Method for Measuring Core Thickness of Textured Geomembrane
D6214-98(2008)	Standard Test Method for Determining the Integrity of Field Seams Used in Joining Geomembranes by Chemical Fusion Methods
D6365-99(2011)	Standard Practice for the Nondestructive Testing of Geomembrane Seams using the Spark Test
D6392-08	Standard Test Method for Determining the Integrity of Non reinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
D6434-04	Standard Guide for the Selection of Test Methods for Flexible Polypropylene (fPP) Geomembranes
D6455-11	Standard Guide for the Selection of Test Methods for Prefabricated Bituminous Geomembranes (PBGM)
D6497-02(2010)	Standard Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures
D6636-01(2011)	Standard Test Method for Determination of Ply Adhesion Strength of Reinforced Geomembranes
D6693-04(2010)	Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D6747-12	Standard Guide for Selection of Techniques for Electrical Detection of Leaks in Geomembranes
D7002-10	Standard Practice for Leak Location on Exposed Geomembranes Using the Water Puddle System
D7003-03(2008)	Standard Test Method for Strip Tensile Properties of Reinforced Geomembranes
D7004-03(2008)	Standard Test Method for Grab Tensile Properties of Reinforced Geomembranes
D7006-03(2008)	Standard Practice for Ultrasonic Testing of Geomembranes
D7007-09	Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials
D7056-07(2012) -	Standard Test Method for Determining the Tensile Shear Strength of Pre-Fabricated Bituminous Geomembrane Seams
D7106-05(2010) -	Standard Guide for Selection of Test Methods for Ethylene Propylene Diene Terpolymer (EPDM) Geomembranes
D7238-06 -	Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus

D7240-06(2011) -	Standard Practice for Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test)
D7272-06(2011) -	Standard Test Method for Determining the Integrity of Seams Used in Joining Geomembranes by Pre-manufactured Taped Methods
D7274-06a(2011) -	Standard Test Method for Mineral Stabilizer Content of Prefabricated Bituminous Geomembranes (BGM)
D7275-07(2012) -	Standard Test Method for Tensile Properties of Bituminous Geomembranes (BGM)
D7407-07(2012) -	Standard Guide for Determining The Transmission of Gases Through Geomembranes
D7466-10	Standard Test Method for Measuring the Asperity Height of Textured Geomembrane
D7700-12	Standard Guide for Selecting Test Methods for Geomembrane Seams
D7703-11	Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Lance System
D7747-11	Standard Test Method for Determining Integrity of Seams Produced Using Thermo-Fusion Methods for Reinforced Geomembranes by the Strip Tensile Method
D7749-11	Standard Test Method for Determining Integrity of Seams Produced Using Thermo-Fusion Methods for Reinforced Geomembranes by the Grab Method
Geogrids	
D6213-97(2009)	Standard Practice for Tests to Evaluate the Chemical Resistance of Geogrids to Liquids
D6637-11	Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method
D7737-11	Standard Test Method for Individual Geogrid Junction Strength
Common	
D5141-11	Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device
D6088-06(2011)	Standard Practice for Installation of Geocomposite Pavement Drains
D6140-00(2009)	Standard Test Method to Determine Asphalt Retention of Paving Fabrics Used in Asphalt Paving for Full-Width Applications
D6244-06(2011)	Standard Test Method for Vertical Compression of Geocomposite Pavement Panel Drains
D6388-99(2005)	Standard Practice for Tests to Evaluate the Chemical Resistance of Geonets to Liquids
D6454-99(2011)	Standard Test Method for Determining the Short-Term Compression Behavior of Turf Reinforcement Mats (TRMs)

D6523-00(2009)	Standard Guide for Evaluation and Selection of Alternative Daily Covers (ADCs) for Sanitary Landfills
D6524-00(2011)	Standard Test Method for Measuring the Resiliency of Turf Reinforcement Mats (TRMs)
D6525-00(2006)	Standard Test Method for Measuring Nominal Thickness of Permanent Rolled Erosion Control Products
D6566-00(2006)	Standard Test Method for Measuring Mass per Unit Area of Turf Reinforcement Mats
D6567-00(2006)	Standard Test Method for Measuring the Light Penetration of a Turf Reinforcement Mat (TRM)
D6818-02(2009)	Standard Test Method for Ultimate Tensile Properties of Turf Reinforcement Mats
D6916-06c(2011)	Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks)
D6917-03(2011)	Standard Guide for Selection of Test Methods for Prefabricated Vertical Drains (PVD)
D6918-09	Standard Test Method for Testing Vertical Strip Drains in the Crimped Condition
D6992-03(2009)	Standard Test Method for Accelerated Tensile Creep and Creep-Rupture of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method
D7005-03(2008)	Standard Test Method for Determining the Bond Strength (Ply Adhesion) of Geocomposites
D7179-07e1 -	Standard Test Method for Determining Geonet Breaking Force
D7180-05(2009) -	Standard Guide for Use of Expanded Polystyrene (EPS) Geofoam in Geotechnical Projects
D7273-08 -	Standard Guide for Acceptance Testing Requirements for Geonets and Geonet Drainage Geocomposites
D7409-07e1 -	Standard Test Method for Carboxyl End Group Content of Polyethylene Terephthalate (PET) Yarns
D7498-09	Standard Test Method for Vertical Strip Drains Using a Large Scale Consolidation Test
D7556-10	Standard Test Methods for Determining Small-Strain Tensile Properties of Geogrids and Geotextiles by In-Air Cyclic Tension Tests
D7557-09	Standard Practice for Sampling of Expanded Polystyrene Geofoam Specimens
D7748-12e1	Standard Test Method for Flexural Rigidity of Geogrids, Geotextiles and Related Products

Annexure F – Project Compliance Sheet

Sr #	Deliverable	Report Section	Remarks
1	Comprehensive list of geotech products with their applications and end-users to improve quality and reduce cost	3.2 3.3	Complied
2	Upgraded/Modified usage policy of Geotech products in MoRTH (Ministry of Road Transport & Highways)	9.2 Annex B	Complied
3	Hand book in Geosynthetics application for Roads & Highways	Annexure H	Complied - All products and applications included instead of just roads and highways
4	Inclusion of Life-cycle cost method of analysing cost-effectiveness of geotextiles and technical preference for superior construction methods using geotech in 'Orange Book' of MoRTH	5.1	Complied – Covered landfills and canal lining applications over and above roads.
5	Solutions for different field level realities to help engineers to choose appropriate material for a given situation	4	Complied
6	Schedule of Rates for geosynthetic given in MoRTH & and other states	6.3.2 Annex C	Complied - Fourteen state and their regions identified
7	Standard Schedule of Rates for specific geosynthetic and related materials required for road construction involving geotextiles which may be adopted by all states	9.3	Complied
8	Areas for application based research for appropriate utilization of geotech in infrastructure development	9.7	Complied
9	Comparative analysis of standardization and regulatory mechanism/laws/rules in developed countries. This will include a clear benchmarking and identification of gaps in terms of product standards and regulatory / policy interventions for Geotech segment, between India and the countries where the market for particular products is mature and well established.	9.6 and 6.3.3 & 7.2	Complied
10	Details of international bodies involved in development, certification or accreditation of standards for different products in the geotech segment.	7.1	Complied
11	Specimen of tenders used for awarding contracts which have well defined specifications and guidelines for usage of geotech.	9.5 Annex K	Complied
12	Business case for usage of geotech for select applications	5.2	Complied
13	Convening series of brain storming sessions and Compilation of the recommendations.	Annex B	Complied
14	Discussions with the ultimate end users & out come	6.1 Annex B	Complied
15	Presentation to technical textile manufacturers to study the feasibility of indigenous manufacturing at an affordable cost.	6.2	Complied
16	Presentation to user Ministries, State Govt. agencies and agencies involved in decision making for enacting those recommended regulations.	6.1.1 6.1.4 Annex N	Complied
17	Applicable standards for each of the products in India, considering variations arising due to application segment and the end user type.	6.4 9.6	Complied
18	Details of regulatory mechanism/laws/rules for these products in India, if any.	6.3.3	Complied

19	Standards and regulatory mechanism/laws/rules in place for the target products in place in developed countries like USA, Germany, Japan, UK, etc. Relevant section of such acts / rules / regulations should be cited in separate annexure to the report.	7.2 9.6	Complied
20	Areas for amending the existing Indian laws/rules/regulations & new regulations required to be brought for mandatory usage of geotextiles in Indian context.	9.2 9.3 9.4 9.5 9.10	Complied
21	Approach to be followed for facilitating the identified regulatory and policy changes	10	Complied
22	Benefits and cost involved for such Regulatory Measures	9.1	Complied
23	Comments from an "advisory panel" comprising of lawyers specialized in respective areas and legal drafting of the proposed legislative changes (bidders may have legal experts as consortium partners).	9.1	No regulatory changes recommended hence no legal opinion required
24	Report should also cover all the aspects of allied fields and cross-cutting applications of Geotech segment.	9.7 4.12	Complied
25	Report finalization and submission to Ministry of Textiles to take it to next level.		Complied
Responsibilities			
Analysis of prevalent scenario with respect to the target areas			
Sr #	**Deliverable**	**Report Section**	**Remarks**
The engaged Consultant will be required to conduct as "As-Is Analysis" on the above target areas for all types of products under the Geotech sub-segment. This will essentially cover:			
1.	Current usage policy of Geotech products in MoRTH	6.3.1	Complied
2.	Current applications of geosynthetics used to improve quality and reduce cost	5.2	Complied
3.	Current method of application of geotech products prescribed in the Orange book of MoRTH.	6.3.1	Complied
4.	Current geotech products used for different situation	4	Complied
5.	Schedule of rates for geosynthetic materials provided by MoRTH and all state Govt. agencies.	6.3.2	Complied
6.	The current level of standardization and regulatory mechanism/laws/rules in place in India	6.3 6.4	Complied
7.	Need of standards and regulations for each product category and its impact on overall consumption	6.4	Complied
8.	Feedback of key institutional consumers in India for such type of products with regard to the issues of standards faced by them while sourcing such products either domestically or from overseas.	6.1	Complied
Analysis of global scenario with respect to the target areas			
Sr #	**Deliverable**	**Report Section**	**Remarks**
The engaged Consultant will have to present a detailed knowledge base on the above target areas globally. The countries to be covered will primarily be the markets where the market for particular products is mature and well established e.g. Israel, USA, UK, Germany, France, Japan, China etc.			
1.	The Consultant will identify various international bodies which are involved in developing measures to promote usage of Geotextiles	7.1	Complied
2.	The Consultant will also present an analysis of practices carried		

	out on the target areas in different countries. This will lay the founding stone for development in India.		
	○ This analysis will include an exhaustive list of standards available globally for products in the Geotech segment	9.6	Complied
	○ Summary of all relevant regulations/laws/rules that mandate the usage of Geotech segment in various applications	7.2	Complied
	○ Case studies on usage of Geotech in illustrative projects of reasonable scale	7.4	Complied
	○ Specimen of tenders used for awarding contracts which have well defined specifications and guidelines for usage of Geotech	9.5 Annex K	Complied
3.	The Consultant will then provide comments on suitability and applicability of replicating the international standards and regulations in India and finally recommend the standards, regulations and policy changes required which are suitable for Geotech segments	7.5	Complied
4.	The consultant will also provide global (USA, UK, Germany, France, Japan, China and particularly Israel) details on areas where geosynthetics are used to improve quality and reduce cost, usage policy of Geotech products in various applications, geotech products used in different situations, etc.	7.4 7.2	Complied
<u>Discussion with Stakeholders</u>			
Sr #	**Deliverable**	**Report Section**	**Remarks**
The engaged Consultant will have to discuss all the recommended guidelines/ suggestions/ schemes/ policy/ performance standards/ schemes/ regulatory changes with relevant stakeholders			
1.	For example, suggested policy changes for mandating use of Geotech have to be done in consultation with key stakeholders and nodal agencies such as NHAI, BRO, CPWD, CRRI, IRC, and Railways, etc. and fine tune the same. As a result of this consultation with stakeholders and nodal agencies, the consultant has to design an approach paper highlighting key policy / regulatory changes required to promote the usage of the Geotech in India, and an approach towards facilitating the identified regulatory and policy changes	9 10	Complied
2.	The consultant also has to prepare a business case for usage of Geotech for select applications, including a clear cost benefit analysis	5.1 5.2	Complied
3.	Discussion with manufacturers to study the feasibility of indigenous manufacturing at an affordable cost	6.2	Complied

Annexure G - References

Books:

- ✓ Geofabrics, An introduction to geosynthetics; GEOfabrics Limited, Skelton Grange Rd, Stourton Leeds LS10 1RZ,United Kingdom

- ✓ Guide to the Specification of Geosynthetics; August 2006, IGS Secretariat, 226 Sitton Road, Easley, South Carolina 29642, U.S.A.

- ✓ Handbook of geosynthetics; Geosynthetic Materials Association (GMA), 1801 County Rd B West, Roseville MN

Paper Abstracts:

- ✓ Penwill-Cook, Frances; India: Paving Roads the Geotextile Way; www.roadtraffic-technology.com; March 4, 2010.

- ✓ Lal, Ram Asrey; Emerging Market Trends in Technical Textiles; Regional Office of the Textile Commissioner, Ministry of Textile, Govt of India; September 2010.

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- ✓ Verma, M S; Technical Textiles – Growth Potential and Prospects in India; Reliance Industries Ltd; March 2010.

- ✓ Indoria, R. P.; Specifications for Geotextiles in India; Indian Roads Congress; November 2010.

- ✓ Kumar, Anil; Standardization of Geosynthetics; Bureau of Indian Standards.

- ✓ Global Industry Analysts, Inc.; Geosynthetics – A Global Strategic Business Report; Feb 2010.

- ✓ Sharma, Arun Kumar; Geosynthetics – The Third Revolution in Civil Engineering Materials; Indian Highways Magazine: June 2012

- ✓ Chi, Jingkui; History, Development, and Future Prospects for Geosynthetics Industries in China; Geosynthetics Magazine; August 2009

- ✓ Hicks, R.G and Jon A. Epps; Life Cycle Costs for Asphalt-Rubber Paving Materials; Oregon State University and University of Nevada-Reno.

- ✓ Zhao, Aigen and Gregory N. Richardson; US Regulations on Solid Waste Containment Facilities; Tenax and GN Richardson and Associates; 2003.

- ✓ Stark, Timothy D. and Luis F. Pazmino, Stanford Slifer, and Duff Simbeck; Fabricated geomembranes: advantages and uses; Waste Age Magazine, September 2010.

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- ✓ Bearden, Julie B. and Joseph F. Labuz; Fabric for reinforcement and separation in unpaved roads, Department of Civil Engineering, University of Minnesota, 500 Pillsbury Drive S.E., Minneapolis, Minnesota 55455-0220
- ✓ Zornberg, Jorge G. and Nicholas Sitar; Limit Equilibrium as basis for design of geosynthetic reinforced slopes; ASCE.
- ✓ Zhou, Dr. Yun; Geosynthetic engineering: Geosynthetic Protectors; Continuing Education and Development, Inc.
- ✓ Floss, R. and G. Bräu; Design Funundamentals for Geosynthetic Soil Technique; Technische Universität München, Zentrum Geotechnik, Germany.
- ✓ Freedonia Group; Geosynthetics to 2015; May 2011.
- ✓ PTI - Press Trust of India; Technical textile market to touch Rs 1.58 lakh crore by FY 2017; The Economic Times; August 3, 2012.
- ✓ Rupp, Jurg; Geotextiles: The Concrete Alternative; www.textileworld.com; Jan/Feb 2011

Websites:

- ✓ www.geosyntheticsmagazine.com
- ✓ www.interdrain.net
- ✓ www.terramgeosynthetics.com
- ✓ www.maccaferri-india.com
- ✓ www.strataindia.com
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Annexure H – Handbook for Geosynthetics

Please find handbook for geosynthetics as separate booklet accompanying this report.

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traveled way and not on the shoulder forms a "bathtub" section that can trap water beneath the surface of the traveled way. To prevent this effect, RHMA-G should be placed over the whole cross section of the road (traveled way and shoulders).

For additional information and applicability of RHMA in new construction and rehabilitation projects refer to Asphalt Rubber Usage Guide available on the Department Pavement website.

631.4 Other Types of Flexible Pavement

There are other types of flexible pavements such as cold mix, Resin Pavement, and Sulphur Extended Hot Mix Asphalt. The other types of pavements are either used for maintenance treatments or not currently used on State highways. For pavement preservation and other maintenance treatments refer to the Department's Maintenance Manual.

631.5 Stress Absorbing Membrane Interlayers (SAMI)

SAMI are used with flexible layer rehabilitation as a means to retard reflective cracks, prevent water intrusion, and (in the case of SAMI-R (rubberized)) enhance pavement structural strength. Two types of SAMI are:

- Rubberized (SAMI-R). SAMI-R is a rubberized chip seal.
- Geosynthetic Pavement Interlayer (GPI), consists of asphalt-imbued geotextile.

Sound engineering judgment is required when considering the use of a SAMI.

- Consideration should be given to areas that may prohibit surface water from draining out the sides of the overlay, thus forming a "bathtub" section.
- Since SAMI-R can act as a moisture barrier, it should be used with caution in hot environments where it could prevent underlying moisture from evaporating.
- When placed on an existing pavement, preparation is required to prevent excess stress on the membrane. This includes sealing cracks wider than ¼ inch and repairing potholes and localized failures.

A SAMI may be placed between layers of new flexible pavement, such as on a leveling course, or on the surface of an existing flexible pavement. A GPI should not be placed directly on coarse surfaces such as a chip seal, OGFC, areas of numerous rough patches, or on a pavement that has been cold planed. Coarse surfaces may penetrate the fabric and the paving asphalt binder used to saturate the fabric may collect in the voids or valleys leaving areas of the fabric dry. For the GPI to be effective in these areas, use a layer of HMA prior to the placement of the GPI.

GPI is ineffective in the following applications:

- When placed under rubberized hot mix asphalt (RHMA). This is due to the high placement temperature of the RHMA-G mix, which is close to the melting temperature of the GPI.
- For providing added structural strength when placed in combination with new flexible pavement.
- In the reduction of thermal cracking of the new flexible pavement overlay.

Topic 632 - Engineering Criteria

632.1 Engineering Properties

(1) *Smoothness.* The smoothness of a pavement impacts its ride quality, overall durability, and performance. Ride quality (which is measured by the smoothness of ride) is also the highest concern listed in public surveys on pavement condition. Smoothness specifications have been improved and incentive/disincentive specifications have been developed to assure designed smoothness values are achieved in construction. Incentive / disincentive specifications can be used where the project meets the warrants for the specification. For up to date and additional information on smoothness and the application of the smoothness specifications see the smoothness page on the Department Pavement website.

(2) *Asphalt Binder Type.* Asphalt binders are most commonly characterized by their physical properties. An asphalt binder's physical properties directly relate to field

STANDARD SPECIFICATIONS

STATE OF CALIFORNIA
BUSINESS, TRANSPORTATION AND HOUSING AGENCY
DEPARTMENT OF TRANSPORTATION

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88 GEOSYNTHETICS

88-1.01 GENERAL

88-1.01A Summary

Section 88 includes specifications for furnishing geosynthetics.

88-1.01B Submittals

For each type of geosynthetic submit:

1. Certificate of compliance
2. Test sample representing each lot
3. MARV

Label submittals with the manufacturer's name and product information.

88-1.01C Quality Control and Assurance

Treat geosynthetics to resist degradation from exposure to sunlight. Furnish geosynthetics in covers to protect against damage from moisture, sunlight, and shipping and storage.

88-1.02 MATERIALS

88-1.02A General

Reserved

88-1.02B Filter Fabric

Geosynthetics used for filter fabric must be permeable and nonwoven. Filter fabric must be manufactured from one of the following:

1. Polyester
2. Polypropylene
3. Combined polyester and polypropylene

When tested under the referenced ASTMs, properties of filter fabric must have the values shown in the following table:

Filter Fabric

Property	Test	Value		
		Class A	Class B	Class C
Grab breaking load, 1-inch grip, lb min in each direction	ASTM D 4632	157		
Apparent elongation, percent min in each direction	ASTM D 4632	50		
Hydraulic bursting strength, psi min	ASTM D 3786	210		
Ultraviolet resistance, percent min retained grab breaking load, 500 hours	ASTM D 4355	70		
Permittivity, sec^{-1} min	ASTM D 4491	0.5	0.2	0.1
Apparent opening size, average roll value, U.S. standard sieve size, max	ASTM D 4751	40	60	70

88-1.02C Geocomposite Wall Drain

Geocomposite wall drain must consist of a polymeric core with filter fabric integrally bonded to one or both sides of the core creating a stable drainage void.

Filter fabric must comply with section 88-1.02B.

Geocomposite wall drain must be no more than 2 inches thick.

When tested under ASTM D 4716, properties of geocomposite wall drain must have the value shown in the following table:

Geocomposite Wall Drain

Property	Test	Value
Transmissivity, gal/min/ft gradient = 1.0, Normal stress = 5,000 psf	ASTM D 4716	4

88-1.02D Geotechnical Subsurface Reinforcement

88-1.02D(1) General

Geosynthetic reinforcement used for geotechnical subsurface reinforcement must be either geotextile or geogrid.

When tested under ASTM D 4491, geotextile permittivity must be at least 0.05 sec^{-1}.

Geogrid must have a regular and defined open area. The open area must be from 50 to 90 percent of the total grid area.

88-1.02D(2) Long Term Design Strength

Determine the LTDS of geosynthetic reinforcement from the ultimate tensile strength in the primary strength direction divided by reduction factors. Calculate LTDS from the guidelines in Geosynthetic Research Institute Standard Practice GG4a, GRI GG4b, or GRI GT7.

The product of the reduction factors must be at least 1.30. Determine the reduction factor for creep using a 75 year design life for permanent applications. For temporary applications, use a 5 year design life to determine the reduction factor. Determine the installation damage reduction factor from the characteristics of backfill materials used.

If test data is not available, use default values of reduction factors in the Geosynthetic Research Institute Standard Practice to determine LTDS.

Submit the LTDS and its supporting calculations at least 15 days before placing geosynthetic reinforcement. The calculations must be signed by an engineer registered as a civil engineer in the State. Do not install unless authorized.

88-1.02E Silt Fence Fabric

When tested under the referenced ASTMs, the properties of silt fence fabric must have the values shown in the following table:

Silt Fence Fabric

Property	Test	Value	
		Woven	Nonwoven
Grab breaking load, 1-inch grip, lb min, in each direction	ASTM D 4632	120	120
Apparent elongation, percent min, in each direction	ASTM D 4632	15	50
Water flow rate, gal per minute/sq ft min and max average roll value	ASTM D 4491	10–100	100–150
Permittivity, sec^{-1} min	ASTM D 4491	0.1	1.1
Apparent opening size, inches max average roll value	ASTM D 4751	0.023	0.023
Ultraviolet resistance, percent min retained grab breaking load, 500 hours	ASTM D 4355	70	70

88-1.02F Gravel-Filled Bag

When tested under the referenced ASTMs, the properties of gravel-filled bag must have the values shown in the following table:

Gravel-Filled Bag

Property	Test	Value
Grab breaking load, lb, 1-inch grip min, in each direction	ASTM D 4632	205
Water flow rate, gal per minute/sq ft min and max average roll value	ASTM D 4491	80–150
Permittivity, sec^{-1} min	ASTM D 4491	0.2
Apparent opening size, inches max average roll value	ASTM D 4751	0.016
Ultraviolet resistance, percent min retained grab breaking load, 500 hours	ASTM D 4355	70

88-1.02G Sediment Filter Bag

When tested under the referenced ASTMs, the properties of sediment filter bag must have the values shown in the following table:

Sediment Filter Bag

Property	Test	Value
Grab breaking load, lb, 1-inch grip min, in each direction	ASTM D 4632	255
Water flow rate, gal per minute/sq ft min and max average roll value	ASTM D 4491	80–200
Permittivity, sec^{-1} min	ASTM D 4491	1.0
Apparent opening size, inches max average roll value	ASTM D 4751	0.023
Ultraviolet resistance, percent min retained grab breaking load, 500 hours	ASTM D 4355	70

88-1.02H Temporary Cover

When tested under the referenced ASTMs, the properties of temporary cover must have the values shown in the following table:

Temporary Cover

Property	Test	Value
Grab breaking load, lb, 1-inch grip min, in each direction	ASTM D 4632	200
Apparent elongation, percent min, in each direction	ASTM D 4632	50
Water flow rate, gal per minute/sq ft min and max average roll value	ASTM D 4491	75–120
Permittivity, sec^{-1} min	ASTM D 4491	1.0
Apparent opening size, inches max average roll value	ASTM D 4751	0.007
Ultraviolet resistance, percent min retained grab breaking load, 500 hours	ASTM D 4355	70

88-1.02I Rock Slope Protection Fabric

RSP fabric must be a permeable, nonwoven, needle-punched geotextile. The fabric must be manufactured from one of the following:

1. Polyester
2. Polypropylene
3. Combined polyester and polypropylene

Polymers must be either virgin compounds or clean reworked material. Do not subject virgin compounds to use or processing other than required for initial manufacture. Clean reworked material must be previously processed material from the processor's own production that has been reground, pelletized, or solvated. The fabric must not contain more than 20 percent of clean reworked material by weight. Do not use recycled materials from either post-consumer or post-industrial sources.

When tested under the referenced ASTMs, the properties of Class 8 and Class 10 RSP fabric must have the values shown in the following table:

RSP Fabric

Property	Test	Value	
		Class 8	Class 10
Mass, oz/sq yd min	ASTM D 5261	7.5	9.5
Grab breaking load, lb, 1-inch grip min, in each direction	ASTM D 4632	200	250
Apparent elongation, percent min, in each direction	ASTM D 4632	50	50
Permittivity, sec^{-1}, min	ASTM D 4491	1.0	0.70
Apparent opening size, U.S. Standard sieve size: min and max	ASTM D 4751	70–100	70–100
Ultraviolet resistance, percent min retained grab breaking load, 500 hours	ASTM D 4355	70	70

88-1.02J Paving Fabric

Geosynthetics used for paving fabric must be nonwoven. When tested under the referenced ASTMs, properties of paving fabric must have the values shown in the following table:

Paving Fabric

Property	Test	Value
Mass per unit area, oz/sq yd min	ASTM D 5261	4.1
Grab breaking load, lb, 1-inch grip min, in each direction	ASTM D 4632	100
Apparent elongation, percent min, in each direction	ASTM D 4632	50
Hydraulic bursting strength, psi min	ASTM D 3786	200
Melting point, °F min	ASTM D 276	325
Asphalt retention, gal/sq yd min	ASTM D 6140	0.2

88-1.02K Paving Mat

Geosynthetics used for paving mat must be a nonwoven fiberglass and polyester hybrid material. When tested under the referenced ASTMs, properties of paving mat must have the values shown in the following table:

Paving Mat

Property	Test	Value
Breaking force, lb/2 inches min	ASTM D 5035	45
Ultimate elongation, percent max	ASTM D 5035	5
Mass per unit area, oz/sq yd min	ASTM D 5261	3.7
Melting point, °F min	ASTM D 276	400
Asphalt retention, gal/sq yd min	ASTM D 6140	0.10

88-1.02L Paving Grid

Geosynthetics used for paving grid must be a geopolymer material formed into a grid of integrally connected elements with openings. When tested under the referenced ASTMs, properties of paving grid must have the values shown in the following table:

Paving Grid

Property	Test	Value		
		Class I	Class II	Class III
Tensile strength at ultimate, lb/in[a] min	ASTM D 6637	560 x 1,120	560	280
Aperture size, inch min	Calipered	0.5	0.5	0.5
Elongation, percent max	ASTM D 6637	12	12	12
Mass per area, oz/sq yd min	ASTM D 5261	16	10	5.5
Melting point, °F min	ASTM D 276	325	325	325

[a] For Class I, machine direction x cross direction. For Class II and Class III, both directions.

88-1.02M Paving Geocomposite Grid

Paving geocomposite grid must consist of a paving grid specified in section 88-1.02L bonded or integrated with a paving fabric as specified in section 88-1.02J.

Paving geocomposite grid must have a peel strength of at least 10 lb/ft determined under ASTM D 413.

88-1.02N Geocomposite Strip Membrane

Geocomposite strip membrane must be various widths of strips manufactured from asphaltic rubber and geosynthetics. When tested under the referenced ASTMs, properties of geocomposite strip membrane must comply with the requirements shown in the following table:

Geocomposite Strip Membrane

Property	Test	Requirements
Strip tensile strength, lb/inch min	ASTM D 882	50
Elongation at break, percent min	ASTM D 882	50
Resistance to puncture, lb min	ASTM E 154	200
Permeance, perms max	ASTM E 96 / E 96M	0.10
Pliability, 1/4 inch mandrel with sample conditioned at 25 °F	ASTM D 146	No cracks in fabric or bitumen
Melting point, °F	ASTM D 276	325

88-1.02O Subgrade Enhancement Geotextile

Subgrade enhancement geotextile must be either polyester or polypropylene. When tested under the referenced ASTMs, properties of subgrade enhancement geotextile must have the values shown in the following table:

Subgrade Enhancement Geotextile

Property	Test	Value[a]				
		Class A1	Class A2	Class B1	Class B2	Class B3
Elongation at break, percent	ASTM D 4632	<50	≥50	<50	<50	≥50
Grab breaking load, lb, 1-inch grip min, in each direction	ASTM D 4632	250	160	--	320	200
Wide width tensile strength at 5 percent strain, lb/ft min	ASTM D 4595	--	--	2,000	--	--
Wide width tensile strength at ultimate strength, lb/ft min	ASTM D 4595	--	--	4,800	--	--
Tear strength, lb min	ASTM D 4533	90	60	--	120	80
Puncture strength, lb min	ASTM D 6241	500	310	620	620	430
Permittivity, sec^{-1} min	ASTM D 4491	0.05	0.05	0.20	0.20	0.20
Apparent opening size, inches max	ASTM D 4751	0.012	0.012	0.024	0.012	0.012
Ultraviolet resistance, percent min retained grab breaking load, 500 hours	ASTM D 4355	70	70	70	70	70

[a]Values are based on MARV in the weaker principal direction except apparent opening size is based on maximum average roll value.

88-1.02P–88-1.02S Reserved

88-1.03 CONSTRUCTION

Not Used

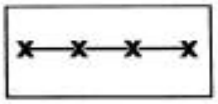
88-1.04 PAYMENT

Not Used

Annexure J – Virginia Silt Fence Guidelines

STD & SPEC 3.05

SILT FENCE



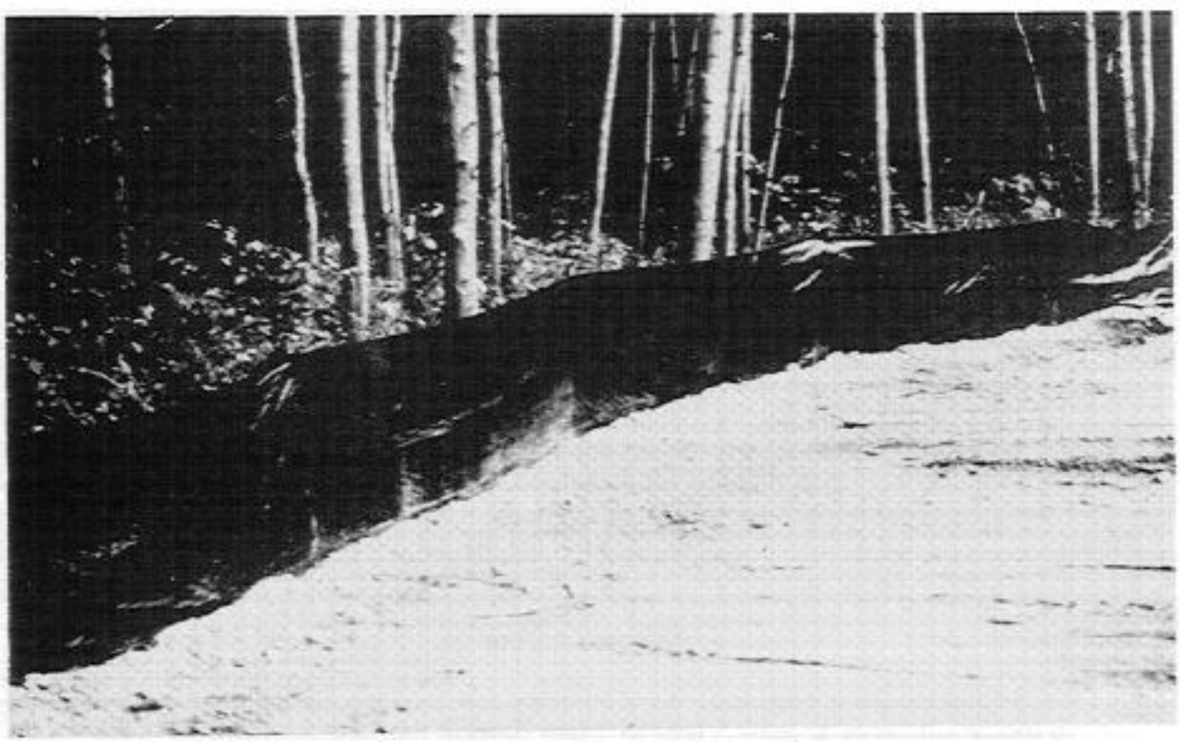
Definition

A temporary sediment barrier consisting of a synthetic filter fabric stretched across and attached to supporting posts and entrenched.

Purposes

1. To intercept and detain small amounts of sediment from disturbed areas during construction operations in order to prevent sediment from leaving the site.

2. To decrease the velocity of sheet flows and low-to-moderate level channel flows.



Conditions Where Practice Applies

1. Below disturbed areas where erosion would occur in the form of sheet and rill erosion.

2. Where the size of the drainage area is no more than one quarter acre per 100 feet of silt fence length; the maximum slope length behind the barrier is 100 feet; and the maximum gradient behind the barrier is 50 percent (2:1).

3. In minor swales or ditch lines where the maximum contributing drainage area is no greater than 1 acre and flow is no greater than 1 cfs.

4. Silt fence will not be used in areas where rock or some other hard surface prevents the full and uniform depth anchoring of the barrier.

Planning Considerations

Laboratory work at the Virginia Highway and Transportation Research Council (VHTRC) has shown that silt fences can trap a much higher percentage of suspended sediments than straw bales, though silt fence passes the sediment-laden water slower. Silt fences are preferable to straw barriers in many cases because of their durability and potential cost savings. While the failure rate of silt fences is lower than that of straw barriers, many instances have been observed where silt fences are improperly installed, inviting failure and sediment loss. The installation methods outlined here can improve performance and reduce failures.

As noted, flow rate through silt fence is significantly lower than the flow rate for straw bale barriers. This creates more ponding and hence more time for sediment to fall out. Table 3.05-A demonstrates these relationships.

Both woven and non-woven synthetic fabrics are commercially available. The woven fabrics generally display higher strength than the non-woven fabrics and, in most cases, do not require any additional reinforcement. When tested under acid and alkaline water conditions, most of the woven fabrics increase in strength, while the reactions of non-woven fabrics to these conditions are variable. The same is true of testing under extensive ultraviolet radiation. Permeability rates vary regardless of fabric type. While all of the fabrics demonstrate very high filtering efficiencies for sandy sediments, there is considerable variation among both woven and non-woven fabrics when filtering the finer silt and clay particles.

Design Criteria

1. No formal design is required. As with straw bale barriers, an effort should be made to locate silt fence at least 5 feet to 7 feet beyond the base of disturbed slopes with grades greater than 7%.

TABLE 3.05-A

TYPICAL FLOW RATES AND FILTERING EFFICIENCIES OF PERIMETER CONTROL

Material	Flow Rate (gal./sq.ft./min)	Filter Efficiency(%)
Straw	5.6	67
Synthetic Fabric	0.3	97

Source: VHTRC

2. The use of silt fences, because they have such a low permeability, is limited to situations in which only sheet or overland flows are expected and where concentrated flows originate from drainage areas of 1 acre or less.

3. Field experience has demonstrated that, in many instances, silt fence is installed too short (less than 16 inches above ground elevation). The short fence is subject to breaching during even small storm events and will require maintenance "clean outs" more often. Properly supported silt fence which stands 24 to 34 inches above the existing grade tends to promote more effective sediment control.

Construction Specifications

Materials

1. Synthetic filter fabric shall be a pervious sheet of propylene, nylon, polyester or ethylene yarn and shall be certified by the manufacturer or supplier as conforming to the requirements noted in Table 3.05-B.

2. Synthetic filter fabric shall contain ultraviolet ray inhibitors and stabilizers to provide a minimum of six months of expected usable construction life at a temperature range of 0° F to 120° F.

3. If wooden stakes are utilized for silt fence construction, they must have a diameter of 2 inches when oak is used and 4 inches when pine is used. Wooden stakes must have a minimum length of 5 feet.

TABLE 3.05-B

PHYSICAL PROPERTIES OF FILTER FABRIC IN SILT FENCE

Physical Property	Test	Requirements
Filtering Efficiency	ASTM 5141	75% (minimum)
Tensile Strength at 20% (max.) Elongation*	VTM-52	Extra Strength - 50 lbs./linear inch (minimum) Standard Strength - 30 lbs./linear inch (minimum)
Flow Rate	ASTM 5141	0.2 gal./sq.ft./ minute (minimum)
Ultraviolet Radiation Stability %	ASTM-G-26	90% (minimum)

* Requirements reduced by 50% after six months of installation.

Source: VHTRC

4. If steel posts (standard "U" or "T" section) are utilized for silt fence construction, they must have a minimum weight of 1.33 pounds per linear foot and shall have a minimum length of 5 feet.

5. Wire fence reinforcement for silt fences using standard-strength filter cloth shall be a minimum of 14 gauge and shall have a maximum mesh spacing of 6 inches.

Installation

1. The height of a silt fence shall be a minimum of 16 inches above the original ground surface and shall not exceed 34 inches above ground elevation.

2. The filter fabric shall be purchased in a continuous roll cut to the length of the barrier to avoid the use of joints. When joints are unavoidable, filter cloth shall be spliced together only at a support post, with a minimum 6-inch overlap, and securely sealed.

3. A trench shall be excavated approximately 4-inches wide and 4-inches deep on the upslope side of the proposed location of the measure.

4. When wire support is used, standard-strength filter cloth may be used. Posts for this type of installation shall be placed a maximum of 10-feet apart (see Plate 3.05-1). The wire mesh fence must be fastened securely to the upslope side of the posts using heavy duty wire staples at least one inch long, tie wires or hog rings. The wire shall extend into the trench a minimum of two inches and shall not extend more than 34 inches above the original ground surface. The standard-strength fabric shall be stapled or wired to the wire fence, and 8 inches of the fabric shall be extended into the trench. The fabric shall not be stapled to existing trees.

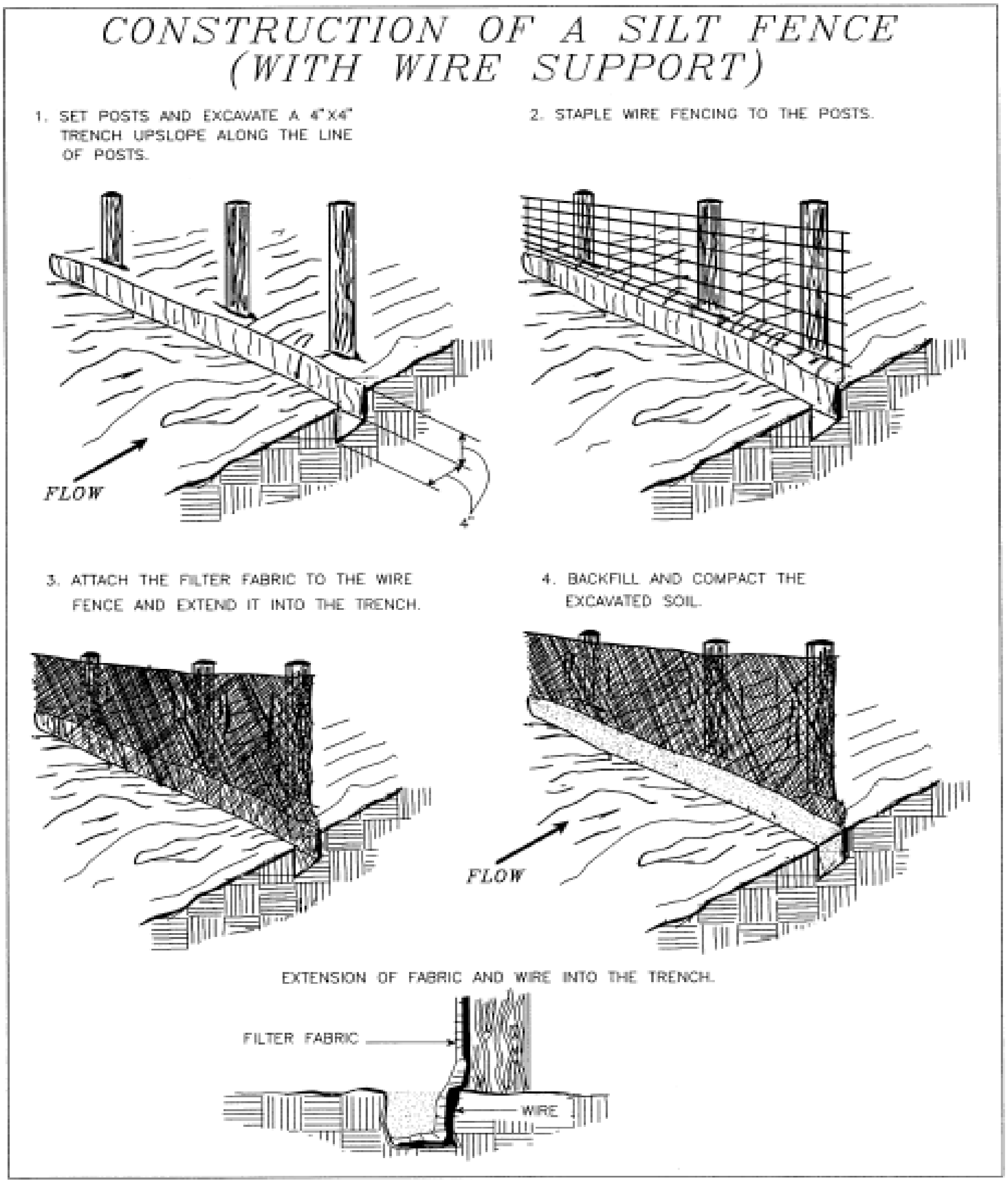
5. When wire support is not used, extra-strength filter cloth shall be used. Posts for this type of fabric shall be placed a maximum of 6-feet apart (see Plate 3.05-2). The filter fabric shall be fastened securely to the upslope side of the posts using one inch long (minimum) heavy-duty wire staples or tie wires and eight inches of the fabric shall be extended into the trench. The fabric shall not be stapled to existing trees. This method of installation has been found to be more commonplace than #4.

6. If a silt fence is to be constructed across a ditch line or swale, the measure must be of sufficient length to eliminate endflow, and the plan configuration shall resemble an arc or horseshoe with the ends oriented upslope (see Plate 3.05-2). Extra-strength filter fabric shall be used for this application with a maximum 3-foot spacing of posts.

   All other installation requirements noted in #5 apply.

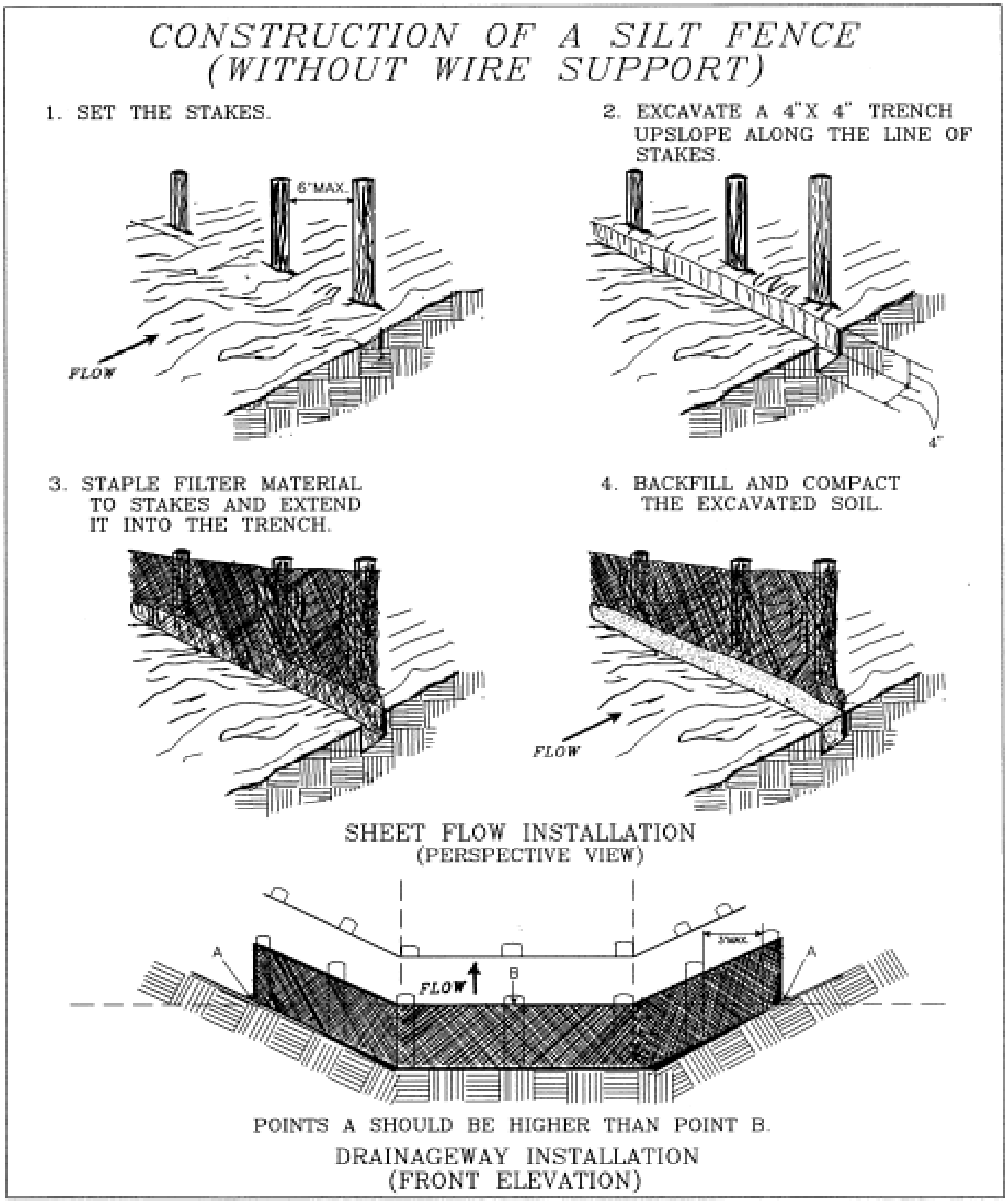
7. The 4-inch by 4-inch trench shall be backfilled and the soil compacted over the filter fabric.

8. Silt fences shall be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized.



Source: Adapted from Installation of Straw and Fabric Filter Barriers for Sediment Control, Sherwood and Wyant

Plate 3.05-1



Source: Adapted from Installation of Straw and Fabric Filter Barriers for Sediment Control, Sherwood and Wyant

Plate 3.05-2

Maintenance

1. Silt fences shall be inspected immediately after each rainfall and at least daily during prolonged rainfall. Any required repairs shall be made immediately.

2. Close attention shall be paid to the repair of damaged silt fence resulting from end runs and undercutting.

3. Should the fabric on a silt fence decompose or become ineffective prior to the end of the expected usable life and the barrier still be necessary, the fabric shall be replaced promptly.

4. Sediment deposits should be removed after each storm event. They must be removed when deposits reach approximately one-half the height of the barrier.

5. Any sediment deposits remaining in place after the silt fence is no longer required shall be dressed to conform with the existing grade, prepared and seeded.

Annexure K – International Tender Specimens

1. Washington State, USA –

Contract Provisions

For Construction of:

SR 500 MP 4.58 TO MP 5.96

N.E. 112TH AVE./GHER RD. INTERCHANGE

CLARK COUNTY

VOLUME 1 OF 2

STATE PROJECT

Washington State Department of Transportation

WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION
OLYMPIA, WASHINGTON 98504

July 10, 2003

ATTENTION: ALL BIDDERS AND PLANHOLDERS

SR 500, Contract 6625
N.E. 112th Ave./Gher Rd. Interchange
State Project

ADDENDUM NO. 4

The Plans for this project are amended as follows:

On sheet 48 (revised by Addendum No. 2), in the detail for Temporary Geotextile Wall Section, the note specifying wall backfill material and compaction is revised to read:

Wall backfill material shall be GRAVEL BORROW, compacted using Method C.

The Bidders are instructed to revise sheet 48 of the Plans as a revised plan sheet has not been prepared for attachment to this addendum.

Bidders shall furnish the Secretary of Transportation with evidence of the receipt of this addendum. This addendum will be incorporated in the contract when awarded and when formally executed.

Donald R. Wagner, P.E.
Regional Administrator

Construction Requirements

The ditches and ponds shall be constructed to the lines, grades, and details shown in the Plans. All excavated materials shall become the property of the Contractor and removed from the project.

The Contractor is advised that areas of asphalt, concrete, and curbing may be encountered where excavation is required.

Measurement

Pond excavation will be measured by the cubic meter in its original site, and the quantities calculated by the neat line of the staked cross sections.

Payment

Payment will be made in accordance with Section 1-04.1 for the following bid item:

"Pond Excavation Incl. Haul", per cubic meter.

CONSTRUCTION GEOTEXTILE

Description

Section 2-12.1 is supplemented with the following:

> ***(November 17, 1997)***
> ***Geosynthetic Retaining Wall***
> The Contractor shall furnish and construct temporary or permanent geosynthetic retaining walls in accordance with the details shown in the Plans, these specifications, or as directed by the Engineer.

Materials

(November 17, 1997)
Section 2-12.2 is supplemented with the following:

> The provisions of this section shall also apply to geogrids.

(November 17, 1997)
Borrow
Section 9-03.14 is supplemented with the following:

(November 17, 1997)
Borrow for Geosynthetic Retaining Wall
All backfill material used in the reinforced soil zone of the geosynthetic wall shall conform to requirements of Section 9-03.14(1) and shall be free draining, free from organic or otherwise deleterious material. The material shall be substantially free of shale or other soft, poor durability particles, and shall not contain recycled materials, such as glass, shredded tires, portland cement concrete rubble, or asphaltic concrete rubble. The backfill material shall meet the following requirements:

Property	Test Method	Allowable Test Value
Los Angeles Wear, 500 rev.	AASHTO T 96	35 percent max.
Degradation	WSDOT Test Method 113	15 min.
pH	AASHTO T 289-91	Quantity **

** 4.5 to 9 for permanent walls and 3 to 10 for temporary walls

Wall backfill material satisfying these gradation, durability and chemical requirements shall be classified as nonaggressive.

Geotextile and Thread for Sewing

Section 9-33.1 is supplemented with the following:

(November 17, 1997)
Geotextiles and Thread for Retaining Walls

The term geosynthetics shall include both geotextiles and geogrids.

Geotextile reinforcement in geosynthetic retaining walls shall conform to the properties specified in Tables 7 and 8 for permanent walls, and Tables 7 and 9 for temporary walls.

Geogrids shall consist of a regular network of integrally connected polymer tensile elements with an aperture geometry sufficient to permit mechanical interlock with the surrounding backfill. The long chain polymers in the geogrid tensile elements, not including coatings, shall consist of at least 95 percent by mass of the material of polyolefins or polyesters. The material shall be free of defects, cuts, and tears. Geogrid reinforcement in geosynthetic retaining walls shall conform to the properties specified in Table 8 for permanent walls, and Table 9 for temporary walls.

For geosynthetic walls which use geogrid reinforcement, the geotextile material placed at the wall face to retain the backfill material as shown in the Plans shall conform to the properties for Construction Geotextile for Underground Drainage, Moderate Survivability, Class A.

The thread used to sew geotextile seams in exposed wall faces shall be resistant to ultraviolet radiation.

Geotextile Properties

Section 9-33.2 is supplemented with the following:

(November 17, 1997)
Geosynthetic Properties For Retaining Walls and Reinforced Slopes

All geotextile properties provided in Table 7 are minimum average roll values. The average test results for any sampled roll in a lot shall meet or exceed the values shown in the table. The test procedures specified in the table are in conformance with the most recently approved ASTM geotextile test procedures, except for geotextile sampling and specimen conditioning, which are in accordance with WSDOT Test Methods 914 and 915, respectively.

Table 7: Minimum properties required for geotextile reinforcement used in geosynthetic reinforced slopes and walls.

Geotextile Property	Test Method	Geotextile Property Requirements Woven/Nonwoven
Water Permittivity	ASTM D4491	.02 sec.$^{-1}$ min.
AOS	ASTM D4751	.84 mm max.
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	900 N/530 N min.
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	$< 50\% / \geq 50\%$

Seam Breaking Strength[1]	ASTM D4632	700 N/430 N min.
Puncture Resistance	ASTM D4833	280 N/220 N min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	280 N/220 N min.
Ultraviolet (UV) Radiation Stability	ASTM D4355	70% (for polypropylene and polyethylene) and 50% (for polyester) Strength Retained min., after 500 Hr. in weatherometer

[1]Applies only to seams perpendicular to the wall face.

For geogrids, the summation of the geogrid joint strengths determined in accordance with Geosynthetic Research Institute test method GRI:GG2 occurring in a 300 mm length of grid in the direction of loading (i.e., perpendicular to the wall face) shall be greater than or equal to the ultimate strength (T_{ult}) of the grid element to which they are attached. For this determination, T_{ult} is to be determined using Geosynthetic Research Institute test method GRI:GG1. If the joint spacing is greater than or equal to 300 mm, two joints shall be included in this summation of joint strengths. The ultraviolet (UV) radiation stability, ASTM D4355, shall be a minimum of 70% strength retained after 500 hours in the weatherometer for polypropylene and polyethylene geogrids, and 50% strength retained after 500 hours in the weatherometer for polyester geogrids.

(November 17, 1997)
Geosynthetic Properties For Temporary Retaining Walls
Wide strip geosynthetic strengths provided in Table 9 are minimum average roll values. The average test results for any sampled roll in a lot shall meet or exceed the values shown in the table. These wide strip strength requirements apply only in the geosynthetic direction perpendicular to the wall face. The test procedures specified in the table are in conformance with the most recently approved ASTM geosynthetic test procedures, except for geosynthetic sampling and specimen conditioning, which are in accordance with WSDOT Test Methods 914 and 915, respectively.

Table 9: Wide strip tensile strength required for the geosynthetic reinforcement used in geosynthetic retaining walls.

Wall Location	Vertical Spacing of Reinforcement Layers	Reinforcement Layer Distance from Top of Wall	Minimum Tensile Strength Based on ASTM D4595
***NSE 3+525 to 4+005.089	***0.30	*** 1.2	***21.0
NSW 2+027.460 to 2+480.00***	0.38***	1.2 ***	26***

ASTM D4595 shall be modified to address geogrids as follows: The minimum specimen width shall be 200 mm with a minimum gauge length of 100 mm. The gauge length shall be a minimum of two grid apertures long. The gauge length shall be in increments of whole grid apertures. For the purpose of calculating tensile strength, the specimen width shall be considered to be the distance between the outermost ribs of the specimen as measured at the midpoint of those ribs plus the average center to center spacing between ribs.

Source Approval

Section 9-33.4(1) is supplemented with the following:

(November 17, 1997)

Temporary Geosynthetic Retaining Wall

The Contractor shall submit to the Engineer the following information regarding each geosynthetic proposed for use:

Manufacturer's name and current address,
Full product name,
Geosynthetic structure, including fiber/yarn type, and
Geosynthetic polymer type(s).

If the geosynthetic source has not been previously evaluated or included in the QPL, a sample of each proposed geosynthetic shall be submitted to the Olympia Service Center Materials Laboratory in Tumwater for evaluation and testing. A maximum of 14 calendar days will be required for this testing once the samples and required product information arrive at the Materials Laboratory. Source approval will be based on conformance to the applicable values in Tables 7 and 9. Source approval will not be the basis of acceptance of specific lots of material unless the lot sampled can be clearly identified, and the number of samples tested and approved meet the requirements of WSDOT Test Method 914.

Acceptance Samples

Section 9-33.4(3) is supplemented with the following:

(November 17, 1997)

Temporary Geosynthetic Retaining Wall

If the results of the testing show that the retaining wall geosynthetic lot does not meet the properties specified in Table 7 (geotextiles only) and Table 9 (geotextiles and geogrids), the roll or rolls which were sampled will be rejected, and additional sampling and testing will be performed as specified.

Acceptance by Certificate of Compliance

Section 9-33.4(4) is supplemented with the following:

(November 17, 1997)

Retaining Wall

The Contractor shall provide a Manufacturer's Certificate of Compliance to the Engineer, including polymer type in addition to all information as specified, for all quantities of retaining wall geosynthetic material.

Construction Requirements

Section 2-12.3 is supplemented with the following:

(November 17, 1997)

Geosynthetic Wall Construction Requirements

Submittals

The Contractor shall submit to the Engineer, a minimum of 14 calendar days prior to beginning construction of each wall, detailed plans for each wall and as a minimum, the submittals shall include the following:

1. Detailed wall plans showing the actual lengths proposed for the geosynthetic reinforcing layers and the locations of each geosynthetic product proposed for use in each of the geosynthetic reinforcing layers.

2. The Contractor's proposed wall construction method, including proposed forming systems, types of equipment to be used and proposed erection sequence.

3. Manufacturer's Certificate of Compliance, samples of the retaining wall geosynthetic and sewn seams for the purpose of acceptance as specified.

4. Details of geosynthetic wall corner construction, including details of the positive connection between the wall sections on both sides of the corner.

5. Details of terminating a top layer of retaining wall geosynthetic and backfill due to a changing retaining wall profile.

Approval of the Contractor's proposed wall construction details and methods shall not relieve the Contractor of their responsibility to construct the walls in accordance with the requirements of these Specifications.

Wall Construction
The Contractor shall excavate for the retaining wall in accordance with Section 2-09, and conforming to the limits and construction stages shown in the Plans.

The Contractor shall direct all surface runoff from adjacent areas away from the retaining wall construction site.

The Contractor shall begin wall construction at the lowest portion of the excavation and shall place each layer horizontally as shown in the Plans. The Contractor shall complete each layer entirely before beginning the next layer.

Geotextile splices shall consist of a sewn seam or a minimum 300 mm overlap. Geogrid splices shall consist of adjacent geogrid strips butted together and fastened using hog rings, or other methods approved by the Engineer, in such a manner to prevent the splices from separating during geogrid installation and backfilling. Splices exposed at the wall face shall prevent loss of backfill material through the face. The splicing material exposed at the wall face shall be as durable and strong as the material to which the splices are tied. The Contractor shall offset geosynthetic splices in one layer from those in the other layers such that the splices shall not line up vertically. Splices parallel to the wall face will not be allowed, as shown in the Plans.

The Contractor shall stretch out the geosynthetic in the direction perpendicular to the wall face to ensure that no slack or wrinkles exist in the geosynthetic prior to backfilling.

For geogrids, the length of the reinforcement required as shown in the Plans shall be defined as the distance between the geosynthetic wrapped face and the last geogrid node at the end of the reinforcement in the wall backfill.

The Contractor shall place fill material on the geosynthetic in lifts such that 150 mm minimum of fill material is between the vehicle or equipment tires or tracks and the geosynthetic at all times. The Contractor shall remove all particles within the backfill material greater than 75 mm in size. Turning of vehicles on the first lift above the geosynthetic will not be permitted. The Contractor shall not end dump fill material directly on the geosynthetic without the prior approval of the Engineer.

Should the geosynthetic be damaged or the splices disturbed, the backfill around the damaged or displaced area shall be removed and the damaged strip of geosynthetic replaced by the Contractor at no expense to the Contracting Agency.

The Contractor shall use a temporary form system to prevent sagging of the geosynthetic facing elements during construction. A typical example of a temporary form system and sequence of wall construction required when using this form are detailed in the Plans. Soil piles or the geosynthetic manufacturer's recommended method, in combination with the forming system shall be used to hold the geosynthetic in place until the specified cover material is placed.

The Contractor shall place and compact the wall backfill in accordance with the wall construction sequence detailed in the Plans. The minimum compacted backfill lift thickness of the first lift above each geosynthetic layer shall be 150 mm. The maximum compacted lift thickness anywhere within the wall shall be 250 mm.

The Contractor shall compact each layer to 95 percent of maximum density. The water content of the wall backfill shall not exceed the optimum water content by more than 3 percent. The Contractor shall not use sheepsfoot rollers or rollers with protrusions. Rollers which have a mass of more than 2,700 Kg shall be used with the vibrator turned off. The Contractor may use rollers which have a mass of 2,700 Kg or less with the vibrator turned on with the prior approval of the Engineer. The Contractor shall compact the zone within 1 meter of the wall face without causing damage or distortion to the wall facing elements or reinforcing layers by using light mechanical tampers approved by the Engineer.

The Contractor shall construct wall corners at the locations shown in the Plans, and in accordance with the wall corner construction sequence and method submitted by the Contractor and approved by the Engineer. Wall angle points with an interior angle of less than 150 degrees shall be considered to be a wall corner. The wall corner shall provide a positive connection between the sections of the wall on each side of the corner such that the wall backfill material cannot spill out through the corner at any time during the design life of the wall. The Contractor shall construct the wall corner such that the wall sections on both sides of the corner attain the full geosynthetic layer embedment lengths shown in the Plans.

Where required by retaining wall profile grade, the Contractor shall terminate top layers of retaining wall geosynthetic and backfill in accordance with the method submitted by the Contractor and approved by the Engineer. The end of each layer at the top of the wall shall be constructed in a manner which prevents wall backfill material from spilling out the face of the wall throughout the life of the wall. If the profile of the top of the wall changes at a rate of 1:1 or steeper, this change in top of wall profile shall be considered to be a corner.

Tolerances

The Contractor shall complete the base of the retaining wall excavation to within plus or minus 75 mm of the staked elevations unless otherwise directed by the Engineer. The Contractor shall place the external wall dimensions to within plus or minus 50 mm of that staked on the ground. The Contractor shall space the reinforcement layers vertically and place the overlaps to within plus or minus 25 mm of that shown in the Plans.

The completed wall(s) shall meet the following tolerances:

	Permanent Wall	Temporary Wall
Deviation from the design batter and horizontal alignment for the face when measured along a 3-meter straight edge at the midpoint of each wall layer shall not exceed:	75 mm	130 mm
Deviation from the overall design batter per 3 meters of wall height shall not exceed:	50 mm	75 mm

Maximum outward bulge of the face between backfill reinforcement layers shall not exceed:	100 mm	150 mm

Measurement
Section 2-12.4 is supplemented with the following:

(January 5, 1998)
Geosynthetic retaining wall will be measured by the square meter of face of completed wall.

Gravel borrow including haul will be measured as specified in Section 2-03.4.

Structure excavation Class B including haul will be measured as specified in Section 2-09.4 and to the limits shown in the Plans.

Payment
Section 2-12.5 is supplemented with the following:

(January 5, 1998)
"Geosynthetic Retaining Wall", per square meter.
"Temporary Geosynthetic Retaining Wall", per square meter.
"Gravel Borrow Including Haul", per tonne or per cubic meter.
"Structure Excavation Class B Incl. Haul", per cubic meter.

The unit contract price per square meter for "Geosynthetic Retaining Wall" and "Temporary Geosynthetic Retaining Wall" shall be full pay to perform the work as specified, including compaction of the backfill material and furnishing and installing the temporary forming system.

DIVISION 5
SURFACE TREATMENTS AND PAVEMENTS

ASPHALT CONCRETE PAVEMENT

Description
The first sentence of the third paragraph of Section 5-04.1 is revised to read as follows:

(February 5, 2001)
Asphalt concrete Class A, Class B, Class D, Class F, Class G, and asphalt concrete Class Superpave are designated as leveling or wearing courses.

Materials

Section 5-04.2 is supplemented with the following:

(******)
Test Requirements
Section 9-03.8 (2) is supplemented with the following:

Asphalt Concrete Pavement Class Superpave
Aggregate for asphalt concrete pavement Class Superpave shall meet the following test requirements:

The aggregate shall meet the Flat and Elongated shape requirements, measured as percent by weight of flat-elongated in accordance with ASTM Test Method D4791, the percent shall not exceed 10 percent. The ratio shall be 5:1.

2. Malta – Geomembranes, Geosynthetics Clay Liners, Geotextile Protectors

WasteServ Malta Ltd

Closing Date: 3 January 2012 at 12.00 Noon

Date Published: 9 December 2011

SUBJECT: TENDER FOR THE SUPPLY AND DELIVERY OF (LINING SYSTEM) GEOMEMBRANE LINER, GEOSYNTHETIC CLAY LINER AND GEOTEXTILE PROTECTOR FOR THE GHALLIS NON-HAZARDOUS WASTE LANDFILL

Tender Document: WSM 121/2011

The cost of this tender dossier is € 50

6.0 Tender Specifications and Conditions

6.1 Contract Objective

6.1.1 This Tender is for the Supply and delivery of a lining System made up of Geomembrane Lining, Geosynthetic Clay Liner and Geotextile Protector for the Ghallis Non-Hazardous Waste Landfill, managed and operated by WasteServ Malta Ltd.

6.1.2 This tender is divided into three (3) lots.

Lot 1: Geomembrane Liner

Lot 2: Geosynthetic Clay Liner

Lot 3: Geotextile Protector

6.2 Contract Term and Frequency of Use

6.2.1 The hours of work shall be within those allowed by the Planning Permit, as indicated below:

Monday to Friday	0700 – 1700hrs*
Saturday	0700 – 1200hrs*
Sunday and Public Holidays	With the permission the Company's representative

* Working hours may exceed the indicated hours above upon agreement with the Company.

6.2.2 The commencement of this tender shall be upon the issuance of the 'Letter of Acceptance', issued by the WasteServ Malta Ltd..

6.2.3 In the attached Delivery Terms Form bidders are requested to quote their earliest delivery period which shall not exceed 6 weeks from the date of order. Any delivery period stated in the Letter of Acceptance shall be final and binding and failure to meet the stated delivery deadlines shall result in the infliction of penalties as specified in this tender document.

6.3 Services Required

6.3.1 The Contractor is to Supply and Deliver to site the material in quantities as stated in the schedule of Rates/ Prices.

6.3.2 <u>The contractor is required to supply the material ONLY and will NOT be involved with the installation of the Lining System.</u>

6.3.3 <u>The Specification and detailed requirements for supply and other materials within the works, are as presented in Annex II</u>. Details relating to the supply of the Lining System ('Geomembrane Liner', Geosynthetic Clay Liner' and the 'Geotextile Protector') is presented in Section 7.2 of the Specifications in Annex II. This information is for the contractor regarding the supply of the appropriate Lining System material. <u>The Contractor will NOT be carrying out the Installation of the Lining System.</u>

6.3.4 The contractor shall have a supervisor on site during the unloading of all materials of the lining rolls. He is to coordinate with WasteServ staff to check that all materials are delivered with the required UV packaging, straps and manufacturer labeling. Any damaged package shall be refused and the contractor is to remove these from site and replace as necessary.

6.4 Specifications for Lot 1 Geomembrane Liner.

6.4.1 The Specification for the supply of Geomembrane Liner for the works, are presented in Annex II. Details relating to the supply of the Geomembrane liner are presented in Section 5 of the Specifications in Annex II.

6.4.2 The design concepts for the construction works were developed to accord with the lining system requirements set out in the Environmental Impact Assessment on the proposed facility and the permit granted by the Malta Environmental and Planning Authority (MEPA). In Coordance with the permit the materials for the lining system supplied by the tenderer shall be subject to quality assurance as set out in Annex 1. This programme will be supervised by an independent CQA Engineer appointed by Wasteserv.

6.4.3 The Contractor should be aware that the Geomembrane Liner forms one element of the proposed lining system together with Geosynthetic clay liner and Geotextile Protector.

6.4.4 The Geomembrane liner shall consist of 2mm thick, high density polyethylene (HDPE) unlaminated material, textured on both sides. The material should be produced from pure (non-recycled) resins and contain no fillers, plasticisers or additives of any kind with the exception of carbon black. Details of the proposed material shall be submitted with the tender document

6.4.5 The rolls shall have a width of between 5.5 to 6.0 metres

6.5 Specification for Lot 2 Geosynthetic Clay Liner

6.5.1 The design concepts for the construction works were developed to accord with the lining system requirements set out in the Environmental Impact Assessment on the proposed facility and the permit granted by the Malta Environmental and Planning Authority (MEPA). In Coordance with the permit the materials for the lining system supplied by the tenderer shall be subject to quality assurance as set out in Annex 1. This programme will be supervised by an independent CQA Engineer appointed by Wasteserv.

6.5.2 The Specification for the construction works details the requirements for supply of all materials for the works, and presented in *Annex II*. Details relating to the supply of the geosynthetic clay liner are presented in Section 5 of the Specification.

6.5.3 The Geosynthetic clay liner is to be loaded to a height of 65 metres of waste. The contractor is to submit tests and data for the bearing pressures for their proposed material.

6.5.4 The rolls shall have a width of between 5.5 to 6.0 metres.

6.6 Specifications for Lot 3 Geotextile Protector.

6.6.1 The proposed Geotextile shall be subjected to a cylinder test. The test should be carried out in accordance with 'the methodology for cylinder testing of protectors for geomembranes, Environmental Agency March 1998. A copy of the test results shall be submitted to WasteServ Malta Ltd.

6.6.2 The Geotextile Protector shall withstand a loading of 65 metres height of waste at an assumed loading of 1 tonne/m^3

6.6.3 Further details are to be provided by the contractor on the Specification Form.

6.6.4 The Geotextile protector rolls are to be protected from degradation by UV protected packaging. Any rolls which are received with a damaged protective packaging or without proper labelling showing the manufactureer details shall not be accepted and the contractor shall remove these rolls from the site.

6.6.5 WasteServ Malta Ltd is to provide samples of the stone to be used for the drainage layer. The Contractractor shall carry out the necessary tests on the stone. The proposed Geotextile protector shall meet the specifications of the stone as the drainage layer.

6.6.6 The rolls shall have a width of between 5.5 to 6.0 metres.

6.6.7 The design concepts for the construction works were developed to accord with the lining system requirements set out in the Environmental Impact Assessment on the proposed facility and the permit granted by the Malta Environmental and Planning

Authority (MEPA). In accordance with the permit, the materials for the lining system supplied by the tenderer shall be subject to quality assurance as set out in Annex 1. This programme will be supervised by an independent CQA Engineer appointed by Wasteserv.

6.7 Failure to comply with all the specifications and conditions as requested by the Company in this Tender Document, shall render the Tender offer null.

6.8 Once the tender is awarded, the Contractor shall abide with all the Conditions, Specifications and Requirements as detailed in this Tender Document. Failure to abide with this clause shall render the Contractor liable to the penalties stipulated in Clause 8.13.

SPECIFICATION FORMS

These forms (Lot 1, 2 &3) shall be filled in and submitted with the tender document. Failure to fill in the form, or a form with incomplete information, shall disqualify the Tender submission.

Kindly note that a separate distinct specification form (for any lot) shall be submitted for each option given – failure to provide a separate specification form for each option given shall render the tender offer null (see also clause 1.2.7 and 2.8.4).

Whilst every attention has been taken to list all the specifications, it is the Tenderer's sole responsibility to ensure that they include all the necessary details/information to provide the service requested in this tender document.

LOT 1 GEOMEMBRANE LINER

SPECIFICATIONS FORM

(To be completed by the Tenderer or an Authorised Representative)

1. Manufacturer Details	
Name of Manufacturer :	
Address :	
Country :	
Tel No. :	Fax No.:
Email :	

2. Geomembrane Liner Description

3. Geomembrane Liner Specifications		
Thickness		mm
Carbon Black Content	ASTM D1603 (3)	% by mass
Carbon Black Dispersion	ASTM D5596	
Density		kg/m^3
Tensile Properties		
Stress at yield	ASTM D6693 Type IV	N/mm
Stress at break	ASTM D6693 Type IV	N/mm
Elongation at yield	ASTM D6693 Type IV	%
Elongation at break	ASTM D6693 Type IV	%
Puncture Resistance	ASTM D4833	N
Stress Crack Resistance	ASTM D5397	hours

4. Rolls Specifications	
Weight per roll	tonnes
Dimensions of roll	m x m
Total surface area of roll	m^2
Waterproof sheeting	Yes/No
Number of Straps per roll provided	Nr
Straps Strength	kN/m

5. Contractor Details	
Name of Contractor :	
Address :	
Country :	
Tel No. :	Fax No.:
Email :	

LOT 2 GEOSYNTHETIC CLAY LINER

SPECIFICATIONS FORM

(To be completed by the Tenderer or an Authorised Representative)

1. Manufacturer Details	
Name of Manufacturer :	
Address :	
Country :	
Tel No. :	Fax No.:
Email :	

2. Geosynthetic Clay Liner Description

3. Geosynthetic Clay Liner Specifications BS/ISO	
Bentonite	
Montmorilinite Content Methylene Blue Test VDG P69 or XRD	%
Swell Index/Free swell of clay ASTM D 5890	ml
Moisture Content of Clay ASTM D4643 or DIN 18121	%
GCL	
Mass per unit area of finished GCL ASTM D5993 or EN 965	g/m^2
Strip tensile strength ASTM D4595 or ISO 10139	kN/m^2 (M.D.) kN/m^2 (C.M.D.)
Strip Elongation at break ASTM D4595 or ISO 10139	% (C.M.D.) % (M.D.)
Peel strength ASTM D4632	N/10cm

Permeability DIN EN ISO 18130 or ASTM D5887	m/s

4. Rolls Specifications	
Weight per roll	tonnes
Dimensions of roll	m x m
Total surface area of roll	m^2
Waterproof sheeting	Yes/No
Waterproof sheeting description	
Number of Straps per roll provided	Nr
Straps Strength	kN/m

LOT 3 - GEOTEXTILE PROTECTOR

SPECIFICATIONS FORM

(To be completed by the Tenderer or an Authorised Representative)

1. Manufacturer Details	
Name of Manufacturer :	
Address :	
Country :	
Tel No. :	Fax No.:
Email :	

2. Geotextile Protector Description

3. Geotextile Protector Specifications	
CBR puncture resistance (BS EN ISO 12236)	N
CBR puncture displacement (BS EN ISO 12236)	mm
Cone Drop perforation hole diameter (BS EN 918)	mm
Tensile strength (BS EN ISO 10319)	kN/m
Thickness under 2 kPa(BS EN 964 – 1)	mm

4. Rolls Specifications	
Weight per roll	tonnes
Dimensions of roll	m x m
Total surface area of roll	m^2
Waterproof sheeting	Yes/No
Waterproof sheeting description	
Straps per roll provided	Yes/No
Straps Strength	kN/m
Number of straps per roll	Nr

5. Contractor Details	
Name of Contractor :	
Address :	
Country :	
Tel No. :	Fax No.:
Email :	

Failure to comply with all the specifications and conditions as requested by the Company in this Tender Document, shall render the Tender offer null.

Once awarded, the Contractor shall abide with all the Conditions and Specifications as detailed in this Tender Document. Failure to abide with this clause shall render the Contractor liable to the penalties stipulated in Clause 8.13.

Name of Tenderer: ____________________ **Date:** ________________

I.D. No.: ____________________ **Signature:** ________________

SCHEDULE OF RATES – LOT 1

This form shall be filled in and submitted with the tender document. Failure to fill in the form, or a form with incomplete information, or form containing ambiguous financial information (e.g. rates, totals etc) shall disqualify the tendered submission.

KINDLY NOTE THAT A SEPARATE DISTINCT SCHEDULE OF RATES/PRICES SHALL BE SUBMITTED FOR EACH OPTION GIVEN – FAILURE TO PROVIDE A SCHEDULE OF RATES/PRICE FOR EACH OPTION GIVEN SHALL RENDER THE TENDER OFFER NULL. (see also Clause 1.2.7 and 2.8.4)

LOT 1: GEOMEMBRANE				
Item	Description	Total Area of Lining System	Price per m² excluding VAT but incl all relevant expenses, as per tender specifications & conditions	Total amount excluding VAT but incl all relevant expenses, as per tender specifications & conditions
1	Supply & Delivery of Geomembrane Liner	6,000m²	€ /m²	€
2			18% VAT	€
3			Grand Total	€

NB 1. Tenderers submitting their tender offers shall not alter the Schedule of Rates in any way. Failure to comply with this clause shall render the tender offer null.

NB 2. Should tenderers require to submit any additional information, kindly annex the information to the Schedule of Rates or list the information in the space provided on the additional information sheet.

Name of Tenderer: ____________________ Date: ________________

I.D. No.: ____________________ Signature: ________________

SCHEDULE OF RATES – LOT 2

This form shall be filled in and submitted with the tender document. Failure to fill in the form, or a form with incomplete information, or form containing ambiguous financial information (e.g. rates, totals etc) shall disqualify the tendered submission.

KINDLY NOTE THAT A SEPARATE DISTINCT SCHEDULE OF RATES/PRICES SHALL BE SUBMITTED FOR EACH OPTION GIVEN – FAILURE TO PROVIDE A SCHEDULE OF RATES/PRICE FOR EACH OPTION GIVEN SHALL RENDER THE TENDER OFFER NULL. (see also Clause 1.2.7 and 2.8.4)

LOT 2: GEOSYNTHETIC				
Item	Description	Total Area of Lining System	Price per m² excluding VAT but incl all relevant expenses, as per tender specifications & conditions	Total amount excluding VAT but incl all relevant expenses, as per tender specifications & conditions
1	Supply & Delivery of Geosynthetic Clay Liner	6,000m²	€ /m²	€
2			18% VAT	€
3			Grand Total	€

NB 1. Tenderers submitting their tender offers shall not alter the Schedule of Rates in any way. Failure to comply with this clause shall render the tender offer null.

NB 2. Should tenderers require to submit any additional information, kindly annex the information to the Schedule of Rates or list the information in the space provided on the additional information sheet.

Name of Tenderer: ____________________ Date: ______________

I.D. No.: ____________________ Signature: ______________

SCHEDULE OF RATES – LOT 3

This form shall be filled in and submitted with the tender document. Failure to fill in the form, or a form with incomplete information, or form containing ambiguous financial information (e.g. rates, totals etc) shall disqualify the tendered submission.

KINDLY NOTE THAT A SEPARATE DISTINCT SCHEDULE OF RATES/PRICES SHALL BE SUBMITTED FOR EACH OPTION GIVEN – FAILURE TO PROVIDE A SCHEDULE OF RATES/PRICE FOR EACH OPTION GIVEN SHALL RENDER THE TENDER OFFER NULL. (see also Clause 1.2.7 and 2.8.4)

LOT 3: GEOTEXTILE				
Item	Description	Total Area of Lining System	Price per m² excluding VAT but incl all relevant expenses, as per tender specifications & conditions	Total amount excluding VAT but incl all relevant expenses, as per tender specifications & conditions
1	Supply & Delivery of Geotextile Protector	6,000m²	€ /m²	€
2			18% VAT	€
3			Grand Total	€

NB 1. Tenderers submitting their tender offers shall not alter the Schedule of Rates in any way. Failure to comply with this clause shall render the tender offer null.

NB 2. Should tenderers require to submit any additional information, kindly annex the information to the Schedule of Rates or list the information in the space provided on the additional information sheet.

Name of Tenderer: ______________________ Date: __________________

I.D. No.: ______________________ Signature: __________________

3. Montana, USA –

IFB-412010
LIMITED CONSTRUCTION SERVICES - 2011
BEAL MOUNTAIN MINE – DIVERSION CHANNEL CONSTRCUTION
BEAL MOUNTAIN MINE RECLAMATION PROJECT
SILVER BOW COUNTY, MONTANA
September, 2011

CALL FOR BIDS

Montana Department of Environmental Quality (DEQ) is soliciting a Contractor for the Beal Mountain Mine – Diversion Channel Construction. The Beal Mountain Mine is located approximately 10 miles southwest of Fairmont (Gregson) Hot Springs in Silver Bow County, Montana. The project site can be reached from Interstate 90 (I-90) at the junction of Exit 211 (Fairmont Highway and I-90). Take Fairmont highway approximately 2 miles southwest to the junction with German Gulch. Take German Gulch Road approximately 10.5 miles south-southwest to the Beal Mountain Mine area. The site location and diversion channel are shown on the Drawings. This procurement is being treated as an informal solicitation for limited construction services.

PROJECT LOCATION

The Beal Mountain Mine is located approximately 10 miles southwest of Fairmont (Gregson) Hot Springs in Silver Bow County, Montana. The project site can be reached from Interstate 90 (I-90) at the junction of Exit 211 (Fairmont Highway and I-90). Take Fairmont highway approximately 2 miles southwest to the junction with German Gulch. Take German Gulch Road approximately 10.5 miles south-southwest to the Beal Mountain Mine area. The site location and the diversion channel are shown in the contract Drawings.

BID SUBMITTAL

The selected Contractor shall furnish all labor, materials, equipment, and supervision of activities associated with the diversion channel construction, as shown on the DRAWINGS (Exhibit A). If interested, please respond to this informal solicitation by completing the bidder and unit price information on the attached Bid Form (Exhibit B). **Sealed bids will be received at the office of the Montana Department of Environmental Quality, 1100 N. Last Chance Gulch, until 2:00 p.m. on Tuesday, October 4, 2011,** in a sealed envelope marked "Beal Mountain Mine – Diversion Channel Construction", and then publicly opened thereafter. All responses must be identified as responding to limited solicitation IFB-412010. A complete bid will include 1) Bid Form with bid price filled in words and signed, 2) Bid Bond, and 3) Copy of current Montana Certificate of Contractor Registration. All bids not containing these documents will be disregarded. If a contract is awarded, DEQ will select the Contractor and the parties will execute the attached contract.

Bids may be mailed or hand delivered to:

Hand Delivered	Mailed
Department of Environmental Quality Remediation Division Attention: Pebbles Clark 1100 North Last Chance Gulch Helena, Montana	Department of Environmental Quality Remediation Division Bid Box P.O. Box 6969 Helena, MT 59604-6969

Note: Contractor must comply with the requirements for payment of wages set out in Title 18, Chapter 2, Part 4, MCA. The rates applicable to this project will generally be the rates specified for heavy and highway construction. The current Montana Prevailing Wage Book can be downloaded from the State of Montana's website at the address below. Davis-Bacon information can be obtained from http://www.access.gpo.gov/davisbacon/. Contractor agrees to pay required wage rates and comply with all other legal requirements for fringe benefits, hours and working

Payment: Payment for this item will be made in increments of the lump sum price bid. Fifty (50%) percent of the lump sum price bid shall be paid upon submittal of certificates of insurance, approval of all submittals required at the Preconstruction Conference and when Contractor is fully mobilized to the site. The remaining fifty (50%) percent of the lump sum price shall be paid when required site cleanup work is one hundred (100%) percent complete and Contractor has demobilized from the site. **The bid price for Bid Item 1.0 shall not exceed ten (10%) percent of the total bid price.**

Bid Item 2.0 Wattle Removal and Disposal

General: This Work shall consist of the removal and disposal of erosion control wattles from various site locations as shown on the Drawings (Sheet 2). Contractor shall dispose of all wattles at a licensed solid waste disposal facility (i.e. landfill). At no time will onsite burning or burial of the wattles be allowed. Loads transported to the solid waste disposal facility shall be covered prior to transport.

Contractor shall provide all labor, tools, equipment, materials, and incidentals necessary to complete the work as specified.

Measurement: Measurement shall be by the actual number of tons of wattles removed and disposed at the permitted disposal facility, as indicated on the delivery ticket(s) obtained from the disposal facility.

Payment: Payment will be made according to the unit price per ton of Wattle Removal and Disposal, as shown on the Bid Form of the Contract Documents.

Bid Item 3.0 Diversion Channel – Type A

General: This Work shall consist of excavating a channel, compacting the subgrade, placing vegetative backfill material, and Turf Reinforcement Mat (TRM) as shown on the Drawings (Sheets 2, 3, and 4). The diversion channel shall be constructed by cut and fill methods and lined as shown on the Drawings. Contractor shall prevent sediment transport away from the site during construction. Materials and work performed shall comply with Section IV, Technical Specifications, Subsection 202.00, Excavation and Embankment.

1. Preparing the Diversion Channel: Contractor shall excavate approximately 1638 linear feet of Diversion Channel – Type A. The diversion channel shall be excavated to the neat lines and grades as shown on the Drawings (Sheet 3). Excess excavated diversion channel material shall be hauled to a stockpile area within the borrow area, as approved by the Engineer. Diversion channel subgrade shall be compacted in accordance with Section IV, Technical Specifications, Section 202.00, Excavation and Embankment.

2. Vegetative Backfill: Vegetative backfill material shall be excavated within the borrow area as shown on the Drawings (Sheet 2) and hauled to the Diversion Channel -Type A work area using existing roads. Contractor shall coordinate with other onsite contractors regarding vegetative backfill excavation area and haul routes.

   Vegetative backfill material shall be reasonably free of rocks, hard lumps of soil, stumps, or brush. Vegetative backfill material shall be placed within the surface water diversion channel to achieve the neat lines and grades as shown on the Drawings (Sheets 3 and 4).

   Following vegetative backfill excavation, Contractor shall grade the disturbed borrow source area to prevent ponding with excavated cut faces sloped to a maximum 2:1 (H:V).

3. Fertilize and Seed: Following placement of the vegetative backfill material and prior to placement of the turf reinforcement mat, the channel bottom and side slopes shall be fertilized and seeded by broadcast method, in accordance with Bid Item No. 5 Fertilize and Seed.

4. Turf Reinforcement Mat: Contractor shall provide and install Excel PP5-8 Turf Reinforcement Mat (TRM) or equivalent. The TRM shall be installed as shown on the Drawings (Sheet 4) and in accordance with the manufacturer's recommendations and as approved by Engineer. The Turf Reinforcement Mat shall meet or exceed the following properties:

Excel PP5-8 Turf Reinforcement Mat			
Tested Property	**Test Method**	**Value**	**Units**
Tensile Strength	ASTM D6818	20.8 (MD), 17.7 (TD)	Lb / in
Elongation	ASTM D6818	30 (MD), 20 (TD)	%
Mass per Unit Area	ASTM D6566	8.0	Oz / yd2
Thickness	ASTM D1777	8.6	Mm
Light Penetration	ECTC TASC 00197	35	% Open
Resiliency	ASTM D6524	89	%
UV Stability	ASTM 4355	100	%
Porosity	Computed	97	%

Work Included:

- Diversion Channel – Type A excavation;
- Diversion Channel Subgrade Compaction;
- Placement of Vegetative Backfill;
- Fertilize and Seed; and
- Install Turf Reinforcement Mat.

Contractor shall provide all labor, tools, equipment, materials, and incidentals necessary to complete the work as specified.

Measurement: Measurement shall be by the actual number of linear feet of Diversion Channel – Type A, as measure by the Engineer along the channel centerline.

Payment: Payment will be made according to the unit price bid per linear foot for Diversion Channel – Type A, as shown on the Bid Form of the Contract Documents.

Bid Item No. 4: Sediment Detention Basin

General: This Work shall consist of minor excavation of the sediment detention basin, compaction of the subgrade, and placement of riprap to the lines and dimensions as shown on the Drawings (Sheets 2, 3, and 4). The sediment detention basin shall be constructed by cut and fill methods to the lines and grades as shown on the Drawings. Contractor shall prevent sediment transport away from the site during construction. Materials and work performed shall comply with Section IV, Technical Specifications, Subsection 202.00, Excavation and Embankment.

1. Sediment Detention Basin Excavation: The sediment detention basin shall be constructed as shown on the Drawings (Sheet 3 and 4). The sediment detention basin shall be compacted in accordance with Section IV, Technical Specifications, Section 202.00, Excavation and Embankment.

4. Mossel Bay, South Africa - Gabions and Geotextile/Membrane

Mossel Bay Municipality

TENDER 27/2011

SUPPLY AND DELIVERY OF GABIONS AND GEOTEXTILE/MEMBRANE

CLOSING DATE: 8 APRIL 2011	CLOSING TIME: 12:00

NAME OF BIDDER* ....

ADDRESS* ....

....

....

....

TEL NUMBER* ....

FAX NUMBER* ....

TENDER AMOUNT, INCL VAT

(*TO BE COMPLETED BY BIDDER) ....

MBM DATABASE REG NO* ....

Prepared by:
Mossel Bay Municipality
PO Box 25
Mossel Bay
6500
Tel No: +27 (44) 606-5000

1.4 SPECIAL CONDITIONS OF CONTRACT

1.4.1 Introduction

The Mossel Bay Municipality wishes to enter into a contract with a suitable supplier or suppliers for the gabions and geotextile/membrame for a period of one year, from 1 July 2011 to 30 June 2012.

1.4.2 Conditions

1.4.2.1 Materials will be ordered as and when required.

1.4.2 Conditions

1.4.2.1 Material will be ordered as and when required.

1.4.2.1 Bidders are required to indicate the delivery period (refer to section 2) after the receipt of an official order.

1.4.2.3 If the successful (preferred) bidder does not deliver the material within the delivery period as indicated, the bidder must inform the Municipality in writing of delays in delivery.

1.4.2.4 Should the bidder failed to inform the Municipality and the material is not delivered within the delivery period, the Municipality will automatically source the material from the alternative bidder.

1.4.2.5 All prices must be valid for a period of one year, from 1 July 2011 to 30 June 2012.

1.4.3 Alternative Bids

1.4.3.1 Bidders may submit alternative bids. Full details must be supplied

SECTION 2.1: SPECIFICATIONS

2.1.1 Gabions

A galvanized plastic coated mild tensile steel wire in accordance with the SANS 675 specification (mesh wire of 2.7mm and selvedge wire of 3.4mm diameter)

2.1.2 Reno Mattresses

2.0mmØ diameter wire (3.0mmØ O/D for PVC) and in a 60mm x 80mm (nominal) hexagonal mesh configuration

2.1.3 Geotextile/Membrane

(a) Thickness – 1.5mm to 4.4mm
(b) Tearing strength – 280 to 1130N
(c) Bursting strength – 1700 to 5500Kpa

SECTION 2.2: MBD 3.1 PRICING SCHEDULE – FIRM PRICES
NOTE: ONLY FIRM PRICES WILL BE ACCEPTED. NON-FIRM PRICES (INCLUDING PRICES SUBJECT TO RATES OF EXCHANGE VARIATIONS) WILL NOT BE CONSIDERED

IN CASES WHERE DIFFERENT DELIVERY POINTS INFLUENCE THE PRICING, A SEPARATE PRICING SCHEDULE MUST BE SUBMITTED FOR EACH DELIVERY POINT

2.2.1 ALL PRICES MUST INCLUDE VAT

ITEM	PRICE	DELIVERY COST (0 – 25 KM)	DELIVERY COST (25 – 60 KM)
1. Gabions			
(a) 2m x 0.5m x 0.50m			
(b) 2m x 1m x 0.50m			
(c)2m x 1m x 1m			
(d) 2m x 1.5m x 1m			
(e) 4m x 1m x 0.50m			
(f) 4m x 1m x 1m			
(g) 6m x 2m x 0.50m			
2. Reno Mattresses			
Sizes			
(a) 2m x 1m x 0.30m			
(b) 6m x 2m x 0.17m			
(c)6m x 2m x 0.23m			
(d) 6m x 2m x 0.30m			
3. Rock sizes			
(a) 100mm to 250mm			
4. Geotextile/ Membrane			

0 – 25 km: refers to delivery to Mossel Bay Municipal Stores, Hartenbos
25 – 60 km: refers to delivery in Herbertsdale, Vlees Bay, Boggoms Bay, Friemersheim, Ruiterbos, Great Brak River

2.2.2 DELIVERY PERIOD

ITEM	DELIVERY PERIOD
1. Gabions	
(a) 2m x 0.5m x 0.50m	
(b) 2m x 1m x 0.50m	
(c)2m x 1m x 1m	
(d) 2m x 1.5m x 1m	
(e) 4m x 1m x 0.50m	
(f) 4m x 1m x 1m	
(g) 6m x 2m x 0.50m	
2. Reno Matrasses	
(a) 2m x 1m x 0.30m	
(b) 6m x 2m x 0.17m	
(c)6m x 2m x 0.23m	
(d) 6m x 2m x 0.30m	
3. Rock sizes	
(a) 100mm to 250mm	
4. Geotextile/ Membrane	

Specifications

TECHNICAL SPECIFICATION FOR THE CONSTRUCTION OF ONE MULTIPURPOSE GEOTEXTILE REEFS AT MIRYA

1 General

1.1 Abbreviations

The following abbreviations are used in the Bill of quantities.

PS	:	Provisional Sum
LS	:	Lump Sum
BS	:	British Standard
IS	:	Indian Standard
mm	:	millimeters
cm	:	centimeters
Sq.cm.	:	square centimeters
m	:	meters
m^2	:	square meter
m^3	:	cubic meters
T	:	tonnes (1000 kg)
Kg	:	Kilograms
do	:	ditto
Drg.No	:	Drawing Number
Dia	:	Diameter
max.	:	maximum
min	:	minimum
MHHW	:	Mean Higher High Water Level
MLHW	:	Mean Lower High Water
MSL	:	Mean Sea Level
MHLW	:	Mean High Low Water
MLLW	:	Mean Lower Low Water
No(s).	:	number(s)
Rs.	:	rupees

1.2 Standards

Work shall be carried out in accordance with the standards, specifications and bye-laws issued by the Indian Standard Institution. In absence of such specifications or other similar organizations or other relevant standards issued elsewhere the specifications of specified approved manufacturers shall be followed. These shall, in every case, be the latest issue of such standards, specifications, bye-laws, etc. including all revisions, amendments and addenda subsequently issued. In absence of all these specifications instructions from and directions of the Engineer shall be followed.

2 Specific Points To Be Noted:

2.1 All drawings are for basic guideline explaining the scheme. These should be studied in conjunction with the specifications, etc. Any discrepancies should be brought to the notice of the Employer and clarified before the tender is submitted or work is awarded. All clarifications and details explained by the Employer shall be final. These shall be followed and work executed without any additional cost to the contract.

2.2 The tender drawings given are quite extensively detailed, however there may be certain detail which may require further more detailing while actual execution or there may be certain detail which could have been in advertently overlooked. Such details shall not constitute extra items.

The drawings are for guidelines for the Contractor when he works out his quotation. Any item of works not indicated on the drawing but in line with the design and with the thinking shall be deemed to be a part of the contractual obligation and nothing extra shall be paid to the Contractor for the same.

2.3 The successful Tenderer shall have to prepare a statement showing method of working for each item of work for quality assurance and this shall be submitted to the Engineer for their approval prior to start of work. The Contractor is required to prepare and submit detailed working drawings and construction information including:

- Working drawings including detailed site layouts including reference point coordinates
- Topographic and bathymetric survey results including drawings and provision of original survey data.
- Reports and records of all tests for all materials and proposed works to be carried out by the contractor or his manufacturer or supplier or organisation/parties worked under BOQ item 5
- Quantity surveys and drawings and/or records as required for the measurement and payment of the works.
- As built drawings for all permanent works, incorporating all changes or ammendments made in the course of the construction works.

3 Full Provisions

3.1 The various items of work detailed in various parts include all allowance necessary, without extra measurement or charges for meeting the requirements of various components/parts of the contract documents (viz. Technical specifications, drawings and bills of quantities etc) and any or all of the followings unless specifically provided for.

(i) Compliance with all the conditions of the contract including General Conditions of Contract, Bill of quantities, Technical Specifications, Drawings including Notes thereon, Specifications in Standards, Specifications of Manufacturers and relevant Indian Standards wherever applicable. However, in case if there is any discrepancy between drawing and tender, the explanation given by the Engineer shall prevail.

(ii) All labour, materials, tool and plants, equipment, transport which may be required in preparation and for entire execution and completion of the works, including waste of materials, carriage and cartage, carrying in, return of empties, hoisting, setting, fitting and fixing in position.

(iii) Local Conditions; nature of works, local facilities for supply of labour and material, accessibility to site, and all other matters affecting the execution and completion of the works.

(iv) Duties, etc. as stated in Special Condition of Contract.

(v) Supervision Competent supervision of the works.

(vi) Labour : Reasonable terms and conditions of employment, liabilities to pay compensation, wages as per statutory enactments, temporary accommodation, sanitation, compliance with Contract Labour Act.

(vii) Water: Provision of all water required including temporary plumbing and drinking water connections.

(viii) Stores/Offices Provision of all structures such as temporary workshops, stores, offices, labour camps etc. required for efficient execution of the works and their maintenance during execution to approval of the Engineer, their removal thereafter and cleaning up of site on completion of works.

(ix) Precautions against Risks :Precautions to prevent loss or damage from all or any risk, insurance of sheds or any temporary accommodation. Watching and lighting and provisions, pertaining to these as in General Conditions of Contract.

(x) Notices, Fees, etc. Compliance with statutory provisions or regulations and or bye-laws of any local authority and or any public service company or authority affected by the works.

(xi) Setting out the works including all apparatus required.

(xii) Site Drainage: Removal of all water that may accumulate due to springs, sub-soil water, rains, flood/tides and any other causes on the site during the progress of the works or in trenches and excavations.

(xiii)	Work: Execution of work in workmen like manner and provide facilities for inspection etc.
(xiv)	Rectification of bad work :Rectification or removal and reconstruction of any work which (as decided by the Employer or his representative has been executed with unsound or imperfect material or unskilled workmanship or a quality inferior to that contracted for, or lack of supervision whether during construction, or reconstruction or prior to the expiry of the maintenance period.
(xv)	Protection :Responsibility for damage and loss of any building, materials, etc. at the site until handing over.
(xvi)	Cleaning Site and Works :Removal by the Contractor, of all tools, plants and materials from the site; sweeping buildings, washing floors, cleaning joinery, removal of splashes of paint and handing over the whole site in a neat and tidy condition.
(xvii)	Completion :Completing the works to the satisfaction of the Engineer on or before the date of completion.
(xviii)	Difficult Position :Accessibility or otherwise to site, at easy or difficult positions in works.
(xix)	Errors : Rectification of all errors to the satisfaction of the Engineer .
(xx)	Artificial light : All artificial lighting by electric power, when the need arises, for carrying out works.

4 Salient Features of the Project

4.1 The salient features of the project are shown in Table 1 and Figure 1 . Severe erosion is occurring in the north part of the bay and accretion in the south part.

4.2 The overall project design for erosion control at Mirya is:

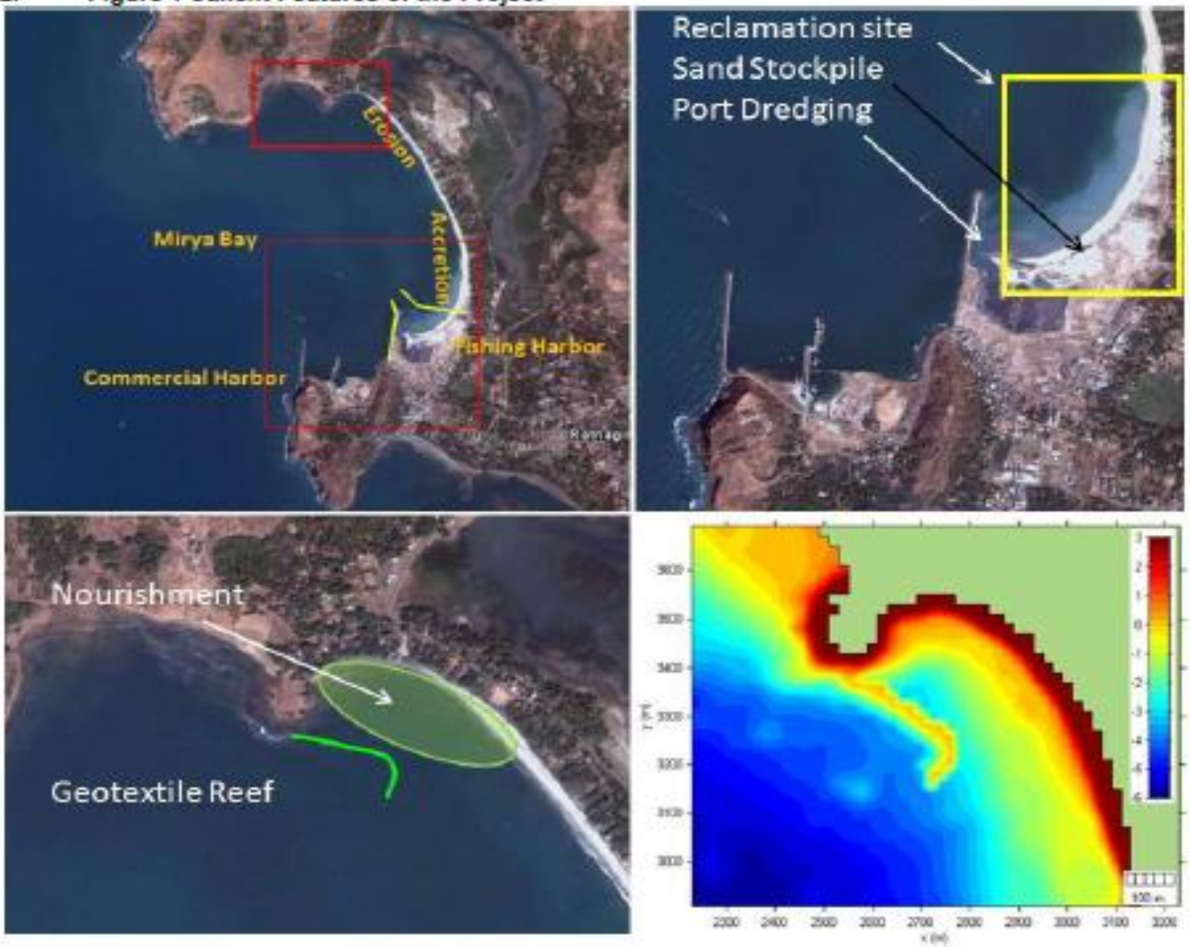
(i) Constructing a small headland "Cup Reef" to trap sand at the northern end of the Bay.

(ii) Beach nourishment using 450,000 m^3 of sand to return to the beach most of sand trapped within and around the existing fishing port, including the sand trapped behind the fish harbor breakwater. Beach nourishment is a separate contract.

1. Table 1 Outline Features for the Reef at Northern Mirya Bay

Parameter	
Distance offshore (m, to MSL from inner-most section of reef)	260
Depth of water (m)	1.5-3 m
Crest height (below LAT) (m)	0
Longshore length of reef (m)	245
Volume of reef (m^3)	11,157
Predicted salient amplitude (m)	100
Estimated length of the accumulation zone	800m

2. **Figure 1 Salient Features of the Project**



4.3 The reef will be positioned approximately 260 m offshore with along-shore lengths of 360 m. The reef is to be constructed of sand filled geotextile containers. The individual container units will be oriented in a shore perpendicular fashion.

4.4 Reef Levels The proposed reef and tidal levels are shown in Table 2

3. **Table 2 Reef and Tidal Levels**

	Level (cd)	
Range	Main stem	Outer arm
MHHW	2.3	
MLHW	2.1	
MSL	1.5	
MHLW	1.2	
MLLW	0.5	

Offshsore 100year significant height Hs	8.3	
Offshore wave 100year H1 1%	13.9	
Depth limiting wave height(m)	2.75	
Bed level(cd) at reef site	-3.0	-2.6
Reef Height (cd)	2.7	2.4
Design Crest level at construction (cd)	-0.3	-0.2
Estimated settlement(m)	-0.1	-0.1
Indicative pancaking 5% (m)	-0.1	-0.1
Estimated final crest level	-0.5	-0.4

9 Procurement of high quality geotextile tubes (boq items nr 2)

9.1 Supply of Geotextile tubes

All geotextile tubes shall be new and undamaged. No materials which are not new or damaged will be accepted. The tubes shall follow the designs as shown in the album of drawings. Sizes must be plus or minus 50mm of the specified size.

- The geotextile must be proven on multipurpose reefs to be strong enough to withstand the long-term forces of the ocean, must be non-woven staple fibre geotextiles and inert in the sea
- The materials must have no environmental impacts, such as pollution or leaching
- The company providing the containers must demonstrate the geotextiles products have been used and proven on offshore submerged structures.
- The company must have proven ability to manufacture the required shapes of the geobags

The tube material must comply with the specifications in Table 5 below and the dimensions shown in the BOQ and drawings. The fabricating facility shall operate under a management system that is 3rd party certified to ISO 9001:2000 standards. The Geotextile Containers shall be fabricated in such a way so as to ensure an efficient and durable container suitable for offshore applications. Containers shall be supplied pre-fabricated, with the practical minimum need for site closures.

The Contractor shall provide a certificate stating the name of the geotextile manufacturer, product name, style, chemical compositions of filaments and other pertinent information to fully describe the geotextile.

The manufacturer's certificate shall state that the furnished geotextile meets Minimum Average Roll Value (MARV) requirements of the specification as evaluated under the manufacturer's quality control program. A person having legal authority to bind the manufacturer shall attest to the certificate.

9.2 Fabrication

Geotextile tubes shall be fabricated by sewing together standard sheets of high strength, non-woven geotextile material to form a tubular shape. The tube will have lengths, widths and circumferences as specified in the BOQ and Table 9 When filled as specified the containers will take on the shape of a flattened ellipse. Prior to installation the Contractor is responsible for all the geotextiles for damage. Defective geotextiles must be destroyed. The number of seams shall be minimised ; the number of seams should not exceed 4 for the 2.7m containers and 3 for the smaller containers.

9.3 Seams

The number of seams and overlaps shall be minimised ; the number of seams should not exceed 4 for the 2.7m containers and 3 for the smaller containers. Sewn seams shall be constructed in such a manner as to provide a minimum strength across the joint not less to that of the parent material, as listed in Table 5. All factory joints shall include chain stitch (secondary) with overlock stitch (primary) reinforcement. Seam yarn should comply with the strength requirements listed in Table 4 below

5. Table 4 Sowing Yarn Requirements

Description	**Unit**	**Value**	
		Primary	**Secondary**
Polymer		Polyester	Polypropylene
Breaking Strain	Kg	20	36
UV Stability	%	70	70

The *Contractor* shall submit independent test results and statements of quality for the proposed yarn and seam to the Engineer, (as described in Section 3, para 1.8) indicating without exception that the proposed geotextile container seams meet with the requirements of the specification.

6. Table 5 Specifications for Geotextile Tubes

Property	Test Method	Unit	Recommended Geotextile
Physical (MARV)[1]			
Polymer			UV Stabilised Polyester + Polypropylene
Mass - Base	AS3706.1	g/m2	1,080
Mass - Coating	AS3706.1	g/m2	800
Thickness @ 2kPa pressure	AS3706.1 (ASTM D5199)	mm	10.5
Mechanical (MARV)[1]			
CBR Puncture Strength	AS3706.4 (ASTM D5199)	N	10,000
CBR Elongation		mm	50
Wide Width Tensile Strength XD/MD	AS3706.2 (ISO 10319)	kN/m	45/90
Wide Width Tensile Elongation (weakest direction)	AS3706.2 (ISO 10319)	%	88
Trapezoidal Tear Strength (weakest direction)	AS3706.3 (ASTM D 4533)	N	900
Seam Strength Efficiency XD/MD		%	>70/>90
Hydraulic (TYPICAL)			
Water Permeability	AS3706.9	m/s	3.0×10^{-4}
Flow Rate	AS3706.9	$l/m^2/s$	27
Pore Size	AS3706.7	μm	<75
Fines retention (Hydrodynamic)	NFG 38.017 (Modified)	%	95
Durability (MARV)[1]			
Resistance to Weathering (UV resistance after 500hrs exposure)	AS3706.11 (ASTM D4355)	%	75
Abrasion Resistance (Strength retained after 80,000 revolutions)	BAW Rotating Drum	%	75

[1]MARV : Minimum Average Roll Value

1. All geotubes must be sand coloured nonwoven composite 2000 gsm, UV Stabilised Polyester + UV stabilised
2. Polypropylene (PP) fibres shall be ;
   a. 100 denier staple fibre
   b. homogenously needle punched into the polyester geotextile substrate to form an integrally formed dual layer

c. There shall be strong physical bonding between the upper and lower layers formed by needle punching
d. Mass of the 100 denier PP layer shall be not less than 800 gsm

3. Manufacturer shall provide evidence of UV stabilisers added to polypropylene fibre such that they meet the maximum, extra out-door level 4 requirements
4. Suppliers shall provide full details of working seam and performance values in both machine direction (MD) and cross machine direction (XD)

9.4 Samples of the Geotextile Material

The bidder is required to submit four clearly marked samples of the geotextile material proposed for the Geotextile tubes. Each sample should be clearly marked and supplied with the suppliers name and suppliers own specification and independent certification. Each sample should have a minimum dimension of 40cm x 40cm (as described in Section 3, para 1.7) .

9.5 Independent Certification

The bidder is required to submit samples of material including a sample of seam to an independent international laboratory . The name and address of the laboratory will be advised and the bidder will be required to submit a sample of size as advised by the laboratory. The bidder is required to pay for all the costs of the independent testing including the courier of the sample, testing and preparation of the report. The bidder is required to submit a receipt of the sample and the laboratory test results as a part of the bid from the testing laboratory as a part of the bid documents. More details on independent certification is given in Section 3 Evaluation and Qualification Criteria

9.6 Fastening

To provide fastening locations for the bags, webbing straps will be sewn on either side of the geotubes at 2.5m intervals

9.7 Ports

Tube filling ports shall be placed at intervals not exceeding 7.6m (25 feet) along the crest of the tube. Each port should consist of a tube at least 1.5m and circumference slightly larger than the filling pipe. The port sleeves shall be fabricated of the same material as the tubes and shall have drawstring systems to ensure closure.

9.8 Delivery

Geotextiles for tubes shall be delivered only after the the Engineer has received and approved the required submittals. Geotextiles shall be labeled, shipped, stored, and handled in accordance with ASTM D 4873 and as specified herein. Each segment of geotextile tube shall be wrapped in an opaque and waterproof layer of plastic during shipment and storage. The plastic wrapping shall be placed around the geotextile in the manufacturing facility and shall not be removed until deployment.

Each packaged segment of geotextile tube shall be labeled with the manufacturer's name, geotextile type, lot number, roll number, and roll dimensions (length, width, and gross weight). Appropriate handling equipment and techniques, as recommended by the manufacturer and as mentioned in the submittals and approved by the Engineer shall be used.

Geotextile and/or plastic wrapping damaged as a result of delivery, storage, or handling shall be replaced, as directed by the Engineer, at no additional cost to the government. Minor damage can be repaired subject approval by the Engineer.

9.9 Handling

Geotextiles shall not be handled with hooks, tongs, or other sharp instruments. Geotextiles shall not be dragged along the ground. Any surface upon which the geotextile may rest or from which it may be deployed shall be leveled and prepared to a relatively smooth condition free of ruts, erosion rills, obstructions, depressions or debris, or protrusions) greater than 150 mm in height (6 in.) that could snag and tear the fabric. A shallow "swale" or "cradle" may be constructed under low-water conditions on the tube center line to prevent geotextile tubes from rolling during filling operation.

9.10 Storage.

Geotextile tubes shall be: (a) stored in areas where water cannot accumulate, (b) elevated off the ground, and (c) protected from conditions that will affect the properties or performance of the geotextile. Geotextiles shall not be exposed to temperatures in excess of those recommended by the manufacturer or 140°F (60°C), whichever is less. Outdoor storage shall not be for periods that exceed the manufacturer's recommendations or 2 months, whichever is less. Geotextiles shall not be exposed to direct sunlight prior to deployment for more than 14 days. Geotextiles that are exposed to direct sunlight for more than 14 days will be replaced at no cost to the government. Geotextiles must be protected from damage from rats, insect or other form of potential damage.

Basis of Payment for Geotextile Tubes will be based on a lump sum for each bag as specified including delivery to the Contractors shore site. Payment will be authorised based on a certificate of inspection from the Engineer and submission of manufacturers certificates for each geotube. Payment will be made based on 70% of unit rate on delivery to the shore site. An additional 20% will be payable once each individual geotube has been put in place and filled to the correct specifications. The final 10% will be made once all the geotextile tubes have been correctly installed on the site.

10 Supply and Installation of Geo Mat (boq item 3)

The geo mat must be of a non woven composite material. The composite must be of a laid geogrid made of stretch monolithic polypropylene (PP) flat bars with welded junctions and mechanical bonded filter geotextile welded within the geogrid structure. The material must comply with the specifications as shown in Table 6 below

7. Table 6 Specifications for Geo Mat

Property	Test method*	Unit	
Geogrid			
Raw material	-	-	Polypropylene (PP), white
Mass per unit area	EN ISO 9864	g/m²	240
Max. tensile strength, md / cmd**	EN ISO 10319	kN/m	≥ 40 / ≥ 40
Elongation at nominal strength,md / cmd**	EN ISO 10319	%	≤ 8 / ≤ 8
Tensile strength at 2% elongation,md / cmd**	EN ISO 10319	kN/m	16 / 16
Tensile strength at 5% elongation,md / cmd**	EN ISO 10319	kN/m	32 / 32
Aperture size,md x cmd**	-	mm x mm	Approx. 31 x 31
Production specific elongation	-	%	0
Geotextile			
Raw material	-	-	Polypropylene (PP), white
Mass per unit area	EN ISO 9864	g/m²	150
Max. tensile strength, md / cmd**	EN ISO 10319	kN/m	6.0 / 10.0
Elongation at max. tensile strength, md / cmd**	EN ISO 10319	%	50 / 30
Puncture force	EN ISO 12236	N	1,670
Displacement at static puncture strength	EN ISO 12236	mm	30
Detector tested	-	-	Yes
Roll dimensions, width x length	-	m x m	4;75 x 100

**based on, **md = machine direction, cmd = cross machine direction*

Joins of geomats must have an overlap of not less than 1.5 metres. Geomats must be fixed to the geotubes using the web ties on the geotubes. The Contractor must submit details of the fixing and joining arrangements of the geomats to the geotubes to be approved by the Engineer. Outer edges of the geomats must be hemmed using high strength nylon. Temporary fixing of the geomat is required and the Contractor must submit details of this for approval by the Engineer.

<u>Basis of Payment for Geomat</u> will be based on the area in square metres of geomat measured after cutting and joining. The price includes supply, transport, installation and hemming and joining and supply and fixing of ropes and attachments.. The measurement will be based on the area of the final joined and material. No payment will be made for join overlaps or hems of the individual sections. No payment will be made for cutting and loss of material not used.

Payment will be authorised based on a certificate of inspection from the Engineer and submission of manufacturers certificates for each geomat. Payment will be made based on 50% of unit rate on delivery to the site. An additional 30% will be made once the once the geomat has been correctly placed on the seabed. The remaining 20% will be paid once the geomat and all the filled geotextile tubes have been correctly installed on the site

10. Table 9 Schedule of Geotextile Bags

Length (m)	Breadth (m)	X-sectional area (m2)	Filled volume (m3)	Number of bags	Total volume (m3)
9.3	1.6	1.3	12.09	1	12.09
10.4	1.6	1.3	13.52	1	13.52
15.5	1.6	1.3	20.15	1	20.15
28.8	1.6	1.3	37.44	1	37.44
29.7	1.6	1.3	38.61	1	38.61
30.2	1.6	1.3	39.26	1	39.26
33.8	1.6	1.3	43.94	1	43.94
36	1.6	1.3	46.80	17	795.60
27	5.9	11.4	307.80	1	307.80
18	5.9	11.4	205.20	11	2,257.20
27	6.1	13.9	375.30	9	3,377.70
18	6.1	13.9	250.20	4	1,000.80
27	4.8	8.5	216.00	2	459.00
18	4.8	8.5	144.00	18	2,754.00
				69	11,157.11

Supplementary Information

Mirya bay is located 8 km north of Ratnagiri, the west coast District town in the state of Maharashtra,, India. Ratnagiri is about 450 km from Mumbai, Maharashtra, India.

The proposed reef is offshore of the Mirya beach.

The Project Management Unit (PMU), office of the Engineer and employer are at Mumbai and Ratnagiri. Whenever required, the contractors representative is expected to attend meetings with PMU at site, PMU offices at Mumbai and Ratnagiri.

Annexure L – GRI GT13(a) Specification Augmenting AASHTO M288-06 Geosynthetic Specification for Roads

SI METRIC UNITS

Table 2(a) - Geotextile Properties Class 1 (High Survivability)(1)

Property	ASTM Test	Unit	Elongation < 50%	Elongation ≥ 50%
Grab Tensile Strength	D 4632	N	1400	900
Trapezoid Tear Strength	D 4533	N	500	350
CBR Puncture Strength	D 6241	N	2800	2000
Permittivity	D 4491	sec-1	0.02	0.02
Apparent Opening Size	D 4751	mm	0.60	0.60
Ultraviolet Stability(2)	D 4355	% Ret. @ 500 hrs	50	50

Table 2(b) - Geotextile Properties Class 2 (Moderate Survivability)(1)

Property	ASTM Test	Unit	Elongation < 50%	Elongation ≥ 50%
Grab Tensile Strength	D 4632	N	1100	700
Trapezoid Tear Strength	D 4533	N	400	250
CBR Puncture Strength	D 6241	N	2250	1400
Permittivity	D 4491	sec-1	0.02	0.02
Apparent Opening Size	D 4751	mm	0.60	0.60
Ultraviolet Stability(2)	D 4355	% Ret. @ 500 hrs	50	50

Table 2(c) - Geotextile Properties Class 3 (Low Survivability)(1)

Property	ASTM Test	Unit	Elongation < 50%	Elongation ≥ 50%
Grab Tensile Strength	D 4632	N	800	500
Trapezoid Tear Strength	D 4533	N	300	180
CBR Puncture Strength	D 6241	N	1700	1000
Permittivity	D 4491	sec-1	0.02	0.02
Apparent Opening Size	D 4751	mm	0.60	0.60
Ultraviolet Stability(2)	D 4355	% Ret. @ 500 hrs	50	50

Notes:
(1) All values are MARV except UV stability; it is a minimum value and AOS which is a maximum value.
(2) Evaluation to be on 50 mm strip tensile specimens after 500 hours exposure.

Table 3 - Required Degree of Survivability as a Function of Subgrade Conditions, Construction Equipment and Lift Thickness
(Class 1, 2 and 3 Properties are Given in Table 1 and 2; Class 1 + Properties are Higher than Class 1 but Not Defined at this Time)

	Low ground-pressure equipment ≤ 25 kPa (3.6 psi)	Medium ground-pressure equipment > 25 to ≤ 50 kPa (>3.6 to ≤ 7.3 psi)	High ground-pressure equipment > 50 kPa (> 7.3 psi)
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level so that any shallow depressions and humps do not exceed 450 mm (18 in.) in depth or height. All larger depressions are filled. Alternatively, a smooth working table may be placed.	Low (Class 3)	Moderate (Class 2)	High (Class 1)
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 450 mm (18 in.) in depth or height. Larger depressions should be filled.	Moderate (Class 2)	High (Class 1)	Very High (Class 1+)
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than ± 150 mm (6 in.) above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High (Class 1)	Very high (Class 1+)	Not recommended

*Recommendations are for 150 to 300 mm (6 to 12 in.) initial lift thickness. For other initial lift thicknesses:
- 300 to 450 mm (12 to 18 in.): reduce survivability requirement one level;
- 450 to 600 mm (18 to 24 in.): reduce survivability requirement two levels;
- > 600 mm (24 in.): reduce survivability requirement three levels

Note 1: While separation occurs in every geotextile application, this pavement-related specification focuses on subgrade soils being "firm" as indicated by CBR values higher than 3.0 (soaked) or 8.0 (unsoaked).

Source: Modified after Christopher, Holtz, and DiMaggio

The Second China International Exhibition on Solid Waste
Treatment Technology and Equipment, Beijing, 2003

US Regulations on Solid Waste Containment Facilities

Aigen Zhao, PhD, PE
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Introduction

Over 600 million metric tons of solid waste was generated within the USA last year. These solid wastes (both hazardous and non-hazardous) must be properly disposed of in an environmentally safe manner. Despite many of the innovations and technology advancements in recycling and composting of solid waste materials, landfilling is still the most economic means to dispose of solid waste. This will be especially true for developing countries. This paper presents USA regulations for solid waste landfill liner and cover systems, for the readers to assess and compare with their local practice. This paper excludes such solid wastes as radioactive materials that are regulated separately.

USA Regulatory Requirements on Solid Waste Landfills

In the United States, all landfills are regulated at the federal level under the Resource Conservation and Recovery Act (RCRA) promulgated in 1976. RCRA wastes include (1) hazardous wastes, (2) municipal solid wastes (MSW), and (3) industrial wastes not covered under other land disposal restrictions. RCRA wastes do not include radioactive wastes or polychlorinated biphenyls (PCB) wastes.

Hazardous Waste Disposal

Since 1984, hazardous waste landfills are regulated under RCRA Subtitle C. Under Subtitle C, hazardous waste landfills are required to have two liners and two lateral drainage systems. A hazardous waste is defined as follows:

1) a listed (40 CFR251) material defined as a hazardous waste; or
2) waste mixed with or derived from a hazardous waste; or
3) waste not excluded (some wastes, such as municipal solid waste, are specifically identified and excluded as non-hazardous waste); or
4) waste possessing any one of four characteristics (a) ignitability (flash point 60 C°), (b) corrosivity (2>Ph>12); (c) reactivity; and (d) toxicity as determined by the toxicity characteristic leaching procedures (TCLP) test.

For hazardous waste, a double liner system with leak detection capability is required, as shown in Figures 1 and 2. The lower liner system is always a composite liner consisting of a geomembrane over a compacted clay liner(CCL).

Double-liner systems have proven to provide the greatest environmental protection for municipal solid waste (MSW) and hazardous waste landfills. Currently in the United States, 100% of hazardous waste and 24% of municipal solid waste landfills require double–lined systems (Koerner, 2000). The leakage detection system (LDS) is arguably one of the most critical components of double-lined landfills, and must designed to satisfy the following objectives: (1) provide rapid detection of a major breach in the primary liner system, and (2) limit the head acting on the secondary liner to less than the thickness of the LDS. An acceptable level of leakage (ALR) into the LDS is established during the permitting process. This rate of leakage must not saturate the LDS, that is produce a head greater than the thickness of the LDS. To minimize the impact of excessive leakage into the LDS, many hazardous waste landfills use a composite barrier in the upper (primary) liner system. This generally consists of a geomembrane over a geosynthetic clay liner (GCL). Federal regulations outline construction quality assurance (CQA) testing that must be performed during the construction of each landfill cell.

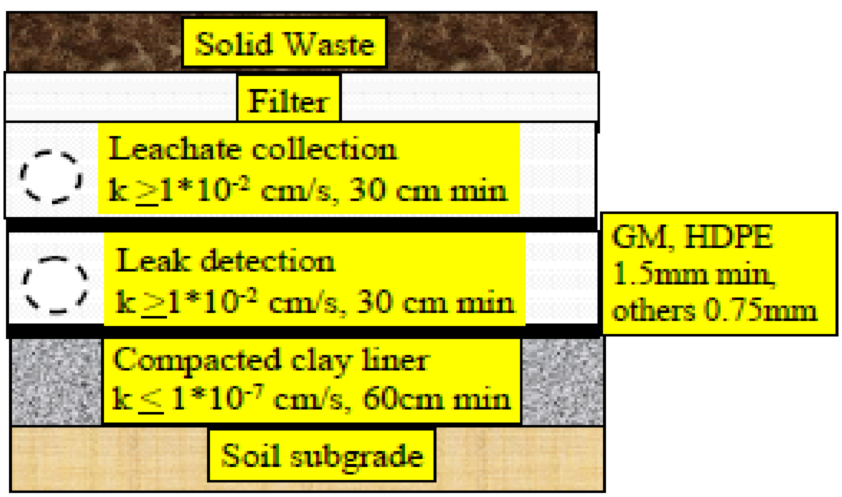

Figure 1. U.S. EPA MTG Subtitle C-Hazardous Solid Waste (Liner System)

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For landfill closures, current Federal regulations require that the final covers on RCRA Subtitle C landfills must limit the infiltration through the cover to a rate less than the leakage rate of the liner system (40 CFR 264.310). Typical RCRA Subtitle C final covers incorporate a composite barrier consisting of a geomembrane and 600 mm of $1*10^{-7}$ cm/sec CCL. Note RCRA Subtitle C final covers rarely have slopes greater than 5-8% such that stability problems are not a concern.

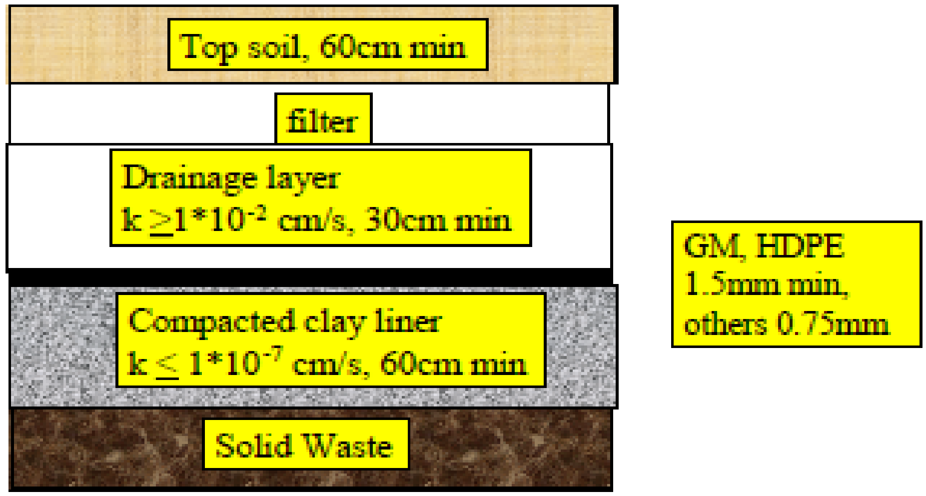

Figure 2. U.S. EPA MTG Subtitle C-Hazardous Solid Waste (Cover System)

<u>MSW Disposal</u>

There are two common types of non-hazardous solid wastes, municipal solid waste (MSW) and industrial waste. MSW landfills are regulated under RCRA Subtitle D. Since 1993, this has required that all new MSW landfills be lined with a single composite liner consisting of a geomembrane plus a clay liner(CCL or GCL). Note that individual States can set more stringent requirements than established by Federal law. Currently, seven States require double liner systems for MSW landfills. While industrial waste regulations are still ambiguous, most States are requiring these facilities to meet RCRA Subtitle D criteria.

Minimum Technology Requirements for Subtitle D non-hazardous wastes liner systems are shown in Figure 3. This minimal liner system is composed of (from bottom up):

1. Prepared soil subgrade foundation layer
2. A compacted clay liner (CCL) on the soil subgrade, with a minimum thickness of 600mm and maximum hydraulic conductivity of $1*10^{-7}$ cm/sec;
3. A geomembrane of 0.75mm or thicker, with a minimum thickness of 1.5mm for HDPE geomembranes. A geomembrane over a CCL forms a composite liner;

4. A leachate collection layer with a minimum thickness of 300mm and minimum hydraulic conductivity of $1*10^{-2}$ cm/sec;
5. A leachate removal system, i.e., perforated pipe network, is located within the leachate collection layer. The maximum head of leachate on the liner system must be less than 300mm; and
6. A filter between the leachate collection and removal system and the waste.

Minimum Technology Guidance concurrently developed by the Federal government provide a minimum program of construction quality assurance (CQA) testing that must be performed during the construction of each landfill cell. The CQA document, commonly referred to as the certification document, must be submitted to the permit authority before the landfill can be operated. The individual States are the permit authority for all MSW landfills.

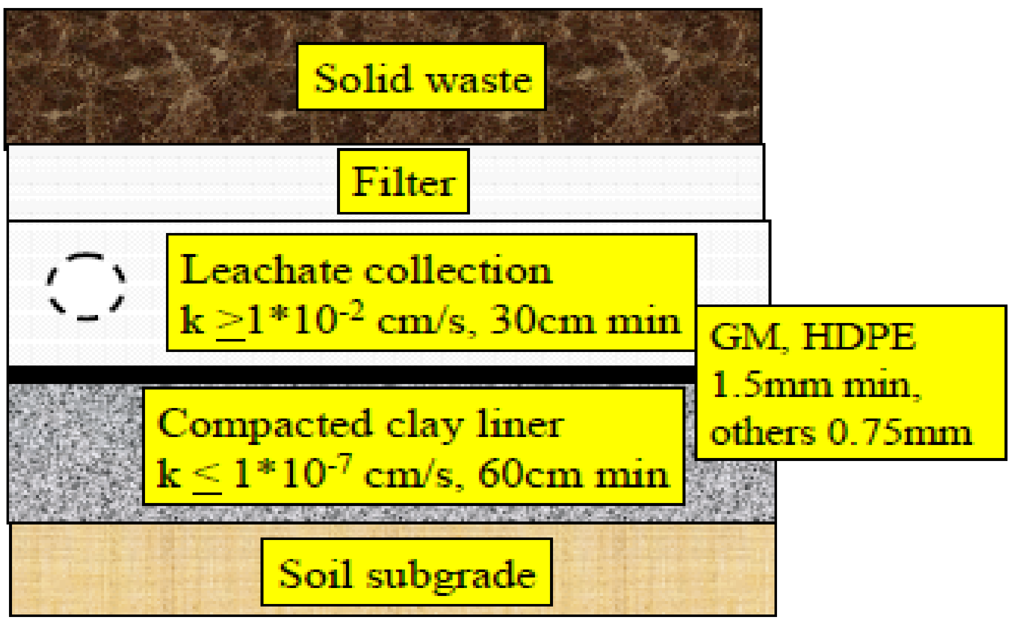

Figure 3. U.S. EPA MTG Subtitle D-Nonhazardous Solid Waste (Liner System)

For landfill closures, current Federal regulations require that a final cover be constructed within one year after the last lift of waste is placed. The final covers on RCRA Subtitle D landfills must limit the infiltration through the cover to a rate less than the leakage rate of the liner system (40 CFR 258.60). The EPA interpreted this requirement by requiring that final covers include a composite barrier consisting of 450mm of a compacted soil barrier having a hydraulic conductivity of less than $1*10^{-5}$ cm/sec overlain by a geomembrane. A nominal 150mm erosion control layer placed over the geomembrane completed the minimum regulatory profile (see Figure 4). This profile is considered a minimal system. In reality this 150mm erosion control layer is inadequate for survival

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and is rarely incorporated alone. A typical erosion control layer must provide sufficient water storage capacity to allow the cover vegetation to survive periods of drought. Except for arid and semi-arid regions of the USA, this typically requires a 450-600mm layer of vegetative support soil beneath a 150mm top soil layer.

Additionally, RCRA Subtitle D final covers are commonly constructed having 25% to 33% slopes. Stability requirements at these slopes require the addition of a lateral drainage layer immediately atop the geomembrane to eliminate excess pore water pressures cause by precipitation induced seepage,

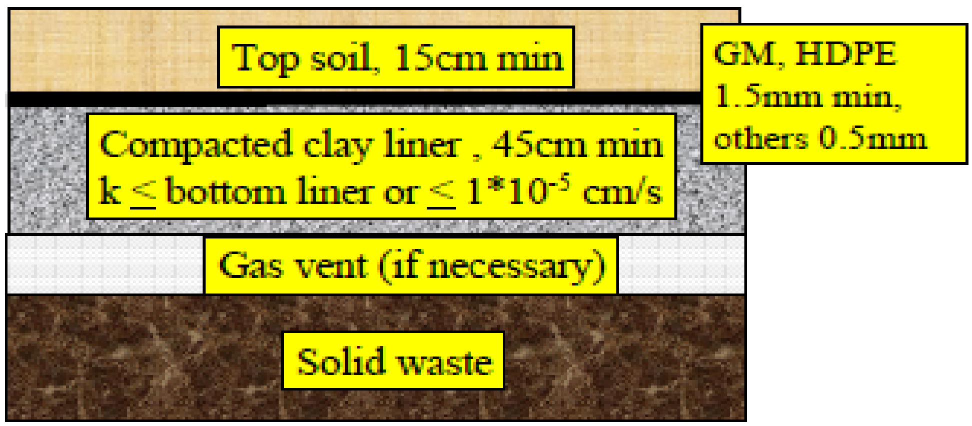

Figure 4. U.S. EPA MTG Subtitle D-Nonhazardous Solid Waste (Cover System)

20-Year Perspective

With more than twenty years of liner installation experience, the current liner trends in the USA are of interest to those beginning such work. Key liner trends during this time frame include the following:

1) HDPE smooth and textured liner systems have dominated the RCRA landfill applications. Textured HDPE liners have been able to achieve excellent slope stability in steep canyon facilities and when the waste height is significant (>100m).
2) The quality of geomembrane installation has improved dramatically in part due to more sophisticated double-wedge welding machines that produce quality seams.
3) Composite liners incorporating a GCL have become as popular as those that incorporate a CCL. Performance data actually shows that the GCL composite liners outperform the CCL composite liners.
4) The hydraulic capacity required of the geosynthetic lateral drainage composites has increased dramatically in both liner and final cover applications. This increase has been the result of failures and abnormal

weather patterns. Requited transmissivities are now routinely in the 10^{-3} $m^3/s/m$ range.

Current development is heavily focused on improving the design and geosynthetic materials used in final closures systems placed over the landfills. MSW landfills, in particular, commonly require these covers be placed on 33% slopes with a required service life of 30+ years. As with liner systems, a new generation of geosynthetics will be developed to solve these problems economically.

Concluding Remarks

US regulations for solid waste landfills were implemented before all geosynthetic components now used in their construction were available. Fortunately, the geosynthetic manufacturers have been able to successfully respond to the challenge and developed components that exceed the industry's original expectations. Their success has allowed greater flexibility in landfill design and an increasing economy in landfill construction. Today's landfill liner system cost less to construct than those built 20-years ago. Few industries can make that claim.

China has the opportunity to learn from the success (and failures) of the last twenty years of landfill construction in the USA. With the development of their geosynthetics industry, there is no reason that they cannot improve upon the performance and economy of the landfills constructed to date.

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Annexure N – Meetings with User Ministries – Minutes

Meeting with MoRTH

Meeting Information

Meeting Date/Time:	May 22, 2013 11.30am	Meeting Facilitator:	Gaurav Sangtani
Location:	Transport Bhavan, 1 Parliament St, New Delhi		
Presentation Link:	N/A		
Meeting Attendees	Shri Rohit Kumar Singh (JS, MoRTH - Highways) Shri K C Varkeyachan (Chief Engineer, MoRTH) Shri S K Nirmal (Supritendant Engineer, MoRTH) Shri Gaurav Sangtani (Consultant. Accenture)		
Reference document	Letter dated April 22, 2013 from the Ministry of Textiles, Office of the Textile Commissioner		

Discussions and Decisions

No.	Subject	Discussions	Action/Issue
1	MoRTH Book of Specifications (Orange Book)	The lack of updated information in the Orange Book was highlightighted, specifically: • The inclusion of only five geosynthetic products applicable to road works as opposed to the eight products identified in the Accenture report. • The lack of complete inclusion of various applications and functions of the products already included in the Orange Book was pointed out as well.	**a) It was mentioned that the revised version of the MoRTH Book of Specifications i.e. Orange Book is due to be published in the near future.** **b) The ITTA and its members were credited with coordinating with the IRC to ring in the required changes in products as well as applications and specifications.** **c) The Ministry of Textiles and ITTA were welcomed to bring any further updates to the office of the Chief Engineer if there were any shortcomings in the upcoming revision of the Orange Book**
2	Mandatory use of Geosynthetics in Pavement Overlays	It was highlighted that certain countries of states like California (USA) have made the use of geosynthetics mandatory for Pavement Overlays. The possibility of implementing such an initiative in India was discussed.	**a) There was lack of conviction on the true beenfit provided by the use of Geosynthetics in Pavement Overlays. It was reasoned that there is a reason why it is not mandatory in more countries/states.** **b) Furthermore for a product providing direct monetary benefit to user agencies/concessionaires, the regulatory support of making it mandatory was thought to be**

			unnecessary. c) The consultant highlighted that due to the selection criterion heavily in favour of lowest bids, there are reservations in use of Geosynthtics.
3	The SORs (Schedule of Rates) and Geosynthetics	a) It was highlighted that only 13 states in the country have at least one Geosynthetic product present in their SORs.	**a) Reason for this was thought to be the lack of conviction on the part of the States in the quality control of Geosynthetics. The sentiment is if there are more testing facilities then States would be able to ensure quality of products being deployed.**
		b) The possibility of the MoRTH sending communication to various states requesting them to include Geosynthetics within their SORs was mooted as well.	**b) This same sentiment as mentioned was cited as a reason why a communication from the MoRTH to the states was not probable.**
4	**Conclusion**	**Next steps**	**a) The suggestions made in the reference documents will be considered, which should address most of the concerns raised.**

Meeting with the Ministry of Railways

Meeting Information

Meeting Date/Time:	May 22, 2013 3.30pm	Meeting Facilitator:	Gaurav Sangtani
Location:	Rail Bhavan, Raisina Rd, New Delhi		
Presentation Link:	N/A		
Meeting Attendees And Distribution:	Shri S K Jain (Member Engineering) Shri Alok Kumar (Executive Director, Civil Engineering, Min. of Railways) Shri Gaurav Sangtani (Consultant, Accenture)		
Reference document	Letter dated April 22, 2013 from the Ministry of Textiles, Office of the Textile Commissioner		

Discussions and Decisions

No.	Subject	Discussion	Action/Issue
1	Geosynthetics in the Railway Works Manual	The lack of updated information in the Railway Works Manual with regards to Geosynthetic products and their applications was highlightighted	• **Shri S K Jain agreed that there are signifincant benefits on use of geotextile. He concurred that if Geotextile is used between aggregate and sub-grade, the Blanket layer thickness can be reduced by 15 cm, which leads to significant savings.** • **Shri Alok Kumar mentioned his willingness to work with Ministry of Textiles and ITTA to on the suggestions highlighted in the reference letter.**
2	Manner of procurement and the SORs (Schedule of Rates)	The inclusion within SORs and the best practice for procurement was discussed	• **Shri S K Jain mentioned that he had experience of using Geotextiles in his prior postings and used method of procuring directly from manufacturers and then supplying to contractors/concessionaires..** • **It was understood that this can be a preferable manner of deployment as quality and cost could be controlled.** • **The SORs would in such a case include implementation costs for Geosynthetics and not for the material itself.**
3	**Conclusion**	**Next steps**	• **The suggestions made in the reference documents will be considered for incorporation in various manuals in coordination with Ministry of Textiles.**

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Presentation to User Ministries to Discuss Recommendations

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Qualitative benefits of Geosynthetics need to be espoused fully

Quantitative benefits of Geosynthetics have been broken out into different facets

Sr #	Application	Cost of Geotextile implementation (A)	Up Front Savings (B)	Lifetime Savings (C)	Net Savings (D)	ROI (D/A)
1	Geotextiles in Road Subgrade Reinforcement per kilometre	₹375,000	₹ 15,55,688	₹ 49,17,354	₹ 64,73,042	1762%
2	Geomembrane & Geotextile in Canal Lining per kilometre	₹ 4,93,00,000	- ₹ 2,95,00,000	₹ 4,35,00,000	₹ 1,40,00,042 (+₹3,11,00,000 /km in tangible indirect benefits)	28%
3	Geocells in Road Subgrade Reinforcement per kilometre	₹16,12,500	₹ 3,18,187	₹ 31,84,354	₹ 35,03,042	217%
4	Geogrid in Reinforced Soil Wall (8m height) per metre	₹14,800	₹ 8,153	₹ 0	₹ 8,153	55%
5	Geotextiles & Geomembranes in Landfills for 5.9 Mn cubic metre *US Case Study	$47,414	$201,864 (savings through sales of additional sand excavated & decrease in cost for liner)	$773,625	$975,489	2057%

Qualitative benefits of Geosynthetics need to be espoused fully

There is lack of clarity on qualitative ancillary benefits of Geosynthetics

- GCLs and Geomembranes in landfill applications prevent toxification of soil and ground water
- Geotextiles in road reinforcement leads to reduction in travel time, pollution due to idling, etc.
- Geomembranes in canal linings help prevent loss of water and result in increased agricultural productivity as well as increased employment along with prevention of water logging and loss of fertile land.
- Geocells in road laying - reduction in travel time, reduction in pollution due to idling, etc.

Insight into international bidding procedures

Key issues in Indian bidding procedures

- Mostly lowest cost selection criteria used
- This leads to cost cutting and does not promote use of progressive technology

Recommendations as per the final report

- Proposed DFOT (Design Build Finance Operate Transfer) model of tendering
- Value engineering contracts: Section 48.202 - FAR 52.248-3 of the US Federal Acquisition Regulations for construction states that all contracts over $100,000 are to provide for value engineering where the contractor is entitled to a share of up to 55% of the savings

Incorporated in section 9.5 of the report

Current impact of inclusion of Geosynthetics in SORs

Geosynthetics are not included in majority of State SORs

- Current inclusion is only in 14 states' Schedule of Rates
- This inclusion consists of only 1-2 products within Geosynthetics, of limited specification variety

SOR Inclusions

Recommendation/ Observation in the final report

- Current inclusion is so basic in nature that is has done nothing to promote use of Geosynthetics within those states. For example –
  (i) Jharkhand does not state the specification
  (ii) Karnataka only includes 200 & 250 gsm Geotextile
- No single point for estimating usage in a State
- Revised SoR product list provided

Updated product list with specification incorporated in section 9.3 of the report

Inclusion in MoRTH Orange Book is essential

Inadequate inclusion of Geosynthetics in departmental guidelines

Recommendation	Next Steps
Revision of MoRTH Orange Book Orange Book Revisions	• 3 more products have been suggested to be included for road applications in Section 700 • Detailed updates have been provided for Section 300, 400, 500 and 600 of Orange Book • Specifications suggested in section 9.6.1 of the report for inclusion in Orange Book • Reminder communication to be sent in Dec' 2013

Incorporated in section 9.2 of the report

Inclusion in handbooks for construction of railways, canals and landfills is needed

Inadequate inclusion of Geosynthetics in departmental guidelines

Recommendation	Next Steps
Revision of other handbooks and guidelines (Railways, Water Resources, Local MCs/PWDs/Irrigation Depts)	Inclusion of geosynthetics in: • Canal linings and embankment protection in the "Water Treatment for Hydraulic Structures" handbook • The Railway Works Manual and/or the Track Design Directorate.

Incorporated in section 9.4 of the report

Essential to observe international best practices

Need for global view on initiatives and government involvement in promotion of geosynthetics

- Inadequate exposure on what other governments/ministries are doing
- Lack of knowledge of other organizations promoting geosynthetics and their modus operandi
- It must be noted that an act/regulation exists for mandatory use in landfills in India, but uptake is slow. It is the responsibility of the governing agency to ensure compliance.

Observations as per the final report

- In 1999, the China Ministry of Water Resources selected 50 hydraulic projects using Geosynthetics as model projects
- Test Procedure of Geosynthetics by the Ministry of Water Resources, and Test Specification for Geosynthetics used in Highway Projects by the Ministry of Communications, China
- Implementation of the industry standard, Application Technical Standard for Geosynthetics used in Water Resources and Hydropower Engineering, was started in China in November 1998
- California DOT (Caltrans) prescribes use of geotextiles for pavement overlays in the HDM section 631.5
- Some US states stipulate use of silt fences during road construction to prevent soil run off (State of Virginia, Std & Spec 3.05)

Incorporated in section 7.2 of the report

Support usage by relevant regulations

Usage needs to increase within public works

- Usage for road, rail and other civil works is nascent
- No stimulus in place to boost usage

Recommendations as per the final report

- <u>No Legal Interventions required</u>
- Inclusion in departmental guidelines and handbooks is essential
- Within these guidelines use can be specified for:
  - ➢ Pavement overlays
  - ➢ Silt fences
  - ➢ Landfills (stipulation exists# but guidebook makes no reference)
  - ➢ Canal linings
- Inclusion of Geosynthetics within *Special Focus Products Scheme for exports* will provide impetus

"Municipal Solid Wastes (Management and Handling) Rules, 2000", Schedule III "Specifications for Landfill Sites" the section on "Pollution Prevention"

Incorporated in section 9.10 of the report

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Standards for geosynthetics in India need to be adopted and developed

Quality ecosystem is still in a nascent stage

- The BIS does not have all standards for Geosynthetics developed
- There is no manufacturer accreditation
- There is no on site inspection/ audit firm for installation
- BTRA is the only accredited lab in the country and is still not being leveraged by manufacturers and users

Recommendations as per the final report

- Specification standards have been provided for all applications based on AASHTO, GRI and ASTM
- A three pronged quality framework proposed
  1) Manufacturer production accreditation
  2) Product quality certification
  3) Onsite control testing
- Status of equipment and requirement for BTRA has been provided in section 9.8

Incorporated in section 9.6 of the report

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Annexure P - Meetings with Manufacturers for Feasibility – Presentation

Manufacturing feasibility has shown good results

Manufacturing feasibility for various production technologies was also carried out and key conclusions are as follows:

- ❑ For the manufacturing feasibility of woven facility with 24 looms : IRR : 23%, ROI : 29% and Payback period 7-8 years
- ❑ For the Manufacturing feasibility for Non-Woven Facility of capacity 16 tons/day : IRR : 16%, ROI : 21% and Payback period ~4 years

- *In the case of a woven geotextiles, the project can be started with minimum number of looms i.e. 4 to 6 then be expanded further*
- *TUFS (Technology Upgradation Fund Scheme) subsidies were recently extended to 2017*

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Assumptions – Woven Geotextiles

ASSUMPTIONS - WOVEN GEOTEXTILE		
1	Shift/day	3
	No. of Working Days / Annum	350
	No. of Working Hours / Shift	8
2	Capacity Utilisation	
	Ist Year	50%
	IInd Year	60%
	IIIrd Year	75%
3	Cost of Power	6
	Cost of Water – Rs per m³	25
4	Consumable Stores and Spares	
	- % of Machinery Cost	1%
5	Packing & Transport	
	Packing Cost Rs per Kg	4
	Transport Cost Rs per Kg	10
6	Labour Wages - Rs per Day	
	Skilled	240
	Semi Skilled	220
	Un-Skilled	200
	Fringe Benefits - For first 3 Years	36%
	From fourth year onwards	40%

7	Repairs and Maintenance	
	- % Of Machine Cost	2%
	- % Of Building Cost & Utilities	2%
8	Administrative Expenses	
	% of Sales Turnover.	2.0%
9	Interest on Term Loan -	
	- Rupee Loan (Government Bond) @	13.5%
	-Interest on Working Capital @	13.5%
10	Selling Expenses as % of Sales Turnover	
	Selling Expenses	3.0%
	Selling Commission	5.0%
11	Product Development & Sampling	5.0%
12	Exchange Rates - as on 11/10/12	
	1 US $	52.75
	1 Euro	67.95
	1 Pound	84.49
	1 CHF	56.26

Production and Sales Projections - Woven Geotextile

Along with the above assumptions the feasibility snapshot below assumes purchase of new machines and not used machines. It is also assumed that the unit will operate at maximum utilization from the 3rd year onwards.

PRODUCTION AND SALES PROJECTIONS - WOVEN GEOTEXTILE			
Sr. #	Fabric	Production Kg. / Day	Selling Rate Rs. / Kg
1	Geo textile - Product 1	3503	216
2	Geo textile - Product 2	3277	216
3	Geo textile - Product 3	7276	227
4	Geo textile - Product 4	6702	227

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Project at a Glance - Woven Geotextile

PROJECT AT A GLANCE - WOVEN GEOTEXTILE		
* Installed Capacity		
Woven Technical Textiles	No Of Looms	24
* Basis For Planning		
Working Days Per Annum		350
Fabric Processing	DAYS	(3 SHIFTS)
Hours Per Shift		8
* Project Cost		
Total	Rs. Lakhs	6955
* Means Of Finance		
Promoters Contribution	Rs. Lakhs	2087
Public Issue / Mutual Funds	Rs. Lakhs	0
Total Equity	Rs. Lakhs	2087
Foreign Currency Loan	Rs. Lakhs	0
Rupee Loan	Rs. Lakhs	4869
Total	Rs. Lakhs	6955

* Financial Results		
Sales Realisation	Rs. Lakhs	12166
Other Income	Rs. Lakhs	0
Cost Of Production	Rs. Lakhs	8125
Gross Operating Profit	Rs. Lakhs	2247
Net Profit	Rs. Lakhs	703
Break Even Point		44.96%
Cash Break Even Point		31.60%
I.R.R.		23%
Return On Investment		29.28%
Breakeven Period		7-8 Years

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Assumptions - Nonwoven Geotextile

ASSUMPTIONS - NONWOVEN GEOTEXTILE		
1	No. of Working Days / Annum	350
	Shifts/Day	3
	No. of Working Hours / Shift	8
2	Capacity Utilisation	
	Ist Year	70%
	IInd Year	80%
	IIIrd Year	90%
3	Cost of Power	6.5
	Cost of Water - Rs. per m³	15
4	Consumable Stores and Spares	
	- % of Machinery Cost	1%
5	Packing & Transport	
	Packing Cost Rs per Kg	4
	Transport Cost Rs per Kg	10
6	Labour Wages - Rs per Day	
	Skilled	220
	Semi Skilled	200
	Un-Skilled	180
	Fringe Benefits - For first 3 Years	36%
	From fourth year onwards	40%

7	Repairs and Maintenance	
	- % Of Machine Cost	2%
	- % Of Building Cost & Utilities	2%
8	Administrative Expenses	
	% of Sales Turnover.	1.0%
9	Interest on Term Loan -	
	- Rupee Loan @	13.5%
	-Interest on Working Capital @	13.5%
10	Selling Expenses as % of Sales Turnover	
	Selling Expenses	3.0%
	Selling Commission	3.0%
11	Product Development & Sampling	3.0%
12	Exchange Rates - as on 12/10/2012	
	1 US $	55.00
	1 Euro	70.00
	1 Pound	84.49
	1 CHF	56.26

Production And Sales Projections - Woven Geotextile

Along with the above assumptions the feasibility snapshot below assumes purchase of new machines and not used machines. It is also assumed that the unit will operate at maximum utilization from the 3rd year onwards.

PRODUCTION AND SALES PROJECTIONS - WOVEN GEOTEXTILE							
Sr #	Products	Weight (GSM)	Raw material	Web width (mm)	Output/day (kg)	Output/day (m²)	Selling rate (Rs/kg)
1	Geotextiles	180	PP	6000	2700	15000	196
		300	PP	6000	2250	7500	187
2	Filtration	500	PP	6000	1125	2250	182
		500	PES	6000	2250	4500	182
		650	PP	6000	1125	1731	176
		650	PES	6000	1125	1731	176
3	Automotive felt	150	PES	6000	2700	18000	204

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PROJECT AT A GLANCE - NONWOVEN GEOTEXTILE			
*	Installed Capacity		
	Needlepunch Products	Tons/Day	13
*	Basis For Planning		
	Working Days Per Annum	350	Days (3 Shifts)
	Hours Per Shift		8
*	Project Cost	Rs. Lakhs	6481
*	Means Of Finance		
	Promoters Contribution	Rs. Lakhs	1371
	TUFS or State Subsidy	Rs. Lakhs	768
	Total Equity	Rs. Lakhs	2139
	Rupee Loan	Rs. Lakhs	4342
	Total	Rs. Lakhs	6481

*	Financial Results		
	Sales Realisation	Rs. Lakhs	7898
	Cost Of Production	Rs. Lakhs	6438
	Gross Operating Profit	Rs. Lakhs	1461
	Net Profit	Rs. Lakhs	505
	Break Even Point		54.25%
	Cash Break Even Point		29.68%
	Average D.S.C.R.		1.77
	I.R.R.		16%
	Return On Investment		21.04%
	Breakeven Period		4 Years

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