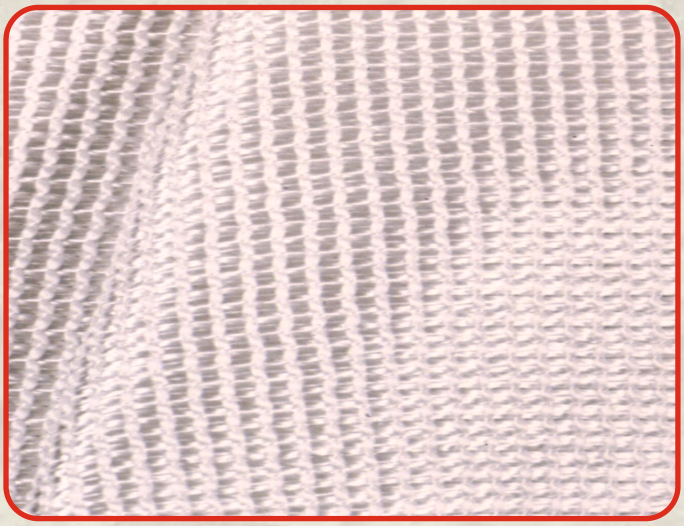
ISSN : 2277-5625 (Print)
ISSN : 2277-5633 (Online)

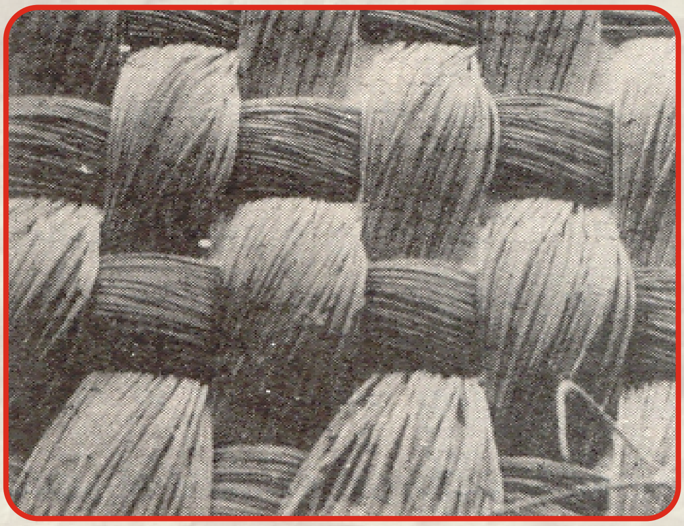
Vol. 12 • No. 1 • January 2023

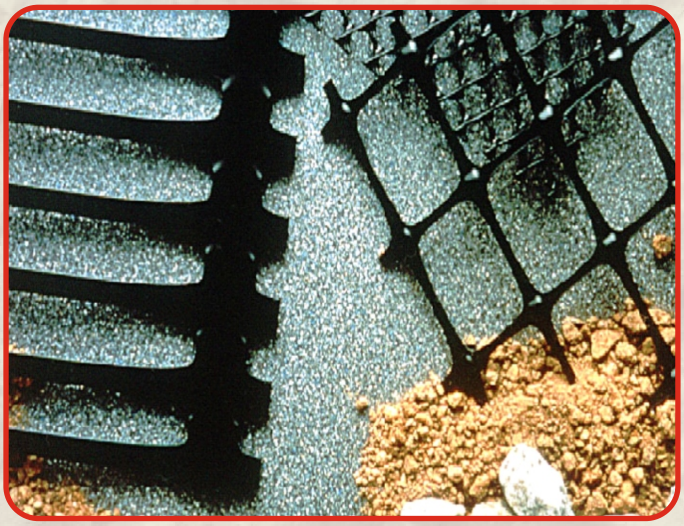
IGS INDIA

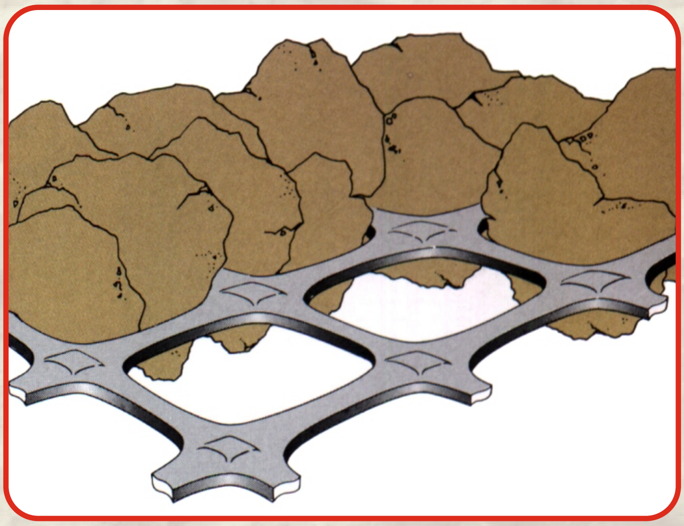
Indian Journal of Geosynthetics and Ground Improvement

Half Yearly Technical Journal of Indian Chapter of International Geosynthetics Society









ABOUT JOURNAL

Geosynthetics are now being increasingly used the world over for every conceivable application in civil engineering, namely, construction of dam embankments, canals, approach roads, runways, railway embankments, retaining walls, slope protection works, drainage works, river training works, seepage control, etc. due to their inherent qualities. Its use in India though is picking up, is not any where close to recognitions. This is due to limited awareness of the utilities of this material and developments having take place in its use.

The aim of the journal is to provide latest information in regard to developments taking place in the relevant field of geosynthetics so as to improve communication and understanding regarding such products, among the designers, manufacturers and users and especially between the textile and civil engineering communities.

The Journal has both print and online versions. Being peer-reviewed, the journal publishes original research reports, review papers and communications screened by national and international researchers who are experts in their respective fields.

The original manuscripts that enhance the level of research and contribute new developments to the geosynthetics sector are encouraged. The work belonging to the fields of Geosynthetics are invited. The manuscripts must be unpublished and should not have been submitted for publication elsewhere. There are no **Publication Charges**.

EDITORIAL BOARD

INDIAN CHAPTER OF INTERNATIONAL GEOSYNTHETICS SOCIETY

INDIAN JOURNAL OF GEOSYNTHETICS AND GROUND IMPROVEMENT

Volume 12, No. 1 January 2023

CONTENTS

All communications to be addressed to :

The Member Secretary
Indian Chapter of IGS
CBIP Building, Malcha Marg, Chanakyapuri, New Delhi 110 021

Subscription Information 2023/ (2 issues)

Institutional subscription (Print & Online)	:	Rs. 900/US$75
Institutional subscription (Online Only)	:	Rs. 600/US$50
Institutional subscription (Print Only)	:	Rs. 600/US$50
Subscription for 10 Years (Print)	:	Rs. 5,000
Subscription for 10 Years (Print & Online)	:	Rs. 8,000

FROM THE PRESIDENT DESK

IGS – India is making all out efforts to spearhead various applications of geosynthetics in the real world problems. Indian Journal of Geosynthetics and Ground Improvement is one of its important means to underscore the accomplished applications and the potential to be harnessed. When India is manufacturer of some of the best products in the field of engineered textile of the world, people expect it to be a place of innovative applications in roads, railways, walls, foundations, hydraulic structures, etc. and actually India has presented several success stories and unique applications.

This journal is instrumental in highlighting such case studies and at the same time some innovations in the methods and design philosophies to equally inspire the researchers and the practicing engineers. I expect this issue to be a matter of great interest to the civil engineers in general and place a land mark of its own. I would make an earnest request to all working in this field to kindly contribute their best to benefit the world.

V. P. Kapadia

Vivek P. Kapadia
President
Indian Chapter of
International Geosynthetics Society

FROM THE EDITOR'S DESK

Dear IGS India Members,

Geo-synthetics are one of the most important materials in infrastructure construction today. This covers everything from natural fibres to polymer geo-membranes. Internationally these materials play a major role in soil stabilisation.

The restoration of river banks in India is an important undertaking to address the issues of erosion, sedimentation, and ecological degradation. Here are some common approaches and measures used for river bank restoration in India.

One of the articles in the journal provides information about Flood protection works, using geotextile bags, also known as geotextile tubes or geotubes, involve the use of large fabric bags filled with sand or other granular materials to create barriers against flooding. These bags are typically made of a permeable geotextile material, which allows water to pass through while retaining the soil or sand inside

There is information available in the journal about Geosynthetic reinforced pavement layers, also known as geogrid-reinforced pavement, involve the use of geosynthetic materials to enhance the structural performance and lifespan of pavements. Geosynthetics, such as geogrids or geotextiles, are integrated within the pavement layers to improve their tensile strength, reduce cracking, and distribute load more effectively.

IGS India is grateful to the author of the various papers for their contributions included in this issue. Through this journal are attempt is to provide useful information to our readers on Geo Synthetic which would help them in better understanding and their knowledge on the state of the art technology and material in this field. We are sure these papers will be of interest to the readers.

We request all the readers for contributing technical papers, case studies and technical news etc., which would be of interest to others, for publishing in the subsequent issues of the journal.

A.K. Dinkar
Member Secretary
Indian Chapter of
International Geosynthetics Society

EXPERIMENTAL AND NUMERICAL MODELLING OF INCLINED PULLOUT BEHAVIOUR OF GEOSYNTHETIC SHEET USED AS VENEER REINFORCEMENT

Riya Bhowmik[1], J. T. Shahu[1], and Manoj Datta[2]

ABSTRACT

There is immense public pressure to close the waste dumps in India, most of which have far exceeded their capacity. Since these dumps usually have a nearly vertical configuration, with little space at the toe for flattening of slopes, veneer reinforcement is provided to stabilise the multi-component cover systems. This study presents the results of the experimental and numerical investigations conducted on geosynthetics of sheet-form used as veneer reinforcement in landfill covers to investigate the influence of pull inclination on anchorage capacities. The geosynthetic sheet was anchored in three types of anchors: run-out, I-type, and L-type. Inclined pullout tests were conducted using an inclined pullout device developed in-house. The geosynthetic sheet was manually fabricated by arranging the longitudinal ribs extracted from a geogrid of 60 kN/m ultimate tensile strength. The model tests were simulated using three-dimensional finite element analyses software PLAXIS 3D. The geosynthetic behaviour was modelled with bending/'plate' elements instead of conventionally used axial/'geogrid' elements.

The experimental and numerical results demonstrated the positive effect of the vertical component of the inclined pullout force: a 22% increase in maximum pullout resistance on increasing pull inclination from 0° to 30°. The results also show that the I- and L-type anchors provide approximately 50% and 95% more pullout force than the run-out anchor, respectively. The numerical results showed that the new approach of modelling geosynthetics using 'bending' elements could satisfactorily capture the peak inclined pullout behavior. However, the post-peak response was not satisfactorily modelled due to the inability of Mohr-Coulomb constitutive relationship in capturing the post-peak strain-softening response.

***Keywords**: Geosynthetics, Veneer Reinforcement, Inclined Pullout Device, Experimental Studies, Finite Element Method, PLAXIS 3D*

1 INTRODUCTION

About 70% of Municipal Solid Waste in India gets disposed of in uncontrolled dumpsites, and hence, there is immense public pressure to close them. These dumps usually have a nearly vertical configuration, with little space at the toe for flattening of slopes which makes laying of the multi-component cover system difficult. Veneer reinforcement, like high-strength geotextiles and geogrids, can provide stability to the cover system on steep slopes; however, their stability depends on the efficiency of the anchors holding them at the top of the slope (Villard and Chareyre 2004), as shown in Fig. 1. Since very little is known about the failure mechanisms in various types of anchors, their design remains problematic.

The present study evaluates the anchorage mechanisms of the geosynthetic sheet on relatively steep slopes. Since the pull induced on the veneer reinforcement is in an inclined direction, it is important to investigate the pullout mechanism of anchored geosynthetic under inclined force and low normal stresses prevalent in the cover system of landfills.

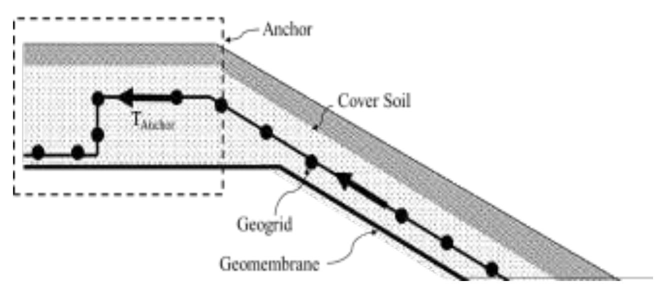


Fig. 1 : Anchorage of veneer reinforcement.

Inclined pullout tests were conducted using an inclined pullout device developed in-house (Bhowmik 2019; Bhowmik et al. 2019a; Bhowmik et al. 2019b; Bhowmik et al. 2020a) on sheets embedded in run-out, I-type, and L-type anchors in Yamuna sand. The model tests were then simulated using three-dimensional finite element analyses software PLAXIS 3D for a better understanding of the stresses and deformations. Bhowmik et al. (2020b) have reported observations and results

1. Department of Civil Engineering, Indian Institute of Technology Jammu, Jammu and Kashmir, 181221, India.

2. Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, 110116, India.

on finite element modelling of inclined pullout behaviour of geogrids. However, owing to the inherent difference in their structure, a geosynthetic sheet has a different mode of interaction than a geogrid. Hence, the results from the present study will be useful in understanding the behaviour of an anchored sheet under inclined pullout.

2. EXPERIMENTAL INVESTIGATIONS

Fig. 2 shows the inclined pullout device used for the tests. The details of the setup are provided in Bhowmik (2019a,b) and Bhowmik et al. (2020a). The device is capable of conducting tests at inclinations ranging from 0 to 90°. The test tank is 1400 mm long, 900 mm wide, and 1000 mm deep. The geosynthetic test samples are 300 mm wide and 800 mm long and are embedded in sand bed in three different anchors, namely, runout anchor with 0.8 m horizontal runout length, I-type anchor with 0.6 m runout and 0.2 m vertically embedded length; and L-type anchor with 0.4 m runout and 0.4 m vertically and horizontally trench-embedded length. The three configurations of the anchors are shown in Fig. 3.

Fig. 2 : Inclined pullout test device.

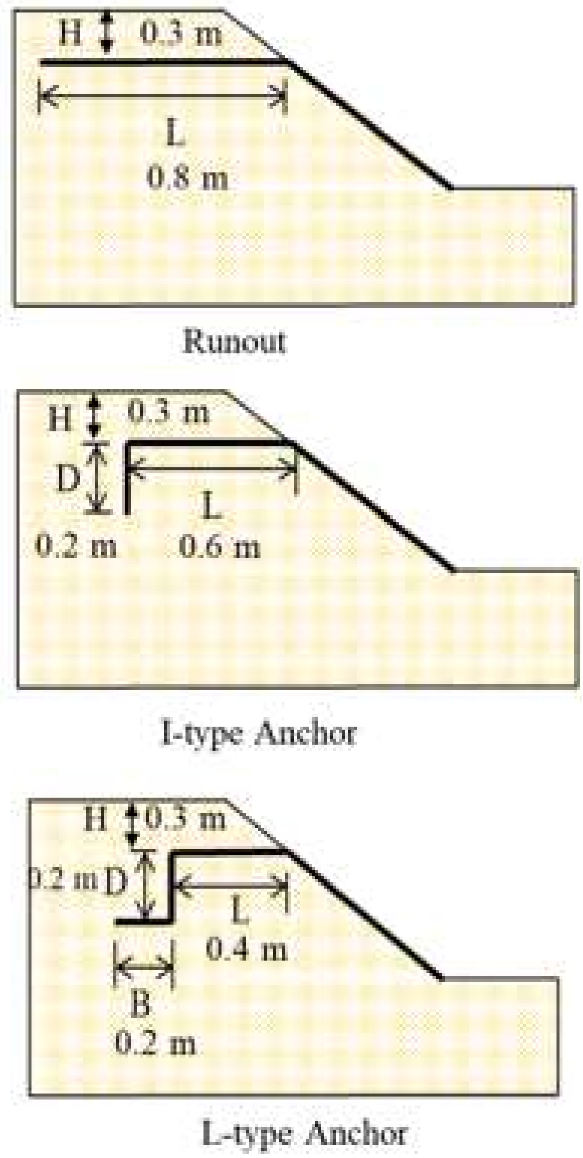


Fig. 3 : Types of anchor considered in present study.

The sheet used in this study was manually fabricated from the ribs of the PET-yarn geogrid having uniaxial strength of 60 kN/m and single rib strength of 1.47 kN. Fig. 2(inset) shows the sheet placed in the test tank in run-out anchor, and secured in place with weights, before laying the overburden layers. All the tests were conducted in Yamuna sand, which is fine alluvial sand having sub-rounded to rounded particles and an angle of shearing resistance of 43°.

2. NUMERICAL INVESTIGATIONS

The finite element modelling of the problem was done in the commercial platform PLAXIS 3D. Taking advantage of the symmetry, only half of the experimental model was simulated. The geosynthetic behaviour was modelled with bending/'plate' elements instead of conventionally used axial/'geogrid' elements. Its properties are derived from the uniaxial tensile force-strain relationship of a single rib in the machine direction. Fig. 4 shows the FE model of the three types of anchors. The behaviour of the sand was simulated using the elastic-perfectly plastic, Mohr-Coulomb constitutive relationship and its properties were kept the same as determined from the laboratory. Table 1 lists the properties used for modelling. The soil-geosynthetic sheet is modelled via zero thickness interface elements whose properties are modelled with the parameter Rinter. The values of Rinter for all three types of anchor were determined as 0.3 from the back-analysis of the corresponding experimental results.

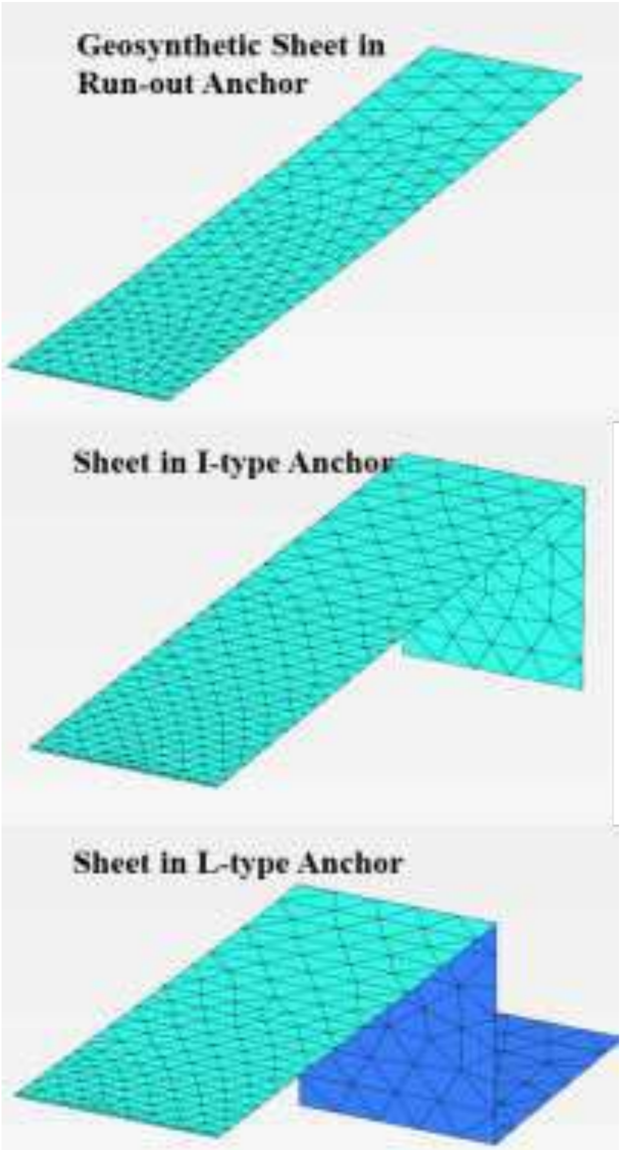


Fig. 4 : FE model of three anchors

3. RESULTS AND DISCUSSION

Figs. 5(a) shows the plot of the load-displacement curves obtained from experimental and numerical modelling for run-out anchor under horizontal pull. Fig. 5(b) shows the same for inclinations of 20° to 30°, respectively. The numerical results showed that the new approach of modelling geosynthetics using bending elements is effective in simulating their inclined pullout behaviour for their stiffness and peak pullout response. However, the post-peak response was not satisfactorily modelled due to the inability of the Mohr-Coulomb constitutive relationship in capturing the post-peak strain-softening response. A similar observation was also reported for geogrids by Bhowmik et al. (2020a).

Table 1 : Properties used in numerical modelling.

Properties	Corresponding Parameter for Linear-elastic model in PLAXIS	'Geogrid' element	'Plate' element
Axial Stiffness (N/mm)	EA	1470	
Unit Weight (N/mm^3)	γ	-	6.5×10^{-6}
Thickness (mm)	d	-	1.2
Young's modulus (N/mm^2)	E	-	1275
Poisson's Ratio	ν	-	0.33

Fig. 5(c) shows the comparison among the experimental and numerical plots for I-type and L-type anchors, respectively. It may be observed that the FE model of the trench anchors couldn't attain the peak value within the prescribed displacement of 90 mm. This may be attributed to the limitation of FEA in modelling penetration of the anchored geogrid into the neighbouring soil during the pullout. Nonetheless, the pullout resistance value corresponding to the displacement of 90 mm showed a good match with the experimentally observed values. Comparing Figs. 5(a) and 5(c), it may also be noted that the I- and L-type anchors provide approximately 50% and 95% higher pullout force than the run-out anchor, respectively.

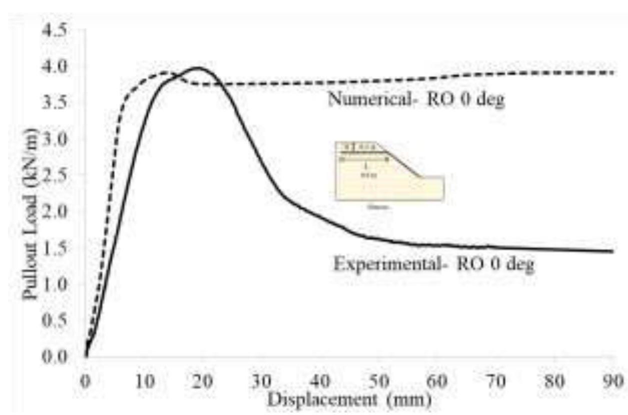


Fig. 5(a) : Run-out anchor under horizontal pull: comparison among experimental and numerical plots

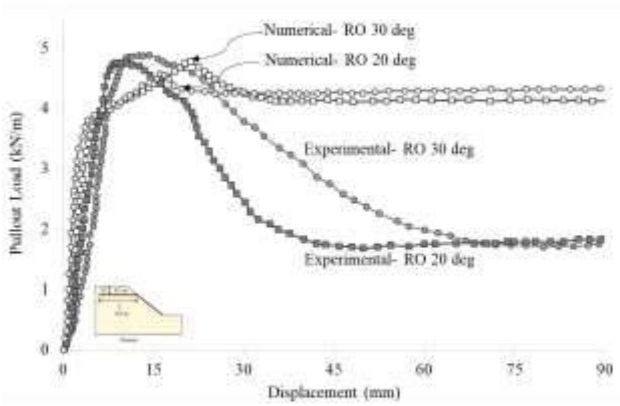


Fig. 5(b) : Run-out anchor under inclined pull: Comparison among experimental and numerical plots

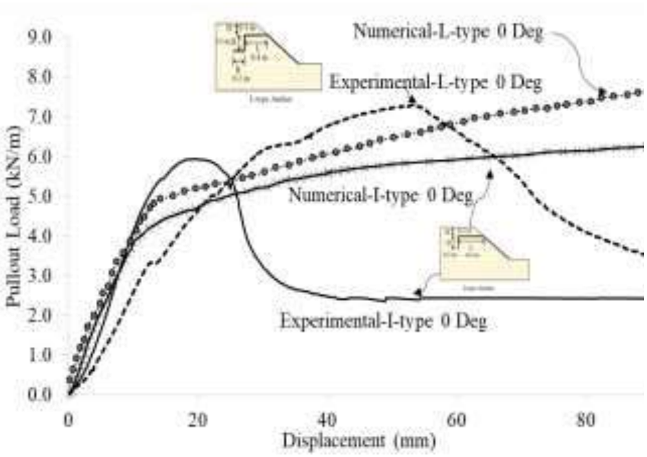


Fig. 5(c) : I- and L-type anchors under horizontal pull: Comparison among experimental and numerical plots

Fig. 6 compares the peak pullout force values for runout anchors obtained from experimental and numerical models. It may be seen that the maximum pullout resistance in the geosynthetic sheet increases by 22% as the pull inclination increases from 0° to 30°. This enhancement in the pullout force values may be attributed to the vertical component of the inclined pullout force which mobilizes greater normal stresses at the soil-reinforcement interface. This shows that consideration of inclination of pull for the design of veneer reinforcement in landfill cover systems will result in a comparatively economical design.

3. CONCLUSION

Experimental and numerical investigations were conducted on the geosynthetic sheet used as veneer reinforcement in landfill cover systems. The influence of inclination of pull was studied using a novel pullout device at the laboratory and Finite Element based numerical modelling in PLAXIS 3D. Based on the results, the following conclusions are drawn:

1. The results from both model tests and numerical analyses show that the peak pullout force increases by approximately 22% as the inclination of the pullout force

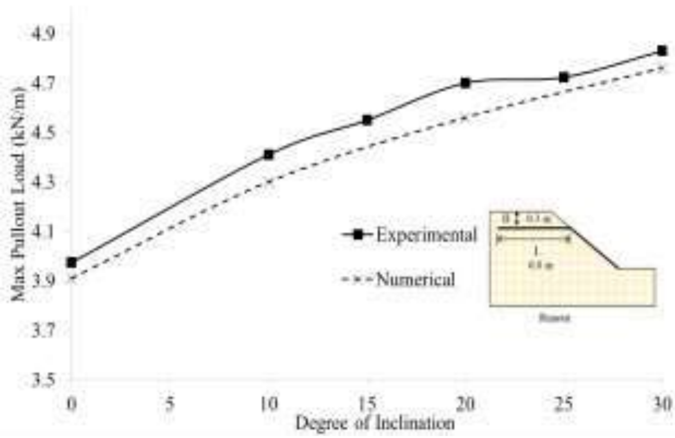


Fig. 6 : Run-out anchor under horizontal pull: Variation in maximum pullout load with increase in pull inclination

increases from 0° to 30° for all three anchors. Thus consideration of this enhanced pullout capacity will result in a comparatively economical design.

2. The adopted numerical modelling approach of using bending elements for the geosynthetic sheet resulted in a satisfactory agreement between the numerical and experimental results in the pre-peak and peak behaviour of the runout anchor.

3. Though the FE model of the trench anchors couldn't attain the peak value within the prescribed displacement, a satisfactory agreement was observed among the maximum pullout force values corresponding to the maximum prescribed displacement of 90 mm.

REFERENCES

Bhowmik, R. (2019). Inclined Pullout Behaviour of Anchored Geogrids used as Veneer Reinforcement in Cover Systems of Landfills. Indian Institute of Technology Delhi.

Bhowmik, R., Shahu, J. T., and Datta, M. (2019a). Experimental investigations on inclined pullout behaviour of geogrids anchored in trenches. Geosynthetics International, (2014), 1–34.

Bhowmik, R., Shahu, J. T., and Datta, M. (2019b). Effect of type of geosynthetic and sand on inclined pullout capacity of anchors. Geotextiles and Geomembranes, 47(6), 767-779.

Bhowmik, R., Shahu, J. T., and Datta, M. (2020a). Finite-Element Modeling of Geogrids in Trenches under Inclined Pull. International Journal of Geomechanics, 20(8), 04020129.

Bhowmik, R., Shahu, J. T., and Datta, M. (2020b). A New Inclined Pullout Device for Laboratory Tests on Geosynthetics. Geotechnical Testing Journal, 43(6), 20190115.

Villard, P., and Chareyre, B. (2004). Design methods for geosynthetic anchor trenches on the basis of true scale experiments and discrete element modelling. Canadian Geotechnical Journal, 41(6), 1193–1205.

FLOOD PROTECTION WORKS USING GEOTEXTILE BAGS AT VULNERABLE BANKS OF RIVER SHARDA IN DISTRICT LAKHIMPUR KHERI - A CASE STUDY

Suresh Maurya[1]

ABSTRACT

Lakhimpur Kheri has witnessed several floods in the past due to heavy rainfall in the month between June to September every year. The lives of the people get affected due to proximity of the people residing on the banks of the River Sharda. Flood protection work taken up by Flood Division Sharda Nagar, UP protected sensitive cluster of villages along left and right bank of river Sharda in district Lakhimpur Kheri. In order to provide protection to the vulnerable reaches, high strength woven geotextile bags were used in construction of Bank revetment and launching apron for a total length of 2410 m and concrete porcupines spacing at 60 m c/c and 500 m c/c in three rows as an additional protection to the banks in order to reducing the velocity of flow. Such application is rapidly deployed to achieve maximum benefit to the community, typically through the use of on-site river bed materials, innovative woven geotextile materials and construction techniques. Flood protection work has protected 140 hectares of cultivated and homestead land including sensitive cluster of villages, other public and private properties. The paper briefly presents the problem and the protection works carried out along the vulnerable reaches of River Sharda in district Lakhimpur Kheri.

Keywords *: flood, protection, geotextile bags, tensile strength*

1. INTRODUCTION

The River Sharda, also known as Mahakali in Nepal, flows along the international boundary between India and Nepal before entering India at Pilibhit District, Uttar Pradesh. The River flows through various districts of Uttar Pradesh and eventually joins the Ghaghra River, which is a tributary of the River Ganga (see Figure 1a). In the eight non-monsoon months of the year, flow of water in the River Sharda is too weak to flush away silt. As the silts keep accumulating, the maximum depth of river is now 12 m in its 40 km stretch. Water in river rises every year during the monsoon period. The problem intensifies when excess water is released from dams of upper reaches leading to floods. Sharda River keep changing its course due to deposits of silt and obstruction to its natural flow. Studied conducted by various researchers shows that morphological changes, anthropogenic disturbances, extensive deforestation and land use pattern contributed in disturbing the equilibrium of Sharda River.

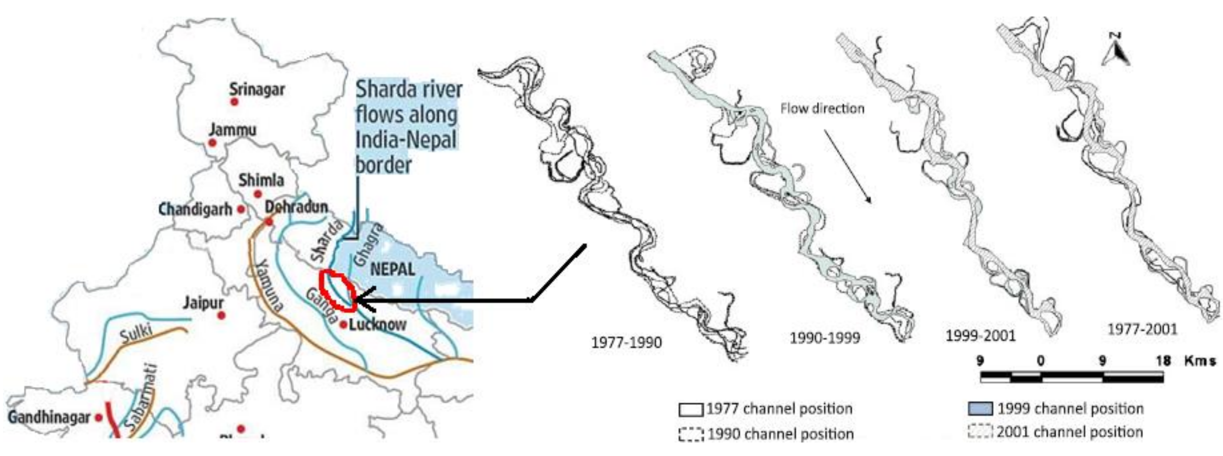


Fig. 1 : (a) Map showing Sharda River and (b) Morphological changes

1. Scientist ‘D’, Central Soil and Materials Research Station, New Delhi

Midha N, Mathur PK, 2013 [1] studied planform dynamics along a 60 km length of Sharda River between 1977 and 2001 and presented changes in River Sharda morphology during different periods by superimposing the digitized river channels (see Figure 1b). Channel showed prominent shifting of meander bends, changes in channel width, alteration of flow due to neck cut-off and avulsion of channel. Gradually, the River Sharda has migrated toward the east with its west bank line becoming more and more unstable. River channel response to anthropogenic disturbance is presented in Table 1.

Table 1 : River channel response to anthropogenic disturbance

Land-use change	Hydrological and geomorphic response
Deforestation/ intensive agriculture in upper reaches	Bank erosion; increase of sediment supply; channel instability; channel widening; increase of migration rate and length; indeterminate avulsion frequency; increase of flood risk
Dam construction	Reduction in discharge; decrease in sediment supply; channel narrowing; change from braiding to meandering; decrease migration rate and avulsion frequency; change in shape and course of river during high discharge
Urbanization	Increase in magnitude and frequency of peak flow; decrease in sediment supply channel degradation; channel widening; accretion downstream
Afforestation	Decrease in sediment supply and runoff; channel narrowing; change to meandering pattern; incision; new terrace level

Midha N, Mathur PK, 2010 [2] studied 10 km stretch of Sharda River along the boundary of Kishanpur Wildlife Sanctuary including Jhadi taal and raised the concern that the bank line shifted by 3.1 km southwards towards the taal during the period from 1948 to 2001. Because of this, distance between taal and sharda channel has reduced to less than 10 m in the year 2008. Such instability of River Sharda can bring threat of inundation and devastating impact to the whole area. Survey study of India topo sheets and digital images reveals that changes in the bank line position shows consistent shift of River Sharda towards Jhadi taal as shown in Figure 2.

Prakash, 1979 [3] studied that both the Indian and Nepal Terai witnessed major change especially after the 1950s. Due to flat terrain, soil fertility and high water table conditions attracted migration of people from less productive hills. Till 1951, the percentage variation in the human population was less than 10 % for Lakhimpur-Kheri. It increased to 18.9 % in the year 1961. In the year 2001 it has reached 32.3 % which is even higher than the entire state of Uttar Pradesh (25.80 %). On the Nepal side, the average increase in the population in the terrai due to migration was 94.3 % between 1981 and 1991. The migration followed uncontrolled conversion of grassland and swamp habitats into cultivable land. This affected large-scale forest in the area.

A study by DFRS, 2002 [4] says that in few districts of Nepal's terrain through which the Sharda River flows lost 17,614 Ha of forest between 1978 and 1996. Large scale land-use changes were also accompanied by various Hydroelectric and Irrigations Projects. Today, Sharda basin consists of several small scattered forests in fragments among vast human-agriculture grid where once continuous forests of terai existed.

Ghani M. U., 2009 [5] presented remedial measure adopted to tackle the erosion problem of Bhira-Palia Kalan railway line by the river Sharda in Lakhimpur Khiri, U.P. Author explained that with the increase in population along

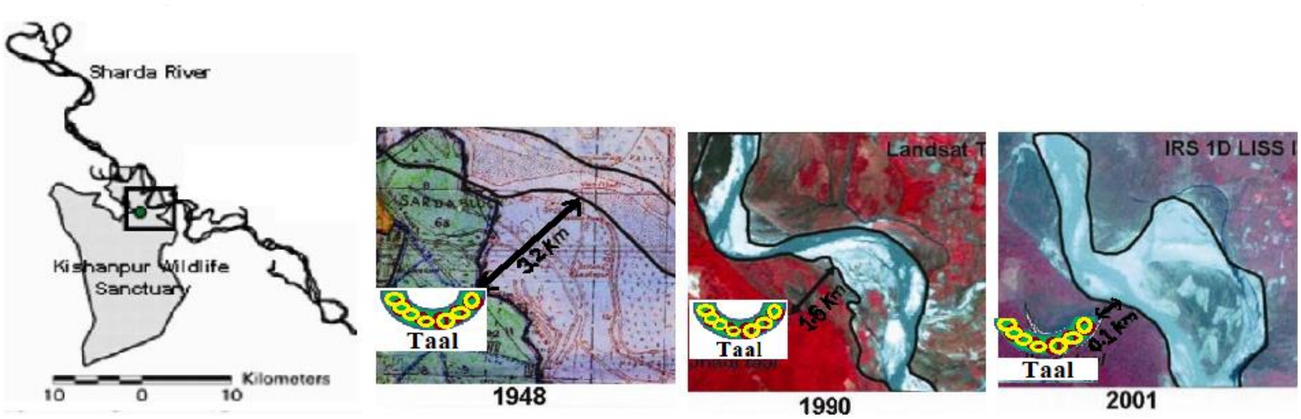


Fig. 2 : Consistent shift of River Sharda towards Jhadi Taal

the bank of the rivers, the resources are over exploited. As such, it is imperative to adopt scientific approach for erosion control. The most responsible factor for river bank erosion is the flow of large quantity of silt in the river. Therefore, there is a great need either to check entry of silt into the river or desilt it when it has entered into the river.

GFCC Report, 2011 [6]. To mitigate the flood problems being faced in the Ganga basin, Ganga Flood Control Commission (GFCC) provide regular assistance to the Ganga basin states to implement the flood management plan in a co-ordinated and phased manner. Scheme of Flood Management Programme (FMP) in the Ganga basin was initiated by the Government of India as central assistance scheme during the Eleventh five year plan and extended in Twelth five year plan. The scheme made good progress in the field of flood management, erosion control and drainage development during its period. One such scheme was taken-up by Flood Division Sharda Nagar (Govt. of Uttar Pradesh), monitored by GFCC and evaluation of innovative geotextile material carried out by CSMRS is presented in this paper. The scheme is to protect sensitive cluster of villages along left and right bank of River Sharda in district Lakhimpur Kheri.

CSMRS Report, 2011 [7]. The geotextile material used in the above scheme was tested for physical, mechanical and hydraulic properties to ensure that the geotextile bag meets the qualifying criteria.

M/o Jal Shakti, 2016 [8]. Conventional method of construction using boulders, timbers etc have been used for flood management works but they have their own limitations. With the advancement in innovative material like geosynthetics and to overcome lack of uniformity and clarity regarding material specification, design and other aspects, expert committee of ministry formulated “Guidelines for Use of Geotextiles, Geotextile Bag, Geotextile Tubes in Construction of Flood Management Works”.

2. FLOOD AND BANK EROSION PROBLEM OF GANGA BASIN STATES

2.1 Flood Problem in Ganga Basin

The River Ganga is the master drain of the Ganga basin states. Ganga basin is spread over 11 states and covers 23 rivers system including River Sharda in Uttar Pradesh. The occurrence of floods in one part or the other is an annual feature during the monsoon period. As reported by Rashtriya Barh Ayog [6], total flood affected area of the country is about 50 million Ha, out of which 24 million Ha., lies in Ganga Basin States as shown in Figure 3 (i.e. nearly 50% of the country area).

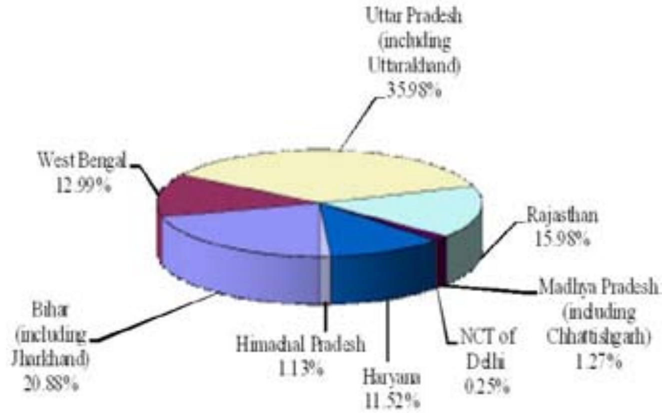


Fig. 3 : Flood prone area of Ganga basin states (Total area: 20.40 Mha)

Among the various Ganga basin States, the State of Uttar Pradesh (particularly its eastern part) and Bihar (particularly its northern part) is the worst flood affected. Recurring floods cause huge loss to life and property every year. The flood problems in the other Ganga basin states are not so severe. As per GFCC Report (2011), the main reasons of flood in the Ganga basin are as under:

(i) Heavy precipitation for long duration in the catchment

(ii) Impediment of flow in tributaries and catchment drains in monsoon season

(iii) Bank erosion by the river during the monsoon season

(iv) Meandering of river causing loss of land, property and life

(v) Inadequate bank full capacity

(vi) Poor maintenance of flood control structures resulting in their damage during the monsoon period

(vii) Inundation of villages situated within the flood plains of the rivers

2.2 Bank Erosion Problem In Ganga Basin

As regard to erosion problems, longitudinal bed slopes of the river Ganga and its tributaries are steep in the upper reaches, become flatter in middle reaches and are almost level in the lower reaches. It has tendency to shift their course by eroding the banks on either side. The upper courses are noted predominantly for deep erosion i.e., bed retrogression. The scoured material is carried downstream by the flow and the middle course undergoes both erosion and aggradation. The lower reaches where the bed slope is flatter and velocities are low, accumulation process takes place i.e., sedimentation and accretion of the river bed is predominant. At the same time due to meandering, erosion and deposition take place simultaneously as shown in Figure 4.

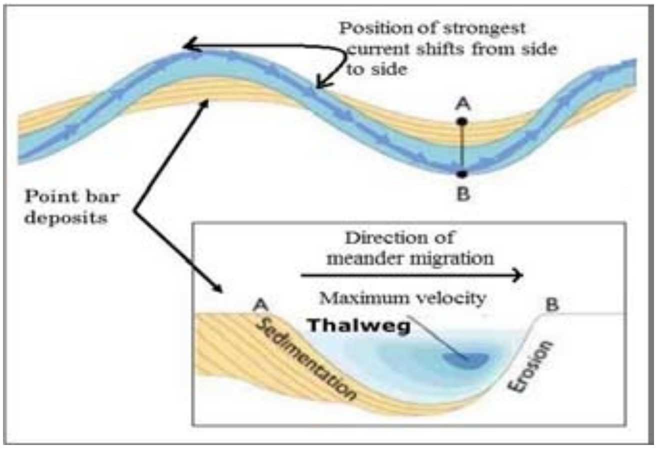


Fig. 4 : Erosion and deposition along the meandering stream

3. FLOOD PROTECTION WORK ON THE BANK OF RIVER SHARDA IN DISTRICT LAKHIMPUR KHERI

3.1 Present Problem of Lakhimpur Kheri by Sharda River

With the migration of River Sharda towards east, west bank line is becoming more and more unstable. Due to heavy rain in a short span, considerable amount of runoff and sediment are being generated which gets quickly transported to the river system downstream and are causing flood on the lower plain reaches near Lakhimpur Kheri. Sharda River has damaged 20 villages in the past two decades. Lakhimpur Kheri is one of the crucial flood affected districts of the U.P state, primarily due to rising load of silt in Sharda and Ghaghra rivers. Due to which the tehsils of Lakhimpur-Kheri district, Palia, Nighasan, Dhaurahra & Gola and Lakhimpur are partially hit by floods. High run-off, continuous land erosion and siltation rates have affected the residents in a cycle of agriculture loss and debt. When the river water rises, residents have no option but to live in shanties they set up on road sides etc. The consequence of flood and erosion can go from simple loss of area to scouring and erosion of bank line. The condition of bank line at vulnerable reaches of River Sharda near Ratauli village [8] is shown in Figure 5.

3.2 Flood Management Programme (FMP) and Benefit

With the objective to effectively tackle the flood and erosion problems of the vulnerable reach of River Sharda under the FMP scheme with title “To protect sensitive cluster of villages along left and right bank of River Sharda in district Lakhimpur Kheri” was considered by GFCC in XIth five year plan and extended in XIIth plan. Layout plan and protection work at Right bank of Sharda River is shown in Figure 6 [8]. The scheme was executed by Flood Division Sharda Nagar (Govt. of Uttar Pradesh) and monitored by GFCC to benefit cluster of villages, other public and private properties and protect 150 hectares of cultivated and homestead land. High strength woven geotextile bags used in the above scheme were evaluated for their quality at CSMRS, New Delhi. This scheme along with many other schemes in River Sharda under FMP of five year plan made good contribution in the field of flood management and erosion control.

3.3 Solution Implementation

For anti-erosion work, variety of protection works can be adopted to reduce the erosive forces of water. But reducing the erosive force is not the only criteria. River water fluctuates between low water level and high flood level and therefore protection works should also be able to perform seepage in and out of the bank slopes. If the seepage is blocked by placing impermeable protection materials like concrete revetments etc., it leads to development of pore pressure which further destabilizes the bank slope. Flood is recurring every year and therefore quick and effective preventive measure adopted was to implement woven geotextile bags, geotextile filter media & concrete porcupines to control flood and erosion problem. The geotextile bags being the permeable material, also at the same time retain the soil particles during receding flows.

Fig. 5 : Vulnerable bank condition before undertaking anti-erosion works

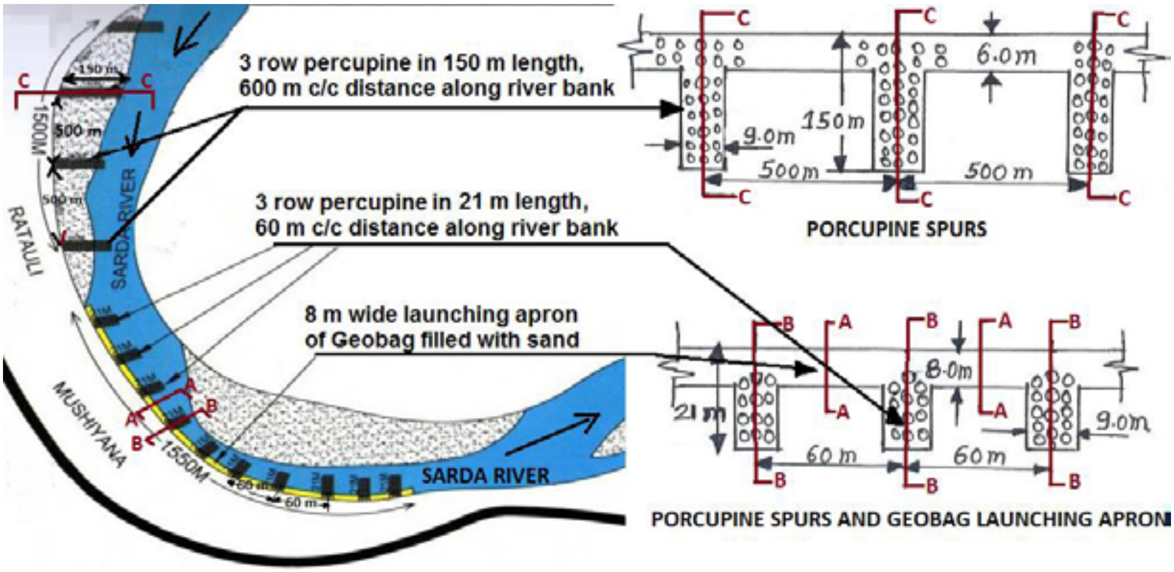


Fig. 6 : Layout plan and protection work

The method adopted involves the construction of bank revetment, launching apron using geotextile bags and by using the porcupines spurs over launching apron with respect to high flood level as shown in Figure. 7. In this method, the local river sand is placed in geotextile bags which resist external stresses without loss of the confined sand. When the infilling sand material is abundantly available at site; filling, transportation and installing the geotextile bags is quick, simpler & economic. The major advantages of this type of protection work is that, they are flexible to accommodate the differential settlement, permeable to manage drainage and economical with less environmental impact in comparison to conventional solution. CWC, 2012 handbook on the "Flood Protection, Anti-Erosion and River Training Works" is useful guide in selecting the appropriate protection works [9].

4. MATERIAL DESIGN, SPECIFICATION AND LABORATORY INVESTIGATION

4.1 Design of Geotextile Bag

The fabric of geotextile bag (geobag) used in the above project is manufactured from polypropylene multifilament (PP-MF) material possessing high tensile strength of 55 kN/m. The PP fibre used in the material has excellent resistance to biological and chemical environments normally found in soils and are stable against exposure to ultraviolet radiation. The envelope size of geobag is 1.09 x 0.69 m, stitched at sides with mouth kept open for infill material. When filled with soil, generally sand, geobags takes the form of pillow shape bag of thickness 20 cm. After filling, open end of the geobag is closed by stitching the bags with the help of hand held stitching

Fig. 7 : Protection work using geotextile bags and porcupine spurs

machine. To achieve good soil tightness and high seam efficiency, the stitched seams are in double stitched pattern to resist high tension and maintain its structural form. The opening size of geobag is design in such a way that it retains the local sand and at the same time allow the greater permeability to flow the water out. This does not allow pore water pressure to build-up in the structure during receding flow. Sand filled bags when placed on bank revetment and apron creates a flexible, monolithic and continuous structure, which is resistance to water forces. Geobags for the projects can be easily customized in various sizes to suit the filling, transportation, pitching and installation requirement. The use of geobags can replace concrete slab, concrete blocks, boulders, rip-rap revetments etc.

4.2 Material Specification and Laboratory Investigation

Geotextile bag is a factory made products; therefore its engineering requirement can be customized to suit site condition in terms of mechanical strength, pore size small enough to prevent migration of fines and high permeability to ensure quick dissipation of pore pressure. Geotextile bags applied along the Sharda River are designed for high tensile strength, puncture resistance, apparent opening size, permeability etc. An evaluation of such product for a specific application needs proper selection of testing program in accordance with the codes listed in table below. The specification of woven fabric geotextile bag is presented in Table 2.

As part of the quality control, Central Soil and Materials Research Station, New Delhi carried out evaluation of woven geotextile material for different lots. The woven geotextile material having mass per unit area of 200 gsm were tested for physical, mechanical and hydraulic properties to ensure that the geotextile bag meets the basic qualifying criteria. All these tests were carried out in accordance with ASTM standard test methods.

5. CONSTRUCTION OF BANK REVETMENT AND LAUNCHING APRON

Woven geotextile bags were filled with locally available river bed sand to the specified height to ensure that appropriate density is achieved. After ensuring that the bags are filled to the required height, the open end of the bags were stitched using hand held stitching machines. For the convenience bags were stored in batches or any suitable multiples as per site space. The laying of geotextile bags for launching apron were carried out when river was dry. For portions in river, stitched bags were manually loaded on boats for further transportation to the site location for installation as shown in Figure 8.

5.1 Bank Revetment

River bank is dressed to the inclination of 1V:2H and over this a layer of geotextile fabric is laid as filter media, anchored at top and bottom of bank slope. After placement of geotextile filter on bank slope, systematic pitching of sand filled woven geotextile bags is carried out all along the bank length of 2410 m. Thickness of pitching on the bank slope is 1.0 m, consisting of six layers of geobags. In building 1.0 m thick pitching, bags are laid in staggered pattern. This pattern gives the lower and upper bags stability and strength, so as not to cause weak line and gapping. IS 14262, 1995 [10] specifies design of revetment guidelines along with selection of filter fabric. Top height of revetment is maintained with respect to HFL of 129.34 m. To reduce the velocity of flow towards bank, porcupines in the form of screens is placed over launching apron at 60 m center-to-center (c/c) distance to provide additional protection to the banks.

Table 2 : Specification of woven fabric geotextile bag (Flood Division Sharda Nagar, Lakhimpur Kheri, 2011)

Properties	Test Method	Unit	Required Value	Tolerances
Mass per unit area	ASTM D 5261	g/m^2	200	± 2 %
Wide Width Tensile Strength (Warp)	ASTM D 4595	kN/m	55	Minimum
Elongation at Break (Warp)	ASTM D 4595	%	25	Maximum
Wide Width Tensile Strength (Weft)	ASTM D 4595	kN/m	40	Minimum
Elongation at Break (Warp)	ASTM D 4595	%	25	Maximum
Puncture Resistance	ASTM D 4833	N	650	Minimum
Trapezoidal Tear Strength (Warp)	ASTM D 4533	N	800	Minimum
Trapezoidal Tear Strength (Weft)	ASTM D 4533	N	500	Minimum
Apparent Opening Size, O_{95}	ASTM D 4751	micron	< 75	Maximum
Water Permeability	ASTM D 4491	$l/m^2/s$	10	± 4

Fig. 8 : Filling, transportation and installation of Geotextile bags [8]

5.2 Launching Apron

Construction of launching apron [8] is carried out with multiple layers of geotextile bags filled with local river bed material. Thickness of launching apron is maintained with respect to low flood level. It is carried out in two different forms i.e., one without porcupine spur as longitudinal protection structure and another with porcupine spur over it as transversal protection structure.

In the longitudinal protection structure, launching of apron is carried out continuously from revetment bottom along the bank line for a width of 8.0 m and depth 4.0 m as shown for cross section A-A in Figure 9.

In the transverse protection structure, at every 60 m c/c distance, launching apron of length 21.0 m and width 9.0 m is extended from revetment bottom towards river as shown for cross section B-B in Figure 10. Maximum depth of launching apron is 4.0 m which is maintained with respect to low flood level. To reduce the velocity of flow towards bank, porcupines in the form of screens is placed over this geobag launching apron.

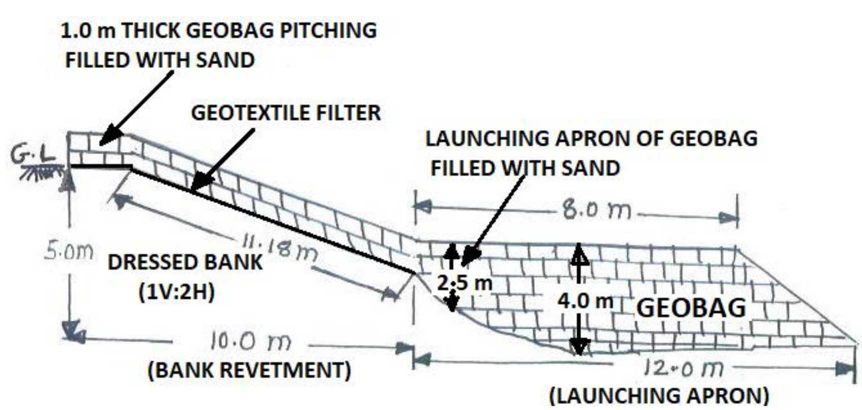


Fig. 9 : Cross section at A-A of longitudinal protection structure

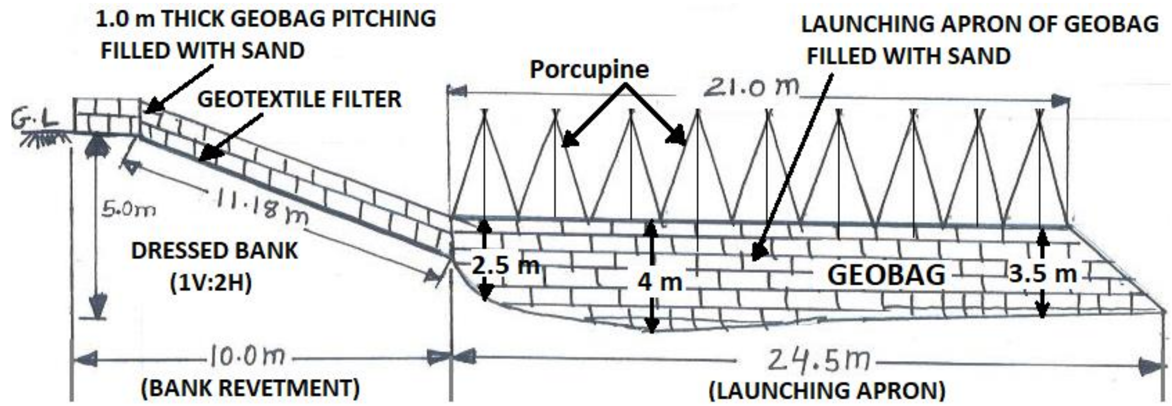


Fig. 10 : Cross section at B-B of transverse protection structure having porcupine spur 21 m length

Thickness of slope pitching on bank and launching apron is carried out in staggered manner to ensure stability of protection works. Here the revetment is a part of bank protection work while launching apron is a part of bed protection work. Bank protection followed by a suitable bed protection can be considered as the key success for any anti-erosion work. Figure 11 shows the implementation of geotextile bags in revetment and launching apron [8].

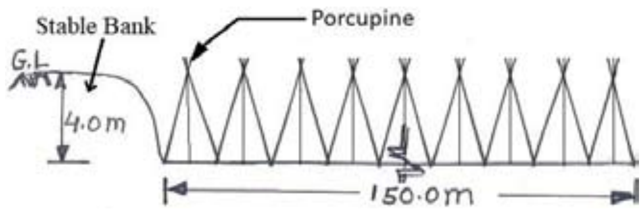
5.3 Concrete Porcupine Spurs

During severe flood Sharda River flow with high velocity and change its course frequently. As a result separate concrete porcupine spurs [8] in the form of screens is placed to provide additional protection to the banks by dampening the velocity of flow and inducing siltation in the vicinity of bank. Erection of porcupine is carried out with six concrete members of size 0.10 x 0.10 x 3.0 m properly fitting/fixing with 12 mm dia. 25 cm long M.S. Nuts and bolts. Placement of porcupine spurs is carried out depending upon the existing river bed level and high flood level. Two different length and c/c spacing between them are provided to suit the site condition.

1. Three row of porcupine spurs in 21 m length and 60 c/c distance along river bank covering 1550 m length (see Figure 10).

Fig. 11 : Implementation of geotextile bags in revetment and launching apron

2. Three rows of porcupine spurs in 150 m length and 500 m c/c distance along river bank covering 1500 m length as shown for cross section C-C in Figure 12.



6. CONCLUSION

Extreme weather events such as floods, pose a significant risk at both global and regional levels to human and natural system. The lives of the people get affected due to proximity of the people residing on the banks of the River. The paper presents the problems and the remedial works carried along the vulnerable reach of River Sharda in district Lakhimpur Kheri. Construction of longitudinal and transverse protection structures using geotextile material and concrete porcupine spur is a permeable, economical and effective in terms of anti-erosion work. The porcupine spurs over geobag launching apron not only increases the height of protection work but also reduces the concentration of flow and protected the bank by keeping the flow away from it. Such application replaces all other conventional methods (e.g Boulders, RCC etc) for immediate protection where flood is a regular phenomenon and construction is to be completed in a limited time period. The use of geotextile materials permitted to carry out the protection works at a faster rate. After flood, considerable amount of silt deposits were noted around the protection work. This stopped the shifting of natural water way towards bank and adjoining villages.

The protection works carried out in 2011 by project authorities have resisted number of floods event without any major damage to properties and loss of land. Figure 13 shows the bank condition [8] during and after the flood and recent google earth image of protection work. The protection is serving as desired and has imbibed a sense of security in the minds of the people living in surrounding area.

Protection works increase the resistance of river banks to erosion and deflects the current away. But due to rise in river bed over the period of time, the problem generally shifts in the upstream or the downstream and necessitate further works to safeguard the land against erosion. Therefore wider opportunities need to be considered to eliminate root causes

Fig. 12 : Cross section at C-C of porcupine spurs, 150 m length

Acknowledgement

The author acknowledges the contributions of the authors in references below for bringing out the meaningful content which have helped to gain knowledge in preparing this technical paper. The author acknowledges the contribution of the Flood Division Sharda Nagar (Govt. of Uttar Pradesh) and CSMRS team by way of active cooperation at the time of laboratory investigation and testing.

REFERENCES

[1] Mathur, P. K.., & Midha N. 2013, Channel Characteristics and Planform Dynamics in the Indian Terai, Sharda River, Environmental Management (2014) 53:120–134, DOI 10.1007/s00267-013-0196-4.

[2] Midha, N. & Mathur, P.K. 2010, Conservation implications of the channel changes in Sharda River on endangered swamp deer population and floodplain ecosystem in Kishanpur Wildlife Sanctuary, Uttar Pradesh. Current Science, 98(5):665–672.

[3] Prakash, O. 1979, Uttar Pradesh District Gazetteers. Kheri, Government of Uttar Pradesh, Department of District Gazetteers, U.P., Lucknow. Government Photo-Litho Press, Roorkee, 265 pp.

[4] DFRS. 2002, The effects of development infrastructure on the forests of Kailali and Kanchanpur. Publication Number 75. Kathmandu.

[5] Ghani, M. U. 2009, Innovative Methods in River Erosion Control - A Case Study of Erosion of Bhira-Palia Railway Line by Sharda River in U.P. Proceeding of 2ND India Disaster Management Congress, NIDM, 4-6 November 2009, Vigyan Bhawan, New Delhi

[6] GFCC Report. 2011, Ganga Flood Control Commission, Annual Report 2010-11, Patna, India

[7] CSMRS Report. 2011, Report on laboratory testing on the Geobags for the Flood Division Sarda Nagar, Lakhimpur Kheri, Uttar Pradesh, Report no. 5/ Geosynthetics/CSMRS/E/09/2011, Central Soil and Material Research Station, New Delhi, India.

[8] M/o WR. 2016, Guidelines for Use of Geotextiles/ Geotextile bag/ Geotextiles tubes in Construction of Flood Management Works, Ganga Flood Control Commission, M/o WR, RD & GR, September 2016.

[9] CWC. 2012, Hand book for flood protection, anti-erosion & river training works. Flood Management Organisation, Central Water Commission. New Delhi, India.

[10] IS 14262. 1995, Planning and design of revetment - guidelines. Bureau of Indian Standards. New Delhi, India.

CALENDER OF UPCOMING EVENTS

Sl. No.	Event Name	Place	Date
1	GeoAfrica 4 – 4th African Regional Conference on Geosynthetics	Cairo, Egypt	February 20-23, 2023
2	12th International Conference on Geosynthetics: 12 ICG	Rome, Italy	September17-21, 2023

LAND RECLAMATION USING GEOTEXTILE TUBES FILLED WITH FINE GRAINED SOIL

Kiran Kumar Rumandla[1], C.Nanda Kishore[1] and Rajib Bhattacharjee[2]

ABSTRACT

Land reclamation was proposed by a private realty developer in East India along River Hooghly to reclaim the land lost due to erosion occurred by tidal courses along the river. The project site is situated at Raichak, 50km east of Kolkata. The total length of the bank proposed for reclamation was around 500m. The initial phase of the project involved reclamation of eroded land and armour protection of the newly formed bank slopes on river side and thereafter to proceed develop the property. Geotextile tubes were selected for its technical efficacy and cost effectiveness besides quicker construction.Geotextile tubes are inflated using sand slurry and the quality of sand is very important to determine the shape of the tube and inflated height. This paper focuses on critical engineering aspects associated with design of the geotextile tube, methodology to pump the tubes in a successful manner while using fine grained soil fills usually available from the alluvial deposits of the Gangetic plane.

1. INTRODUCTION

An upcoming privateowned holiday resort is planned along the pristine banks of River Ganges. The project is situated at Raichak, 50km east of Kolkata(see Figure 1). The total length of the bank is around 500m and the highest tidal level is +4.99m and the lowest tide level is -0.89m. A large variation in the tidal level within the frequency of the tide causes erosion at the project site and deposition across the banks. The first construction phase of the project involves reclamation of eroded bank and armor protection of the newly formed bank slopes in river side to reclaim the lost land in erosion(see Figure 2). The project consultant has proposed to construct a dyke of level of +6.20m using a conventional rubble mounds. This is estimated to consume around 75000cum of rubble stones. The project authority soon realized the difficulties in logistics to transport such huge quantities of rubble stone by small boats. The engineer has contemplated several engineeredoptions and finalized to implement Geotextile tube dykesolution for its sustainability over other options. It isdecided to have geotextile tubes installed to achieve aheight of +5.4m, which is then overlain by a thick layer ofboulders (see Figure 3).

Fig. 1 : Project Location

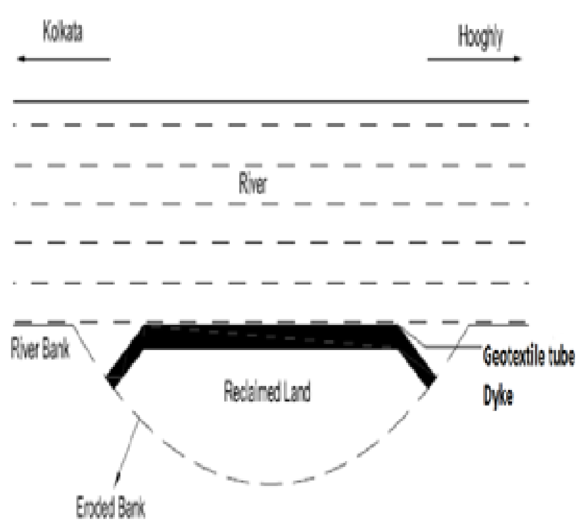


Fig. 2 : Dyke plan

1. TenCate Protective India Pvt.Ltd., India

2. Bhumi Geosynthetics Pvt. Ltd., Kolkata, India

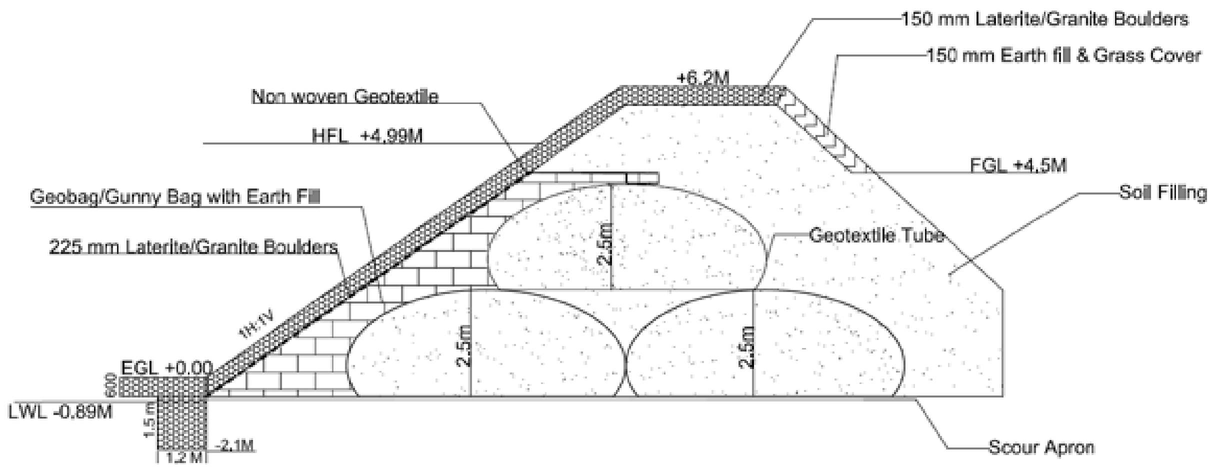


Fig. 3 : Cross-section of the geotextile tube dyke

Fill is dredged from the river to fill the geotextile tube and land reclamation worksin the construction of the bund. The project has a greater challenge in the form of theavailable fill material, which is quite fine (silty) and notideal to act as fill material for tubes. The main challenge is to contain the fine particles within the tube and yet achieve the desired inflated height.

2. GEOTEXTILE TUBE TECHNOLOGY

Geotextile tubes, are tubular containers that are formed in situ on land or in water where mass gravity barrier type structures are required. The tubes are laid out and filled onsite to their required geometrical form. Geotextile tubes range in size from 1 m to 6 m in diameter, and up to 50 m in length. The size of a geotextile tube may be classified in terms of its length and circumference. As an alternative tocircumference, a geotextile tube may also be classified based on an equivalent diameter whereby the diameterequals the circumference divide by pi.The typical features of a geotextile tube are shown in Figure 4. Hydraulic fill is pumped into the geotextile tube through specially manufactured filling ports located at specific intervals along the top of the geotextile tube. During filling, the geotextile tube, being permeable, allows the excess water to pass through the geotextile skin while the retained fill attains a compacted, stable mass within the tube. For hydraulic and marine applications, the type of fill used is sand, or a significant percentage of sand. The geotextile tube units will be subjected to hoop stresses during filling. The hoop stresses will be larger as the diameter of the tube increases and the strength of the tube selected may be critical to resist the stresses. It is recommended to have a factor of safety which ranges from 3 to 5 depending on the method of filling chosen to fill the tubes, parameters of the fill material, criticality of foundation soil, type of structure (temporary/permanent) and type of armor protection layer. A higher factor is applied to the strength of the fabric used for the fabrication of the geotextile tube to allow possibility of burst during filling due to un-regulated pumping pressures, longer exposure to abrasion, ultra violet rays etc.

The geotextile tube shall be fabricated in factory to achieve higher seam efficiencies in order to provide adequate safety against bursting at the filling port/ circumferential seams during filling/pumping the tube. In the present case the seam efficiency is about 80% of the tensile strength. Further, it is critical to design the opening size of the tube in such a way, that it should allow discharge ofwater but retains the soil particles. This depends on the type of filling method and relative discharge deployed for filling the tube which shall be a balance between time of filling and rate of sedimentation. Once filled, the geotextile tube behaves as a mass-gravity unit.The geotextile skin performs three functions that are critical to the performance of the filled geotextile tube. Firstly, the geotextile skin must have the required tensile strength and stiffness to resist the mechanical stresses applied during filling and throughout the life of the units, and must not continue to deform so that the geotextile tube changes shape over time. Secondly, the geotextile skin must have the required hydraulic properties to retain the sand fill and prevent erosion under a variety of hydraulic conditions. Thirdly, the geotextile skin must have the required durability to remain intact over the design life of the units. Where there is potential for foundation scour during the life of the geotextile tube structure it is common practice to install a scour apron during construction. The scour apron consists of a geotextile filter anchored at the extremities by means of a small diameter geotextile tube manufactured as an integral part of the geotextile filter base. Geotextile tubes are used for range hydraulic and marine applications such as revetments, offshore breakwaters, protection dykes and containment dykes.

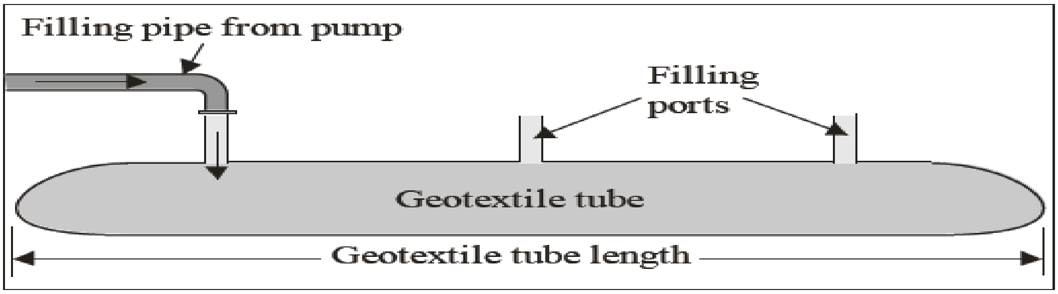


Fig. 4 : Typical features of geotextile tube.

3. SITE CONDITIONS AND INVESTIGATIONS

The silt content in the estuarine waters of river Hooghly generally varies from season to season in a year and also from flood to ebb tides.During monsoon season the silt content in the waters is usually high when compared to non-monsoon season.

3.1 Grain Size of Dredged Material

The grain size analysis of the bed sample is shown in the Table 2.FromTable2 it may be seen that median sediment size (D50) is 0.24 mm. The percentage distribution of medium sand is about 13%, andfine sand is 83%.Hence it can generally be assessed that most of the sediment to be fine sand.

Table 2 : Sampling Results

Classification of Soil	D50 (mm)	Medium Sand %	Fine Sand %	Silt and Clay%
Medium Sand to Fine Sand	0.24	13.157	83.053	3.790

4. DESIGN PHILOSOPHY

The selection and design of the tube becomes very critical for this project for the reason that containment of finer sediments within the tube itself is difficult besides inflation of the tube. This required the engineer to look at the materials of the geotextile tube as well as the processes deployed for filling of the tube while dealing with the two aspects of retention of the sediments in the tube and achieving desired height.

4.1 Materials

Geotextile tube products selected for this project are made out of polypropyleneengineered to offer higher tensile strengths within very low elongation in both circumferential direction and longitudinal directions.Polypropylene fabrics offers resistance against salinity besides higher robustness to endurance. The containment bund was constructed with one tube unit stacked on top of two base tube units. Geotextile tube unit of length 25 m and circumference 15.7 m is used. The properties of the geotextile tube can be referred in Table 3.

4.2 Retention and Containment of Finer Sediments within the Geotextile Tube

The geotextile designed for the tube shall necessarily haveanopening size which accommodates sufficient water flow rates while pumping the tube to prevent risk of tube bursts. However, such opening sizes may not be able to contain the finer sediments pumped. The concept of stokes law is applied to enhance sedimentation which states that therate of sedimentation is inversely proportional to the flow velocity of the sediments which is shown in equation 1.

$$Vsed = \frac{r^2(\rho_s - \rho_o)g}{18_{\eta w}} \quad ...[1]$$

WhereVsed is the settling velocity, ρ is density (the subscripts sand o indicate particle and fluid respectively), g is the acceleration due to gravity, r is the radius of the particle and ηw is the dynamic viscosity of the fluid.The formula can be used to estimate the sedimentation rate at the start of the filling of the geotextile tube.Once the geotextile tube is largely filled, the flow of water through the geotextile tube becomes significantly larger and erosion will occur and the sedimentation rate will decrease causing the filling speed to fall significantly.

4.3 Achieving FilledHeight

Thefill particles trapped within the tube will have greater tendencies to laterally spread for its lower angle of internal friction thus having risks of lowered inflation/ flat tubes.Hence the tubesselected should necessarily have relatively higher lateral restraint which impliesthat the geotextile fabric shall exhibit the tensile strength with in lower range of elongations (within the order of 10~12%). From the authors' experienceone of the key factors influencing the inflated height is thathigher the elongation of the fabric the morewith be thelateral spreading andconsequently the less will bethe inflated height and vice-versa.

4.4 Stability Analysis

The geotextile tube design needs to fulfill the following requirements (Yee, 2002):

- Internal stability
- External stability
- Durability

The critical stressing period for a geotextile tube is during the pumping of slurry into the geotextile tube. Thehydraulic pressure will put the geotextile tube in circumferential as well as longitudinal tension. Designsoftwares (GeoCoPS, SOFFTWIN) that will determine tensions and geometry of geotextile tube are available.The geotextile stresses of the tube during hydraulic filling were analyzed using TUBEWIN geotextile tube program refer to Figure 5.

Table 3 : Geotextile tube specifications

Property	**Test Method**	**Value**
Material	Polypropylene	
Wide Width Tensile Strength(Wrap)(kN/m)	ISO 10319	200
Wide Width Tensile Strength(Weft) (kN/m)	ISO 10319	200
Strain at nominal tensile Strength (Wrap)(%)	ISO 10319	11

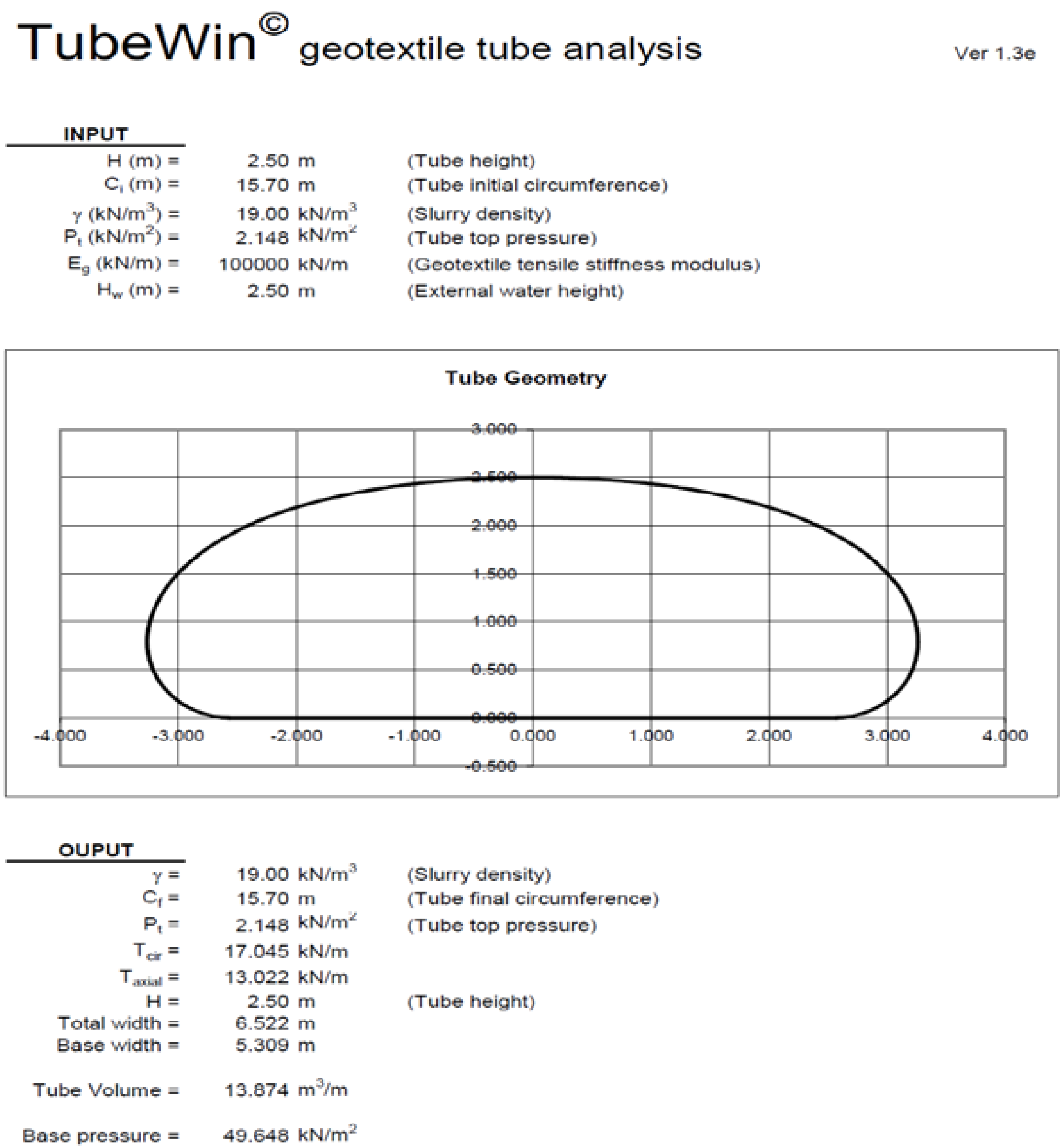


Fig. 5 : Analysis of geotextile tube using TubeWin Software

Strain at nominal tensile Strength (Weft)(%)	ISO 10319	11
Factory Seam Strength(kN/m)	ISO 10321	160
CBR Puncture (KN)	ISO 12236	22
Abrasion resistance(%)	ASTM D 4886	80
UV resistance(500hrs)(%)	ASTM D 4355	90
Permeability(50mm head)(l/ m^2/s)	ISO 11058	20
Opening size (O90)(μm)	ISO 12956	350

5. CONSTRUCTION

The construction procedures deployed at site are in line to the design philosophy. A hopper is designed at around 50m away from the tube and erected at a height which causes flow by gravity refer to Figure 6. The hopper is connected to the geotextile tube by 6” dia. pipe so that it doesn’t get choked. Sufficient river water is drawn during the high tides and incorporated in to the system almost at the bottom of the hopper to take advantage of the gravity force to allow its flow to the tube. The sand thus poured manually in the hopper gets mixed with water and allowed to flow in to the tube. The distance of the hopperand thetube is critical to regulate the velocity of flow. Hence the distance is designed by trial and error method to achieve optimum effectiveness in pumping. The most critical aspect of construction is to fill the tube during high tides to draw water to the pumping system. The tube in high tide will be subjected to lateral movements and hence needs guide posts to hold it in its dyke alignment and position. Thus the construction is planned in such a way that tube is aligned in position during low tides and filling commences as the tide rises.This allows a 4 hour filling window.Sufficient time is allowed for withdrawal of water from the tube. Sufficient allowance is made for sediment losses due to internal erosion. The filling of the tubeof 15.7m circumference and 25m length to the designheight took 72 hours that including intertidal stoppages. Though the filling of the tube has taken relatively longer time, an inflated height ranging from 2.55m ~2.75m is achieved.Scour apron is placed prior to the placing of the geotextile tubes, which would help in reducing erosion below the tubes. When the filling of geotextile tube with sand is completed, all filling ports are then closed. A parallel geotextiletube isthen laid side by side and filled in the same manner refer to Figure 7. When the two bottom tier geotextile tubes have been installed, the gap in-between is filled with sand bags and leveled. The uppertier geotextile tube is then installed following the same process refer to Figure 8.Once the tubes are filled and attained the desired height and the entire segment of the temporary construction platform is completed, earth fill is deposited within and subsequent construction of the dyke with sand bags and boulders is done as per cross-section refer to Figure 9. A non-woven geotextile of mass 500g/m2 is placed at the interface of the sandbags and the boulders. Completed picture of the structure after installation of geotextile tubes and associated works can be seen in Figure 10.

Fig. 6 : Slurry mixing tank used at the project site

Fig. 7 : Installation of bottom tier geotextile tubes

Fig. 8 : Installation of second tier geotextile tube

Fig. 9 : Boulders placement on the geotextile tube

Fig. 10 : Completed structure after installation

6. CONCLUSION

It's often challenging to make use of locally available of marginal quality used in design & construction of long-term structures. However, efforts to design structures which may allow usage of such marginal quality materials will make projects economically viable and sustainable. In the present paper, it is concluded that the locally available materials, such as fine sand, along the banks of River Ganges can be effectively used as fill materialsin to filling geotextile tubes by engineering the geotextile tube materials & adopting well designed construction techniques suitable to the site conditions without the risk of tube bursting, lateral spreading and internal erosion. Optimum hydraulic characteristics, low elongation of geotextile tube material, higher seam strengths andwell-designed construction techniques are key contributors to the performance of the geotextile tubes to achieve desired shape and height when filled with fine sand.

REFERENCES

GRI (1991). GRI Test Method GT11: Standard Practice for "International of Geotextile Tubes used as Coastal and Riverine Structures".

Lawson, C.R. (2006). Geotextile containment for hydraulic and environmental engineering, Proceedings of the Eighth International Conference on Geosynthetics, Yokohama, Japan, Vol. 1, pp 9 – 48.

Yee, T.W.(2002). Construction of underwater dykes using geotextile containment systems, in Proceedings ofthe Seventh International Conference on Geosynthetics, Nice, France, Vol. 3, pp. 1161-1164.

EVALUATION OF INTERFACE BOND STRENGTH OF GEOSYNTHETIC REINFORCED PAVEMENT LAYERS

Vinay Kumar V[1] and Sireesh S[2]

ABSTRACT

The geosynthetic reinforcements are often provided to reduce the rehabilitation cost and to improve the performance of the pavements. With the introduction of various types of commercially available geosynthetics in pavements, along with the improvement of pavement condition against the traffic wheel loads, there is also a disadvantage. The disadvantage is that the geosynthetic interlayer used often tends to reduce the bonding between the pavement layers, and this further accelerates the various types of failure mechanisms in the pavement.

In this study, the evaluation of interface bond strength between the pavement layers is done. The interface bond strength between the granular base layer and the asphalt surface layer with and without geosynthetic reinforcement is determined using shear mechanism. The geosynthetic interlayers used in the current study are geogrids and a geo-jute mat. The bond strength values against the various interlayers are determined and computed.

***Keywords** : Geosynthetic reinforcement, Interface bond strength, Shear mechanism, and Pavement layers.*

1. INTRODUCTION

The primary concern of pavement engineers worldwide is proper maintenance of roads to provide a safe and smooth ride quality to the road users for a maximum period. The road network across the globe majorly consists of flexible (asphalt concrete) pavements. The flexible pavements fail due to two reasons: formation of ruts and bottom-up fatigue cracking on the pavement surface. Rutting on the road surface is caused due to vertical deformations occurring on the natural subgrade surface. The fatigue cracking is originated from the bottom of the hot mix asphalt (HMA) layer, due to the mobilization of tensile strains. Further, when these strains reach the limiting tensile strength of HMA mix, cracks are observed to be initiated in the HMA layer and propagated to the surface. To minimize these failure modes, many design techniques have been employed. Which includes, increasing the stiffness of HMA layer by increasing its thickness, application of specially modified binder in the HMA mix to reduce wheel tracking (Mayama and Sugawara, 1978) and by providing geosynthetic materials (Chen et al. 2009). However, the increase in thickness of HMA layer enhances the cost of construction invariably, and the HMA mix with the special binder is observed to witness thermal cracks. But, geosynthetic materials provided not only reduces the rehabilitation cost and construction cost (by reduced HMA layer thickness), also improves the performance life of the pavement system (Komatsu et al. 1998; Brown et al. 2001).

2. BACKGROUND

The geosynthetic materials are provided at various locations in pavement structure depending upon the requirements or the purpose to be served. The geosynthetic material, when placed at the interface of subgrade and base layers improves the pavement performance life (Al-Qadi et al. 2008). Also, reduces the thickness of base course (Montanelli et al. 1997; Cancelli and Montanelli 1999) and the development of rutting is delayed (Moghaddas and Small 1996; Kinney et al. 1998). The reinforcement when placed at the interface of surface and base layers, improves the performance of pavements by reducing the fatigue strains (high tensile strains) at the bottom of HMA layer (Brown et al. 2001; Bocci et al. 2007). Moayedi et al. (2009) carried out a series of two-dimensional finite-element simulations and learned that the reinforcement placed at the bottom of asphalt concrete layer leads to the highest reduction in vertical deformation. Further, Prieto et al. (2007) reported that the geosynthetic reinforcements improved the performance life of pavement systems against cracking, but were also found to accelerate the delamination of pavement layers. This observation highlights the fact that the introduction of geosynthetic reinforcements may cause debonding, at the interface. Similarly, Brown et al. (2001) found that, with the introduction of reinforcements at the interface, there is a decrease in the shear resistance value. However, these shear resistance values are strongly influenced by

1. Doctoral Student, IIT Hyderabad, Kandi, Sangareddy-502285, India

2. Associate Professor, IIT Hyderabad, Kandi, Sangareddy-502285, India

the mesh dimensions of the grid (Canestrari et al. 2006). Reduction in the Interface bond strength can lead to a variety of distress like slippage cracking, delamination and potholes, etc. in the asphalt concrete pavements (Hu and Walubita 2010). Slippage cracks may be defined as half moon shaped cracks with two ends pointed away from the traffic travel direction (Shahin 1994). Many researchers have either reported the interface shear strength between two asphalt layers (both reinforced and unreinforced) (Caltabiano and Brunton, 1991; Brown et al. 2001; Ferrotti et al. 2012) or between two construction and demolition materials (both reinforced and unreinforced) (Arulrajah et al. 2013). But, however, not much information is available on the interface shear strength between the asphalt concrete surface layer and a granular base layer with and without reinforcements.

With this background, it can be summed up that there are very limited studies done on the interface bond strength of geosynthetic reinforced pavement layers. Hence, an attempt has been made to study the various factors affecting the interface bond strength of geosynthetic reinforced pavement layers.

3. MATERIALS

3.1 Hot Mix Asphalt Concrete

The HMA mix used in the current study is a bituminous concrete mix, prepared at the mix plant and transported to the laboratory. The mix consists of a nominal aggregate size of 13 mm and penetration grade (PG 60-70) bitumen with an optimum bitumen content of 5.5 % by the weight of aggregates. The particle size distribution of the aggregates used in the preparation of bituminous concrete material is as shown in Figure 1. The theoretical maximum density of HMA mix is found to be 2.33 gm/cc, whereas the maximum density obtained in the laboratory is 2.23 gm/cc with a degree of relative compaction of about 96 %.

2. Base Course Material

In the current study, the base course material used for the sample preparation is wet mix macadam (WMM) material. The sieve analysis of WMM material is done according to IS 2386-4 and particle size distribution curve is as shown in Figure 1. The maximum dry density and the optimum moisture content were determined by modified Proctor compaction test according to ASTM D1557 and IS 2720-8. Figure 2 shows the modified Proctor compaction curve obtained for the WMM material, and it is found from the curve that the maximum dry density and optimum moisture content is 2.47 gm/cc and 6.3 % respectively. The physical properties of WMM material are presented in Table 1.

Table 1 : Physical properties of WMM material

Properties	Standards	Values
Aggregate Impact Value (%)	IS 5640	25%
Aggregate Crushing Value (%)	IS 2386-4	30%
Flakiness Index (%)	IS 2386-1	12%
Elongation Index (%)	IS 2386-1	13%
Liquid Limit (%)	IS 2720-5	20%
Plastic Limit (%)	IS 2720-5	15%
Plasticity Index	IS 2720-5	5

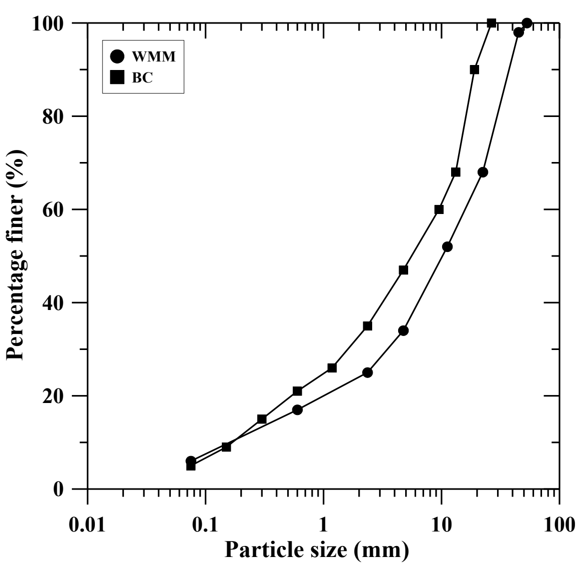


Fig. 1 : Particle size distribution curve for WMM and BC materials

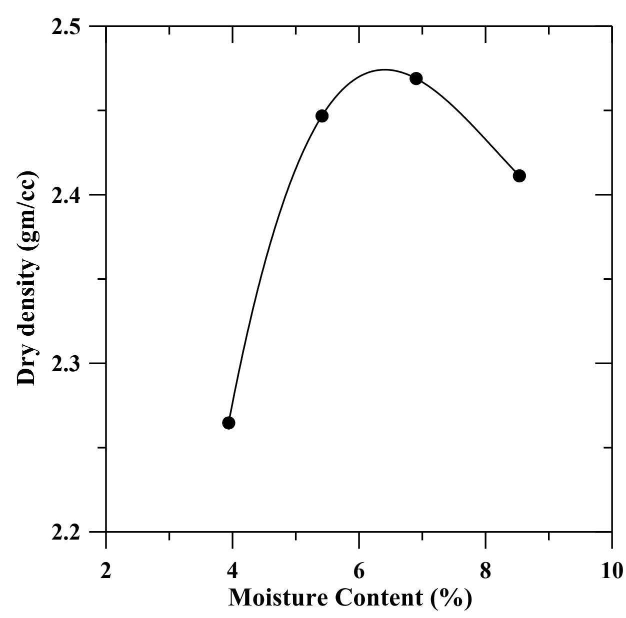


Fig. 2 : Compaction characteristics of WMM material

3.3 Geosynthetic Reinforcement

The current study focuses on analyzing the interface bond strength with different geosynthetic reinforcements placed at the interface of base and surface courses and based on the material type, aperture size, and bonding ability, three types of geosynthetic reinforcements have been selected for the current study and they are:

Woven geo-jute mat without any apertures manufactured either by machine or hand weaving of natural fibers and threads. The tensile strength of material is found to be 20 kN/m and is represented as GR1 in the current study. Bi-axial polypropylene grids represented as GR2 is manufactured with the help of polypropylene material to obtain a grid structure with aperture size equal to 40 mm and possess a tensile strength of 30 kN/m. Polyester grids with a polymeric modified binder coating (GR3) is a biaxial grid manufactured using high density and high tenacity polyester yarns, which are knitted together to form a grid with a uniform mesh opening of 18 mm and has a tensile strength of 40 kN/m.

4. EXPERIMENTAL PROGRAM

4.1 Sample preparation

The sample preparation process consists of two stages and during the first stage, base course material (WMM) is compacted in the lower shear box using a static weight compactor weighing 5 kg and has a height of fall of 50 cm. The WMM material is compacted with a 98 % relative compaction of the modified Proctor density and allowed to dry for about 24 hours similar to the procedure followed in field conditions. During the second stage, a tack coat is applied to the dry base course material at a rate of 0.35 to 0.40 kg/sq.m as per MORTH specifications (MORTH, 2003) and allowed for emulsion breaking. The emulsion breaking time is usually an hour, followed by placing geosynthetic reinforcements before placing the HMA mix and compacting them using the same static weight compactor used to compact WMM material. Figure 3 shows the detailed step by step procedure of sample preparation in the current study. The compacted WMM layer has a thickness of 100 mm, whereas the compacted HMA layer, is only 50 mm thick.

4.2 Test Setup and Procedure:

The test setup consists of a large-scale direct shear test apparatus having two shear boxes of size 300 mm (length) × 300 mm (width) × 100 mm (depth) separated by an interface zone. Figure 4 shows a schematic of the test setup used in the current study. The test apparatus has two shear boxes with a moveable bottom shear box and a fixed upper shear box. Both the boxes are clamped together using shear keys during sample preparation and removed before the application of shear displacement. Once, the sample is prepared as explained in section 4.1; a normal load is applied perpendicular to the sample surface constantly throughout the test. The test procedure is repeated for different normal loads applied and sample combinations. In the current study, four types of samples are prepared namely: NGR, GR1, GR2 and GR3 and tested at a normal stress of 30 kPa, 60 kPa, and 120 kPa respectively. The tests are performed for the above normal stress and sample combinations as per UNI/TS 11214 and ASTM D5321 standards with a constant shear displacement rate of 1 mm/min and terminated once the horizontal or shear displacement reaches 50 mm.

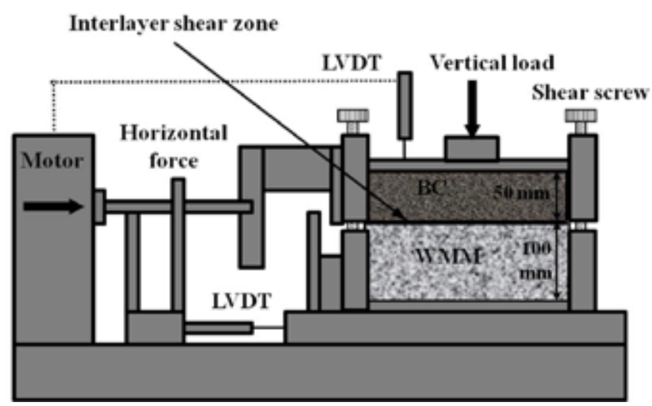


Fig. 4 : Schematic of Interface shear strength test setup

Fig. 3 : (a) WMM material compacted as a base course layer; (b) Geosynthetic reinforcement placed at the interface zone; (c) HMA compacted as a surface course layer

RESULTS AND DISCUSSIONS

The peak and residual interface shear strengths between the unreinforced pavement layers and geosynthetic reinforced pavement layers were obtained separately from the shear stress and horizontal displacement output graphs. Figure 5 show the plots of shear stress variation w.r.t the horizontal displacement for all the sample combinations tested with and without geosynthetic reinforcement. It is observed that the shear stress values are increasing with the increase in normal stress for all NGR, GR1, GR2 and GR3 cases. The shear stress is found to reach a peak value and then reduces to residual shear stress value under a large strain in all the samples tested. However, the peak interface shear strength of NGR case is witnessed to be more than all the other reinforced cases. In reinforced cases, the presence of an interlayer at the interface of base course (bottom layer) and the surface course (top layer) reduces the interface shear strength. The reduction in strength is due to the smooth surface of the reinforcement, which reduces the friction between layers.

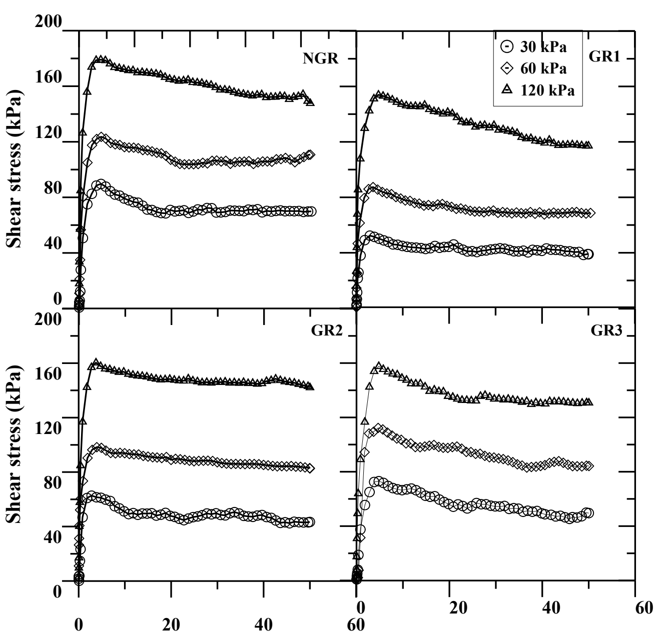


Fig. 5 : Variation of shear stress with horizontal displacement for different normal stress applied

Figures 6 and 7 present the interface shear strength properties of unreinforced and geosynthetic reinforced samples at peak state and residual state respectively. Whereas Table 2 gives the comparison of peak state and residual state interface shear strength properties of all the samples tested.

From Figure 6, it is evident that the interface shear strength is highest for NRG case. Among the geosynthetic reinforced samples, higher interface shear strength is seen in GR3 followed by GR2 and finally GR1. The reason for this would be the presence of apertures in the case of GR3 and GR2 cases, which would improve the interface bond condition by through hole bonding (THB) action. Whereas, the THB is not witnessed in GR1 as there is no aperture openings present. Similar results were observed by Canestrari et al. (2006) and Caltabiano and Brunton, (1991). In contrary to the above conditions, the GR2 sample with a larger aperture (40 mm) opening compared to GR3 sample (18 mm) has a lesser interface shear strength. The reasons for this would be the geosynthetic material composition, the thickness of the reinforcement material and presence of polymer modified binder which enhances the interface bond strength.

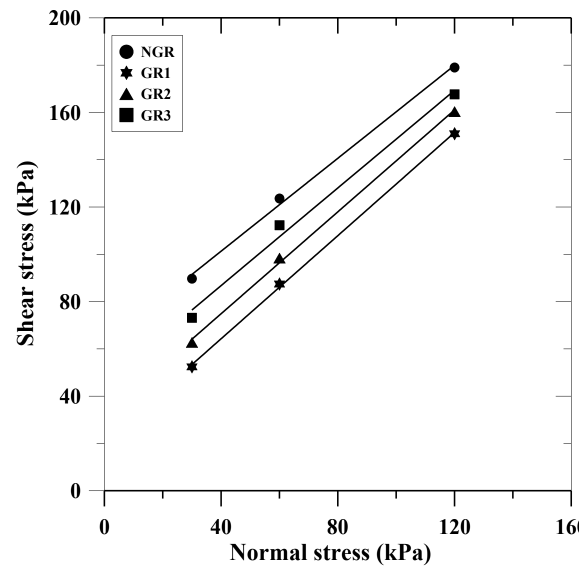


Fig. 6 : Peak interface shear strength characteristics of unreinforced and geosynthetic reinforced pavement layers

Table 2 : Peak and residual state interface shear properties

Interface condition	Peak state		Residual state	
	c (kPa)	Φ (deg)	c (kPa)	Φ (deg)
NRG	62.00	44.49	49.00	40.75
GR1	20.63	47.46	14.50	40.67
GR2	31.73	44.63	20.50	43.90
GR3	45.45	45.84	29.50	40.36

From Figures 6, 7 and Table 2, it is found that there is an apparent reduction in the interface shear strength for samples with geosynthetic reinforcement both at peak and residual states. The rate of decrease in bond strength is evaluated with the help of a performance factor known as the reduction in bond strength (RBS)is introduced. RBS can be expressed mathematically as:

$$RBS\ (\%) = \frac{IBS_{NG} - IBS_G}{IBS_{NG}} \times 100 \quad ...(1)$$

Where, IBS_{NG} is the interface bond strength between unreinforced pavement layers, IBS_G is the interface bond strength between geosynthetic reinforced pavement layers.

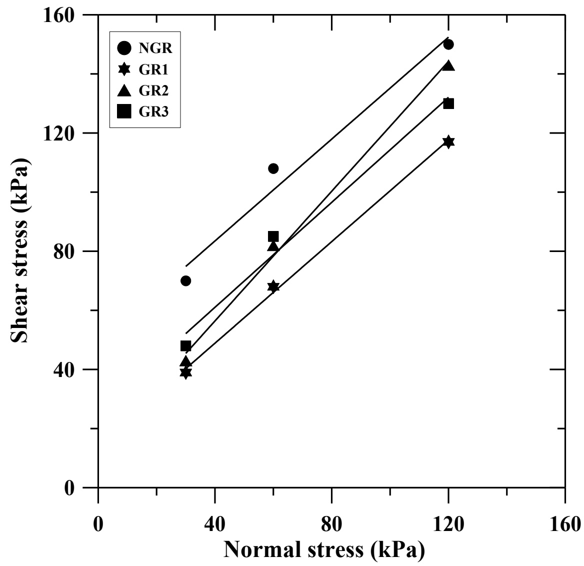


Fig. 7 : Residual interface shear strength characteristics of unreinforced and geosynthetic reinforced pavement layers

From Figure 8, it is understood that GR1 sample has the highest reduction in bond strength compared to the other reinforcement types. The reason could be the absence of aperture openings in reinforcement material

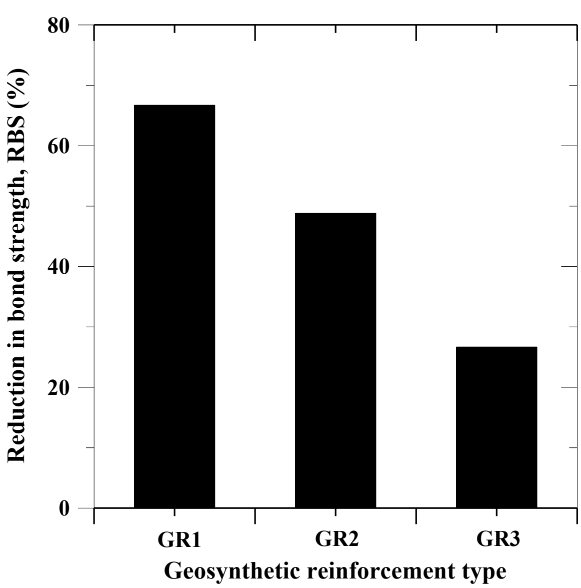


Fig. 8 : Variation of RBS (peak state) with geosynthetic reinforcement type

as there is no direct contact between the layers and the bonding mechanism is entirely dependent on adhesion of reinforcement material to the adjacent layers. The least reduction in bond strength is witnessed in the GR3 sample, although the aperture size of latter is lesser than GR2 sample. The above condition simplifies that the bond strength is not only dependent on the aperture size but also depends on the type of material composition and the presence of the surface coating. The polymer modified binder coated on the surface of GR3 helps to improve the bond strength through adhesion, and the apertures present further improves the bond strength with the THB mechanism.

6. CONCLUSIONS

The Interface bond strength of geosynthetic reinforced and unreinforced pavement layers are determined using the large-scale interface shear strength test and compared in the current study, and the following conclusions can be drawn:

The interface bond strength between the pavement layers plays a vital role in maintaining the entire pavement system as a monolithic unit, which helps to improve the overall performance of pavements. The interface shear strengths of the unreinforced pavement layers are reported to be consistently higher than that of the geosynthetic reinforced pavement layers. This condition can be attributed to the lack of interlocking between the layers and the smooth surface of the geosynthetic reinforcement. The interface shear strength for GR3 sample is found to be higher than that of GR2, whereas the GR1 sample if found to have the least interface shear strength. The interface bond strengths of reinforced pavement layers were compared with the unreinforced pavement layers and a performance factor; RBS was employed to study the reduction in interface bond strength of reinforced pavement layers. The interface shear strength of the geosynthetic reinforced pavement layers not only depend on the aperture openings in the material but also depends on the type of constituent material composition. A geogrid having a larger aperture size with a binder coating on the top and a non-woven backing would be an ideal geosynthetic reinforcement as the non-woven backing provides the interlocking of the aggregate base layer and the binder coating on the top bonds well with the HMA surface course.

REFERENCES

Al-Qadi, I.L., Dessouky, S.H., Kwon, J. and Tutumler, E. (2008). Geogrid in Flexible Pavements: Validated Mechanism, Transportation Research Board, Annual Meeting.

Arulrajah, A., Rahman, M.A., Piratheepan, J., Bo, M.W. and Imteaz, M.A. (2013). Interface Shear Strength Testing of Geogrid-Reinforced Construction and Demolition Materials, Advances in Civil Engineering Materials, Vol. 2, No. 1, pp. 189-200.

ASTM D1557. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA.

ASTM D5321. Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA,

Bocci, M., Grilli, A., Santagata, F.A. and Virgili, A. (2007). Influence of reinforcement geosynthetics on flexion behavior of double-layer bituminous systems, In: International conference on advanced characterization of pavement and soil engineering materials, Athens.

Brown, S.F., Thom, N.H. and Sanders, P.J. (2001). A study of grid reinforced asphalt to combat reflection cracking, J. Associated Asphalt Paving Technologists, Vol. 70, pp. 543-569.

Caltabiano, M.A., and Brunton, J.M. (1991). Reflective Cracking in Asphalt Pavement, J. Associated Asphalt Paving Technologists, Vol. 60, pp. 310-330.

Cancelli, A. and Montanelli, F. (1999). In-Ground Test for Geosynthetic Reinforced Flexible Paved Roads, Proceedings of the Conference on Geosynthetics ’99, Boston, MA, April, Industrial Fabrics Association International (IFAI), Roseville, MN, pp. 863-878.

Canestrari, F., Grilli, A., Santagata, F.A. and Virgili, A. (2006). Interlayer shear effect of geosynthetic reinforcements, In: 10th International conference on asphalt pavements, Québec.

Chen, Q., Abu-Farsakh, M. and Tao, M. (2009). Laboratory Evaluation of Geogrid Base Reinforcement and Corresponding Instrumentation Program, Geotechnical Testing Journal, Vol. 32, No. 6, pp. 1-10.

Ferrotti, G., Canestrari, F., Pasquini, E., and Virgili, A. (2012). Experimental evaluation of the influence of surface coating on fiberglass geogrid performance in asphalt pavements, Geotextiles and Geomembranes. Vol. 34, pp. 11-18.

Hu, X. and Walubita, L.F. (2010). Effects of Layer Interfacial Bonding Conditions on the Mechanistic Responses in Asphalt Pavements, J. Transportation Engineering, Vol. 137, No. 1, pp. 28-36.

IS 2386-1. Methods of Test for Aggregates for Concrete. Part 1. Determination of Particle size and shape, Bureau of Indian Standards, Manak Bhavan, New Delhi.

IS 2386-4. Methods of Test for Aggregates for Concrete. Part 4. Determination of Mechanical properties, Bureau of Indian Standards, Manak Bhavan, New Delhi.

IS 2720-5. Methods of Test for Soils. Part 5. Determination of Liquid and plastic limit, Bureau of Indian Standards, Manak Bhavan, New Delhi.

IS 2720-8. Methods of Test for Soils. Part 8. Determination of Water content- Dry density relation using heavy compaction, Bureau of Indian Standards, Manak Bhavan, New Delhi.

IS 5640. Method of Testing for determining Aggregates Impact Value of soft coarse aggregates, Bureau of Indian Standards, Manak Bhavan, New Delhi.

Kinney, T.C., Abbott, J., and Schuler, J. (1998). Benefits of Using Geogrids for Base Reinforcement with Regard to Rutting, Transportation Research Record. 1611, Transportation Research Board, National Research Council, Washington, D.C., pp. 86-96.

Komatsu, T., Kikuta, H., Tuji, Y. and Muramatsu, E. (1998). Durability assessment of geogrid-reinforced asphalt concrete, Geotextiles and Geomembranes, Vol. 16, No. 5, pp. 257-271.

Mayama, M. and Sugawara, T. (1978). Mechanical properties of various paving mixtures (part 1): stress relaxation behaviour of mixtures, Journal of Japan Petroleum Institute, Vol. 21, No. 5, pp. 342-350.

Moayedi, H., Kazemian, S., Prasad, A., and Huat, B.B.K. (2009). Effect of Geogrid Reinforcement location in paved road improvement, Electronic Journal of Geotechnical Engineering, Vol. 14, Bund. P

Moghaddas, N.F. and Small, J.C. (1996). Effect of Geogrid Reinforcement in Model Track Tests on Pavements, J. Transp. Eng., Vol. 122, No. 6, pp. 468-474.

Montanelli, F., Zhao, A. and Rimoldi, P. (1997). Geosynthetic- Reinforced Pavement System: Testing and Design, Proceedings of the Conference on Geosynthetics ’97, Long Beach, CA, March, Industrial Fabrics Association International (IFAI), Roseville, MN, pp. 619-632.

MORTH. Specifications for Road and Bridge Works, Ministry of Road Transport and Highways, Indian Road Congress (IRC), New Delhi.

Prieto, J.N., Gallego, J., and Perez, I. (2007). Application of the wheel reflective cracking test for assessing geosynthetics in anti-reflection pavement cracking systems, Geosynthetic Int, Vol. 14, No. 5, pp. 287-297.

Shahin, M.Y. (1994). Pavement Management for airports and parking lots, Chapman and Hall, New York.

UNI/TS 11214. Mechanical Properties of Road and Airfield Pavements: Interlayer Shear Performance-related Characterization: ASTRA Test Method.

RESTORATION AND BANK PROTECTION WORKS ALONG THE ROHMORIA REACH OF RIVER BRAHMAPUTRA USING GEOSYNTHETICS - A CASE STUDY

Suresh Maurya[1], Manish Gupta[2], R. Chitra[3] and Nripendra Kumar[4]

1. INTODUCTION

Flood management and bank erosion control has become a prime matter of concern due to its devastating impact in life and property. Many anti-erosion techniques are used as engineered solutions to the problems. This paper highlights the source, flow regime, complex and unique soil erosion characteristics of the Brahmaputra River and describes the case study where Geosynthetic are used as erosion control measures and their effectiveness at one of the vulnerable reach (Rohmoria) along the Brahmaputra River. The Geosynthetic materials used as preventive measures were tested at CSMRS, New Delhi as per project Quality Assurance plan and presented in this paper along with advantages of using Geosynthetic materials.

1.1 The Brahmaputra River System

The river Brahmaputra is one of the largest rivers of the world with a specific yield of 85 ha.m./ sq.km., which is next only to Amazon (87 ha m./sq.km.). It originates from Kanglung Kang glacier east of Manas–Sarovar at an elevation of 5150 m and traverses 1625 km. in Tibet, 918 km. in India (278 km. in Arunachal Pradesh and 640 km. in Assam) and 363 km. in Bangladesh before reaching the Bay of Bengal jointly with the Ganges (Figure 1). The Brahmaputra basin drains a combined international area of approx. 5,80,000 sq.km., out of which 2,93,000 sq.km. is in Tibet, 2,40,000 sq.km. in India and Bhutan and 47,000 sq.km. in Bangladesh. It is the fourth largest river in the world in terms of average discharge at the mouth and second only to the Yellow River in China with respect to the amount of sediment transport.

In India, the Brahmaputra River flows southerly and westerly through the states of Arunachal Pradesh and Assam over a distance of approximately 918 km. In the Himalayas range before entering India, the river is known as the Tsangpo River flowing from west to east, then south through the eastern Himalayas as the Dihang River. In Assam, the Dihang River is joined by Dibang and Lohit River also know as start of Assam valley to form the

Fig. 1 : Brahmaputra River System

1. Scientist 'B', CSMRS New Delhi
2. Scientist 'D', CSMRS New Delhi
3. Scientist 'E', CSMRS New Delhi
4. Scientist 'E', CSMRS New Delhi, nipendra@nic.in

Brahmaputra River. Near the western boundary of Assam, the river turns south to enter Bangladesh changing its name to Jamuna till its confluence with the Ganges from where both the Jamuna and Ganges form the Padma flowing into the Bay of Bengal. The total length of the river in Bangladesh is approximately 363 km.

A longitudinal bank profile of the Brahmaputra presented in Goswami (1985) reveals that the river has a gradient of 0.09 to 0.17 m/km near Dibrugarh, Assam at the start of the valley and it reduces to about 0.1 m/km near Guwahati. Through Assam, the long term average discharge increases from 8,500 to 17,000 cubic meters per second as flows are augmented by major tributaries. The width of the river varies from one km on an individual channel to as much as 10 km in some reaches with multiple braided channels. Almost through its entire length in Assam, the river has three to six channels separated by islands and mid-channel bars under low flow conditions. These bars and islands become submerged during major floods. The pattern of channels changes frequently under flood conditions accompanied by extensive erosion of banks and disposition of sediment forming sand bars. Figure 2 presents the typical braided channels of the Brahmaputra River.

1.2 Flow Regime and Sediment Transport

The Brahmaputra is characterized by high rates of basin erosion, river bank erosion, channel migration, and sediment yield. The channel configuration of the river undergoes large changes in response to variations in the flow regime and the pattern of sediment transport. During November through March (low flow season), the river flows in highly braided channels comprised of numerous sand bars and islands (Figure 2). Each year in May as the flow begins to rise; most of the bars as well as islands get submerged due to raising stage (water depth) in response to high runoff from the monsoon precipitation. Coleman (1969) noted that the most striking feature of the change in the configuration of the Brahmaputra is the continuous shift of the flow channel from one location to another within the bank lines of the river. He reported that the movement of the flow channel is high during the rising stages (May through June), relatively less during the peak of the flood (July through August), most erratic during the receding stages (September through October) and very little during the low flow stages (November through March). Goswami (1985) described that the sediment transport is high during the rising stage marking aggradation of the channel while the falling trend marked by low sediment transport indicating degradation of the channel. During floods, because of change of river hydraulics (mainly, depth, velocity and shear stress), inducing variable sediment transport characteristics and erosive forces, the channel starts shifting at some vulnerable reaches causing serious bank erosion

1.3 Flood And Bank Erosion Problem of The State

Floods, bank erosion and drainage congestion are the major problems faced by the Assam during the monsoon season. The flood of this region is a recurring phenomenon, every year several waves of flood cause damage to huge areas in the state. The loss to people in terms of houses, crops and cattle is immense. The figures of loss runs into hundreds of crores every year apart from huge damages to roads, bridges, schools, communication systems and other such facilities. Table 1 shows flood damage trends in the Brahmaputra valley. Another major problem being faced by the state of Assam is bank erosion. Bank erosion by the rivers has been a serious issue since last six decades as more than 4.27 Lakh Hectares of land was already eroded

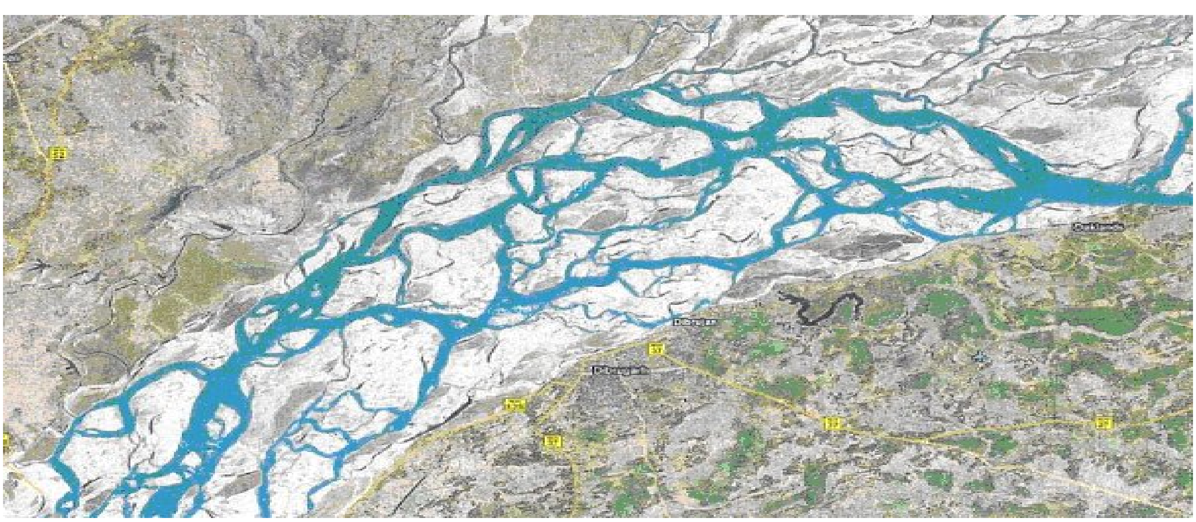


Fig. 2 : Braided channels of Brahmaputra River

away by the river Brahmaputra and its tributaries since 1950, which is 7.40 % of area of the state. As assessed, the annual average loss of land is nearly 8000 Ha. The width of river Brahmaputra has increased up to 15.00 km at some places due to bank erosion.

The river bank erosion has caused major human and economic disasters than the annual flooding. The loss or the discomfort associated with the flooding is temporary but the loss of land due to river bank erosion is permanent and has a long term impact on the economy of the region and its people. Once a section of well developed land (agricultural, industrial, or residential) or productive forest land is lost due to river bank erosion, it can hardly be replaced. Table 2 shows overall damage due to bank erosion in Assam which is alarming in nature. Breaches of embankments due to bank erosion by the river have become a common phenomenon. New areas are being affected by erosion every year. The river line fertile agriculture lands of the state are reducing due to erosion, which has a very negative impact on the rural economy of the state.

The salient hydraulic and bank material factors responsible for bank erosion of the Brahmaputra River system are (i) rate of rise and fall of river water level, (ii) number and position of major channel active during flood stage, (iii) angle at which the flow channel approaches the bank line, (iv) amount of scour and deposition that occurs during flood, (v) variability of cohesive soil in bank material composition, (vi) formation and movement of large bed forms, vii) intensity of bank slumping, and viii) progression of abandoned river courses to present-day channel.

2. FLOOD MANAGEMENT ACTIVITIES USING GEOSYNTHETICS IN RESTORATION AND BANK PROTECTION AT ROHMORIA, DIBRUGARH, ASSAM

In order to provide protection to the people, short & medium term measures were taken up by the Water Resources Department of Assam under various policy initiatives. These measures include construction of bank revetments, stone spurs, boulder deflectors, timber dampeners, pile screens R.C.C porcupines etc. Recently a nine kilometre stretch along the Rohmoria area in Dibrugarh district has been identified as highly affected zone. The flood protection works and anti-erosion works are designed using geotextile and geobags and focus to provide protection of the bed and bank from the erosive forces of the Brahmaputra River.

The Geosynthetic materials used for these protection works were evaluated for their quality as per QA plan at the Central Soil & Material Research Station (CSMRS), Ministry of Water Resources, New Delhi. CSMRS is a premier Institute in the country located at New Delhi which deals with field and laboratory investigations, basic and applied research on problems and also functions as an advisor and consultant in the field of Soil, Concrete & Rock Engineering solutions. A well established Geosynthetic material testing laboratory at CSMRS has the capability

Table 1 : Flood damage trends in the Brahmaputra valley (Bhuyan, 2013)

Year	Average Annual area flooded (mha)		Average Annual population affected	Affected population per ha of flooded area	Average Annual Damage (Rs in Lakh)	Value of crop lost as % of Total Damage
	Total	Cropped				
1953-59	1.13	0.10	860,000	0.8	586	66
1960-69	0.75	0.16	15,20,000	2.0	757	92
1970-79	0.87	0.18	20,00,000	2.3	1,518	89
1980-88	1.43	0.40	45,50,000	3.2	14,552	96
1999-05	1.07	0.38	45,86,000	4.3	71,717	34
2006-11	0.26	0.17	10,28,000	4.0	3,880	22

Table 2 : Overall damage due to bank erosion in Assam (Bhuyan, 2013)

Year	Area eroded in Ha.	Nos. of village affected in No	Family affected in No.	Value of property with land loss, Rs in Lakh
2001	5348	227	7395	377.72
2002	6803	625	17985	2748.34
2003	12589.6	424	18202	9885.83
2004	20724	1245	62258	8337.97
2005	1984.27	274	10531	1534
2006	821.83	44	2832	106.93

of testing woven and nonwoven geotextiles, filters, geomembranes, geonets, geogrids, glass fibre paving mat, G.I wires, polymer rope gabions and geocomposites that are used in drainage, earthwork, erosion control and soil reinforcement applications.

Rohmoria area is about 20 km northeast of Dibrugarh town on the south bank of Brahmaputra in Dibrugarh district of Assam. It is the area between Dibrugarh city and Brahmaputra River and is largely covered with tea gardens. After the 1950 Assam earthquake, Dibang river started pushing southward raising the possibility of flooding and washing away Dibrugarh. The area has witnessed erosion for the last sixty years and more than 25 villages have been wiped out by erosion. During the recent period from 2009-2013, due to heavy floods and erosive forces of the flowing river the bank line along the Rohmoria reach, has shifted by as large as 400 m. A reach of approximately 9 km was identified as highly affected zone and bank erosion and flood protection measures were planned for a stretch of 2.6 km using geotextile filter materials and geobags (Figure 3). The benefitted area would be approximately 18,000 hectares which would protect the population of approximately 1,20,000 inhabitants settled in surrounding area. The erosion control measures started in 2012 have however effectively controlled this erosion problem to a large extent.

The embankment construction was a part of bank protection while the launching apron and key were part of bed protection. This was followed by well dressed bank at a stable inclined slope of IV: 3H. The height of slope was approximately 5.5 m. Bank protection followed by a suitable bed protection can be considered as the key success of river bank protection works. The bank and bed protection were carried with multiple layer of Geotextile bags placed on geotextile filter layer along the bank length of 2600 m. Strips of steel Gabions and PP rope gabions filled with geotextile bags were placed at regular intervals to impart further stability to the scour protection measure. Creating such type of integrated structure with greater area and uniformity in construction reduces damage to the base of structure and chance of sinking considerably. Figure 4 shows typical design section of anti-erosion work.

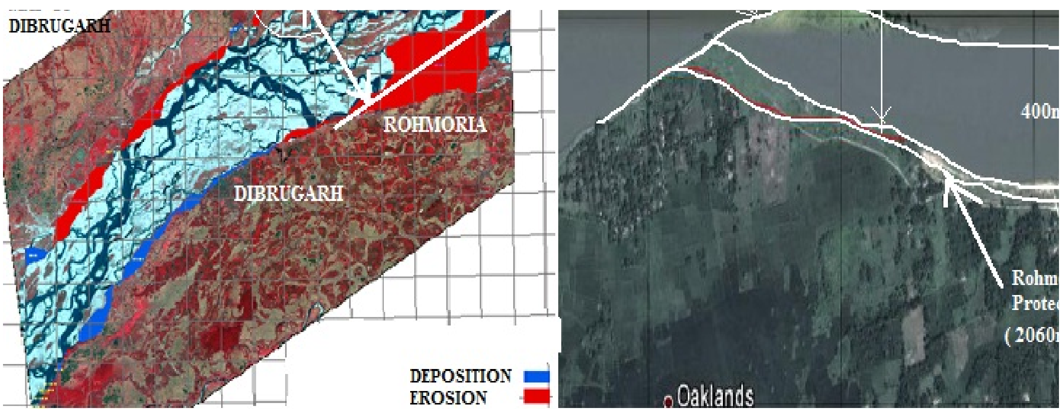


Fig. 3 : Bank Erosion & Rohmoria protection work

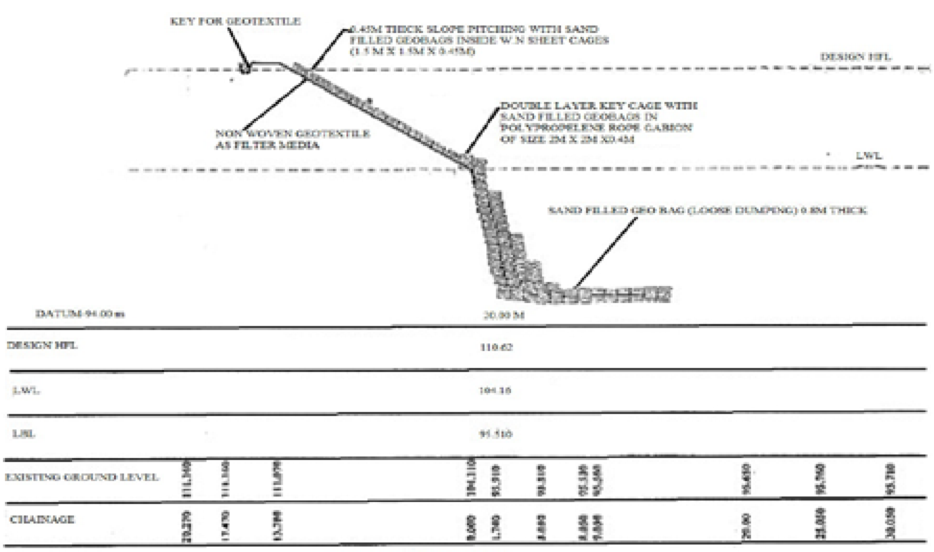


Fig. 4 : Typical design section of anti-erosion work

2.1 Laboratory Investigation

As part of the quality assurance programme, CSMRS, New Delhi carried out extensive testing for evaluating the properties of non-woven geotextile bags, filter media & PP rope gabions to be used for the protection work. The Geotextile bags of size 1.03 m x 0.70 m made up of non-woven Geotextile having mass per unit area in the range of 400 gsm manufactured from polypropylene or polyester, stitching the two sides of the bags with polyester thread. A filter media of non-woven Geotextile having mass per unit area in the range of 400 gsm and Polypropylene rope gabions were of 9 mm diameter rope having weight of 42 gm/m with mesh opening 150mm x 150mm were specified.

The Laboratory tests such as apparent opening size, mass per unit area, thickness, tensile strength & elongation (wrap & weft), Grab tensile strength & elongation (wrap & weft), Permittivity, CBR Puncture strength, Puncture resistance etc were carried out on the above materials received from the projects. All these tests were carried out in accordance with ASTM standard test methods. The tests results are presented in the Table 3, 4 & 5.

Table 3 : Range of results of Laboratory tests carried out on nonwoven geotextile bags.

Properties	Range of Results
Mass per unit area, g/m^2	400- 405
Thickness, mm	3.5 -3.6
Apparent Opening Size, microns	90-100
Tensile Strength (MD), kN/m	29-31
Tensile Strength (CD), kN/m	24.5-26
Tensile Elongation (MD), %	55-60
Tensile Elongation (CD), %	57-60
Grab Tensile strength (MD), N	2005-2015
Grab Tensile strength (CD), N	1560-1565
Permittivity, cm/s	5.5-5.6
CBR Puncture strength, N	5000 to 5100

Table 4 : Range of results of Laboratory tests carried out on Filter media

Properties	Range of Results
Mass per unit area, g/m^2	400-405
Thickness, mm	2.5-2.7
Apparent Opening Size, microns	90-100
Grab Tensile strength, N	1320-1330
Permittivity, L/m2/s	40-45
Puncture resistance, N	780-800

Table 5 : Range of results of Laboratory tests carried out on Polypropylene rope gabions

Properties	Range of Results
Mesh opening size, mm x mm	150 x 150
Tensile strength, kg	1560-1570

2.2 Solution Implementation

Non-woven Geotextile bags were filled with sand to the specified height to ensure that appropriate density is achieved by filling. After ensuring the bags were filled to the required height, the open ends of the bags were closed by stitching the bags at location using hand stitching machines. Stitched bags were manually loaded on boats for further transportation to the site location for installation. The sequence followed for construction was:

1. Placing of bags for launching apron,
2. Key construction,
3. Placement of Geotextile bag on the embankment for bank protection works.

Major portion of construction of launching apron and key was carried out underwater. This was carried out using suitable vessels and appropriate placing methods. Further, the river bank was dressed to the inclination of 1V:3H and over this a layer of non woven geotextile was laid as filter media. After placement of geotextile filter, Geotextile bags were placed along the length on the bank. Strips of gabions filled with Geotextile bags were installed at specified intervals (Figure 5). Total quantity of filter material was 64300 m^2 and Geotextile bags for the protection works was approximately 8,20,000 numbers and these were placed at the rate of 4,000 number of bags per day. The work was completed in six months from October 2011 to April 2012, with an average placement of 1,25,000 numbers of bags per month.

2.3 Solution Performance And Conclusion

The erosion protection measures constructed with Composite Geosynthetics solution at Rohmoria as Emergent works served the purpose & protected the banks area during the flood of June 2013. The use of Geosynthetics materials permitted to carry out works at a faster rate. Speedy construction helped in completing the protection works within the planned period. The use of mechanically woven steel wire mesh and polymer rope Gabions ensured the stability of the Geotextile bags by providing the peripheral confinement to the bank structures.

After flood, considerable amount of silt deposits were noted on the bags. Siltation on the bags indicates the achievement of the desired function of restoration works along the River (Figure 6 & 7). Natural growth of bushes all along the restoration work has added more stability to barrier. Creating such type of work in a selected area has not only provided stability but also reduces the sinking of protection work as a whole. But the performance of restoration work in both the reaches is still to be observed in coming years as a long term measures and thereby further decision can be firmed up for execution for similar vulnerable reaches.

Fig. 5 : Placement of filter media, Geobags & PP Gabions

Fig. 6 : Bank condition during flood

Fig. 7 : Silt deposit on bags after flood

Sometimes conventional system for solution will not be sufficient for desired results. Use of a composite system, such as protection work with Geosynthetics material may prove effective and economically viable. To keep this system to perform in the long run, it is necessary to prevent the erosion from bed and for that Geotextile bags, filled with the locally available material, is the ideal option. While designing the protection works and choosing the products, due care has to be taken for proper design, structural integrity of the system, experienced designer and contractors who installs the system in order to avoid negative criticism.

Following advantages with this application can be outlined-

1. Filling, transportation and installing the Geobags is quick, simpler & economic when required infilling sand material is abundantly available at site. Locally available unskilled labours for filling the bags can add more economy in project.
2. It takes less time in procurement of the geotextile bags than the boulders & aggregates and also length of carriage distance. Therefore huge cost for carriage of rock boulders would be saved.
3. Uniformity in material specification is also achieved and maintained for the entire project.
4. Conventionally used boulders for protection works has become scarce and also damage the ecological balance. Using of sand filled geotextile bags in various forms, size, shape is found perfect replacement for boulder.
5. Restoration and maintenance work is easier than other conventional methods.
6. Creating such type of integrated structure with greater area and uniformity in construction reduces damage to the base of structure and chance of sinking considerably.
7. Such type of application replaces all other methods for immediate protection in the region where flood is a regular phenomenon and construction is to be completed in a constraint time period.
8. Construction of such structure can be used to restrict the flow towards habitat area, thereby delaying the problem to complete the permanent structure to safeguard the land against erosion.

Acknowledgement

The authors acknowledge the contributions of the Chief Engineer, Water Resources Department and his team by way of active cooperation at the time of actual investigation and testing.

REFERENCES

1. Coleman, J. M. (1969), “Brahmaputra River: Channel processes and sedimentation”, Sedimentary Geology, Vol. 3, 129-239.
2. Goswami, D. (1985), “Brahmaputra River Assam, India, Physiography, Basin denudation and channel aggradation”, Water Resources Research 21(7), 959-978.
3. Bhuyan, D.K. (2013), “Flood Management activities in Assam”, Assam Water Conference -2013, 15-20.
4. Gupta, S.D., Ganesh,A., Shevade,B.,Iyer, A. (2013), “Anti-erosion river bank protection with composite Geosynthetics solution”, Assam Water Conference -2013, 74-77.
5. CWC (2012), Handbook for “Flood Protection, Anti-Erosion & River Training Works”.
6. Gupta, M., Chitra, R. and Ratnam, M. (2012),“Geosynthetics in River Bank Erosion Control”, Conf. on Geosynthetics in Infrastructure –Issues and Challenges, Aug. 25-26, 2012, Osmania University, Hyderabad, 383-394.
7. CSMRS (2011), “Report on Laboratory testing for Water Resources Department”, Dibrugarh.

INTERNATIONAL GEOSYNTHETICS SOCIETY

The International Geosynthetics Society (IGS) was founded in Paris, on 10 November 1983, by a group of geotechnical engineers and textile specialists. The Society brings together individual and corporate members from all parts of the world, who are involved in the design, manufacture, sale, use or testing of geotextiles, geomembranes, related products and associated technologies, or who teach or conduct research about such products.

The IGS is dedicated to the scientific and engineering development of geotextiles, geomembranes, related products and associated technologies. IGS has 47 chapters, over 3,000 individual members and 161 corporate members.

The aims of the IGS are:

- to collect and disseminate knowledge on all matters relevant to geotextiles, geomembranes and related products, e.g. by promoting seminars, conferences, etc.
- to promote advancement of the state of the art of geotextiles, geomembranes and related products and of their applications, e.g. by encouraging, through its members, the harmonization of test methods, equipment and criteria.
- to improve communication and understanding regarding such products, e.g. between designers, manufacturers and users and especially between the textile and civil engineering communities

The IGS is registered in the USA as a non-profit organization. It is managed by five Officers and a Council made up of 10 to 16 elected members and a maximum of 5 additional co-opted members. These Officers and Council members are responsible to the General Assembly of members which elects them and decides on the main orientations of the Society.

IGS CHAPTERS

The IGS Chapters are the premier vehicle through which the IGS reaches out to and influences the marketplace and the industry. Chapter activities range from the organization of major conferences and exhibits such as the 10th International Conference on Geosynthetics in September 2014 in Berlin, Germany and its predecessors in Guaruja, Yokohama, Nice and Atlanta to the presentation of focused seminars at universities, government offices and companies. Chapters create the opportunity for the chapter (and IGS) membership to reach out, to teach and to communicate and they are the catalyst for many advances in geosynthetics. Participation in an IGS chapter brings researchers, contractors, engineers and designers together in an environment which directly grows the practice by informing and influencing those who are not familiar with our discipline.

MEMBERSHIP

Membership of IGS is primarily organised through national Chapters. Most individual members (94%) belong to the IGS through Chapters. Chapter participation allows members to be informed about, and participate in, local and regional activities in addition to providing access to the resources of the IGS.

IGS Offers the following categories of membership:

Individual

Individual member benefits are extended to each and every individual member of the IGS including Chapter Members. Additional chapter benefits are provided to Individual Members who join the IGS through a chapter.

Individual Member Benefits include:

- a membership card
- an IGS lapel pin
- on-line access to the *IGS Membership Directory*
- the IGS News, Newsletter, published three times a year
- on-line access to the 19 IGS Mini Lecture Series for the use of the membership
- information on test methods and standards
- discount rates:
  - for any document published in the future by IGS
  - at all international, regional or national conferences organized by the IGS or under its auspices

- preferential treatment at conferences organized by the IGS or under its auspices
- possibility of being granted an IGS award
- Free access to the *Geosynthetics International* journal, now published electronically.
- Free access to the *Geotextiles and Geomembranes* journal, now published electronically.

Corporate

Corporate Membership Benefits include:

- a membership card
- an IGS lapel pin
- on-line access to the *IGS Membership Directory*
- the IGS News newsletter, published three times a year
- on-line access to the 19 IGS Mini Lecture Series for the use of the membership
- information on test methods and standards
- discount rates:
    - for any document published in the future by IGS
    - at all international, regional or national conferences organized by the IGS or under its auspices
- preferential treatment at conferences organized by the IGS or under its auspices
- possibility of being granted an IGS award
- free access to the *Geosynthetics International* journal, now published electronically.
- free access to the *Geotextiles and Geomembranes* journal, now published electronically.
- **advertisement in the *IGS Member Directory* and on the IGS Website**
- **IGS Corporate Membership Plaque**
- **Company Profile in the IGS News**
- **right of using the IGS logo at exhibitions and in promotional literature**
- **priority (by seniority of membership within the IGS) at all exhibits organized by the IGS or under its "auspices"**
- **opportunity to join IGS committees in order to discuss topics of common interest.**

Student

Student Membership Benefits include:

- Electronic access to the IGS News, published 3 times a year
- Special Student discounts at all IGS sponsored/supported conferences, seminars etc.
- Listing in a special student members category in the IGS Directory
- Eligibility for awards (and in particular the IGS Young Member Award).

List of IGS Chapters

Algeria
Algerian Chapter 2018)
ZahirDjidjeli
https://jstgsba.wixsite.com/asag

Argentina
Argentinean Chapter 2009
Dr. Marcos Montoro
marcos_montoro@yahoo.com.ar

Australia and New Zealand
Australasian Chapter 2002
Mr. Graham Fairhead
gfairhead@fabtech.com.au

Austria
Austrian Chapter 2016
Prof. Heinz Brandl
g.mannsbart@tencate.com

Belgium
Belgian Chapter 2001
Mr. Noel Huybrechts
jan.maertens.bvba@skynet.be
info@bgsvzw.be

Brazil
Brazilian Chapter 1997
Mr. Victor Educardo Pimentel
igsbrasil@igsbrasil.org.br

Chile
Chilean Chapter 2006
Mr. Francisco Pizarro
castillofernando072@gmail.com

China
Chinese Chapter 1990
Prof. Chao Xu
c_axu@tongji.edu.cn

Chinese Taipei
Chinese Taipei Chapter of the IGS
Dr. Jason Wu
Cga18241543@gmail.com

Colombia
Colombian Chapter 2013
Prof. Bernardo CaicedoHormaza
bcaicedo@uniandes.edu.co

Czech Republic
Czech Chapter 2003
Mr. ZikmundRakowski
president@igs.cz

Egypt
Egyptian Chapter (2018)
Prof. FatmaElzahraaAlyBaligh
baligh.fatma@gmail.com

Finland
Finish Chapter 2011
Mr. MinnaLeppänen
igsfin.secretary@gmail.com
minna.leppanen@tut.fi

France
French Chapter 1993
Mr. Nathalie Touze
nathalie.touze@irstea.fr

Germany
German Chapter 1993
Dr.-Ing. Martin Ziegler
service@dggt.de
ziegler@geotechnik.rwth-aachen.de

Ghana
Ghana Chapter 2012
Prof. Samuel I.K. Ampadu
skampadu.coe@knust.edu.gh
jkkemeh@hotmail.com

Greece
HGS, Greek Chapter 2005
Mr. Anastasios KOLLIOS
akollios@edafomichaniki.gr

Honduras
Honduran Chapter – Hon-duran Society of Geosynthetics 2013
MSc. Ing. Mr. Danilo Sierra D.
sierradiscua@yahoo.com

India
Indian Chapter 1988
Mr. Vivek P. Kapadia
Dire.civil.ssnnl@gmail.com / sunil@cbip.org

Indonesia
INA-IGS, the Indonesian Chapter 1992
GouwTjieLiong
amelia.ina.igs@gmail.com
ameliamakmur@gmail.com

Iran
Iranian Chapter 2013
Dr. Seyed Naser Moghaddas Tafreshi
Iran_geosynthetics@yahoo.com

Italy
AGI-IGS, the Italian Chapter 1992
Dr. Ing. Daniele Cazzuffi
agi@associazionegeotecnica.it

Japan
Japanese Chapter 1985
Dr. Hiroshi Miki
miki-egri@nifty.com

Kazakhstan
Kazakhstanian Chapter 2012
Mr. ZhusupbekovAskarZhagparovich
astana-geostroi@mail.ru

Korea
KC-IGS, The Korean Chapter 1993
Prof. ChungsikYoo
csyoo@skku.edu

Malaysia
Malaysian Chapter – 2013
Dr. Fauziah Ahmad
cefahmad@yahoo.com

Mexico
Mexican Chapter 2006
Dr. Rosember Reyes Ramirez
contacto@igsmexico.org

Morocco
Morocco Chapter 2014
Mr. HoussineEjjaaouani
ejjaaouani@ipee.ma

Netherlands
Netherlands Chapter 1992
Mr. E.A. Kwast
mail@ngo.nl

North America
North American Geosynthetics Society (NAGS)
(Canada, USA) 1986
Dr. Richard Brachman
richard.brachman@queesu.ca

Norway
Norwegian Chapter of IGS 2008
AinaAnthi
aina.anthi@vegvesen.no
tse-day.damtew@vegvesen.no

Pakistan
Pakistanian Chapter of IGS 2011
Mr. Hasan S. Akhtar
Secretary.igspk@gmail.com

Panama
Panama Chapter 2014
Mr. Amador Hassell
amador.hassell@utp.ac.pa

Peru
Peruvian Chapter 2001
Mr. Jorge Zegaree Pellanne
administracion@igsperu.org
aalza@tdm.com.pe

Philippines
Philippine Chapter 2007
Mr. Mark Morales
mark.k.morales@gmail.com
paul_navarro_javier@yahoo.com

Poland
Polish Chapter 2008
Mr. Jakub Bryk
sekretarz@psg-igs.pl

Portugal
Portuguese Chapter 2003
Mr. Jose Luis Machado do Vale
jose.vale@carpitech.com

Romania
Romanian Chapter 1996
Mr. Laurentiu Marculescu
adiol@utcb.ro

Russia
Russian Chapter of IGS (RCIGS) 2008
Dr. Andrei Petriaev
info@reigs.ru

Slovakia
Slovakian Chapter of IGS 2011
Dr. Radovan Baslik
radobaslik@gmail.com

South Africa
South African Chapter 1995
Mr. Johann Le Roux
secretary@gigsa.org

Spain
Spanish Chapter 1999
Mr. Angel LeiroLópez
pabad@cetco.es
aleiro@cedex.es

Switzerland
Swiss Chapter (2018)
Mr. ImadLifa
svg@geotex.ch

Thailand
Thai Chapter 2002
Prof. SuksunHorpibulsuk
suksun@g.sut.ac.th

Turkey
Turkish Chapter 2001
Dr. Ayse Edincliler Baykal
aedinc@boun.edu.tr

United Kingdom
U.K. Chapter 1987
Mr. Andrew Belton
committee@igs-uk.org

Vietnam
Vietnam Chapter (VCIGS) 2013
Dr. Nguyen Hoang Giang
giangnh@nuce.edu.vn

INDIAN CHAPTER OF IGS

In the year 1985, Central Board of Irrigation and Power, (CBIP) as part of its technology forecasting activities identified geosynthetics as an important area relevant to India's need for infrastructure development, including roads. After approval of IGS Council for the formation of Indian Chapter in October 1988, the Indian Chapter of IGS was got registered under Societies Registration Act 1860 of India in June 1992 as the Committee for International Geotextile Society (India), with its Secretariat at Central Board of Irrigation and Power. The Chapter has since been renamed as International Geosynthetics Society (India), in view of the parent body having changed its name from International Geotextiles Society to International Geosynthetics Society.

The activities of the Society are governed by General Body and Executive Board.

Executive Board of Indian Chapter of IGS 2020-2022

The Executive Board of the IGS (India) consists of President, elected by the General Body, two Vice-Presidents and 16 members. The Secretary and Director (WR) of the CBIP are the as the Ex-Officio Member Secretary and Treasurer, respectively, of the Society.

The present Executive Board is as under:

President

- **Mr. Vivek P. Kapadia,** *Secretary to Government of Gujarat and Director*, SSNNL

Vice-Presidents

- **Dr. R. Chitra,** *Director,* Central Soil & Materials Research Station
- **Dr. Jimmy Thomas,** Geotechnical Consultant

Immediate Past President

- **Mr. M. Venkataraman,** *Chief Executive Officer,* Geosynthetics Technology Advisory Services LLP and Guest Professor, Department of Civil Engineering IIT Gandhinagar

Hon. Members

- **Dr. G.V. Rao,** *Former Professor,* Department of Civil Engineering, IIT Delhi and Guest Professor, Department of Civil Engineering, IIT Gandhinagar
- **Dr. K. Rajagopal,** *Professor,* Department of Civil Engineering IIT Madras

Member Secretary

- **Mr. A.K. Dinkar,** *Secretary,* Central Board of Irrigation & Power

Treasurer

- **Mr. K.K. Singh**, *Director (WR),* Central Board of Irrigation & Power

Past Presidents

The presidents of the society in the past were:

- Dr. R.K. Katti, Director, UNEECS Pvt. Ltd. and Former Professor, IIT Bombay
- Mr. H.V. Eswaraiah, Technical Director, Karnataka, Power Corporation Ltd.
- Dr. G.V. Rao, Professor, Department of Civil Engineering, IIT Delhi
- Dr. D.G. Kadade, Chief Advisor, Jaiprakash Industries Ltd.
- Dr. K. Rajagopal, Professor, Department of Civil Engineering, IIT Madras

Indian Representation on IGS Council

- Dr. K. Rajagopal, Professor, Department of Civil Engineering, IIT Madras
- Dr. G.V. Rao, Former Professor, Department of Civil Engineering, IIT Delhi
- Mr. M. Venkataraman, Geotechnical and Geosynthetic Consultant
- Mr. Vivek P. Kapadia, Secretary to Government of Gujarat and Director, SSNNL

IGS Student Award Winners from India

The IGS has established Student Paper Award to disseminate knowledge and to improve communication and understanding of geotextiles, geomembranes and associated technologies among young geotechnical and geoenvironmental student engineers around the world. The IGS student award consists of US$1,000 to be used to cover travel expenses of each winner to attend a regional conference.

Following from India have been honoured with IGS Student Paper Award:

- Dr. J.P. Sampath Kumar, National Institute of Fashion Technology, Hyderabad
- Dr. K. Ramu, JNTU College of Engineering, Kakinada
- Mrs. S. Jayalekshmi, National Institute of Technology, Tiruchirappalli
- Dr. Mahuya Ghosh, IIT Delhi
- Dr. S. Rajesh, Department of Civil Engineering, IIT Kanpur
- Mr. Suresh Kumar S., Department of Textile Technology, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar

Publications/Proceedings on Geosynthetics

In addition to the proceedings of the events on Geosynthetics, following publications have been brought out since 1985:

1. Workshop on Geomembranes and Geofabrics (1985)
2. International Workshop on Geotextile (1989)
3. Use of Geosynthetics – Indian Experiences and Potential – A State of Art Report (1989)
4. Use of Geotextile in Water Resources Projects - Case Studies (1992)
5. Role of Geosynthetics in Water Resources Projects (1993)
6. Monograph on Particulate Approach to Analysis of Stone Columns with & without Geosynthetics Encasing (1993)
7. 2nd International Workshop on Geotextiles (1994)
8. Directory of Geotextiles in India (1994)
9. An Introduction to Geotextiles and Related Products in Civil Engineering Applications (1994)
10. Proceedings of Workshops on Engineering with Geosynthetics (1995)
11. Ground Improvement with Geosynthetics (1995)
12. Geosynthetics in Dam Engineering (1995)
13. Erosion Control with Geosynthetics (1995)
14. Proceedings of International Seminar & Techno Meet on “Environmental Geotechnology & Geosynthetics” (1996)
15. Proceedings of First Asian Regional Conference “Geosynthetics Asia’1997”
16. Directory of Geosynthetics in India (1997)
17. Bibliography – The Indian Contribution to Geosynthetics (1997)
18. Waste Containment with Geosynthetics (1998)
19. Geosynthetic Applications in Civil Engineering- A Short Course (1999)
20. Case Histories of Geosynthetics in Infrastructure Projects (2003)
21. Geosynthetics – Recent Developments (Commemorative Volume) (2006)
22. Geosynthetics in India – Present and Future (2006)
23. Applications of Geosynthetics – Present and Future (2007)
24. Directory of Geosynthetics in India (2008)
25. Geosynthetics India’08

26. Geosynthetics India' 2011
27. Geosynthetic Reinforced Soil Structures - Design & Construction (2012)
28. Applications of Geosynthetics in Infrastructure Projects (2013)
29. Applications of Geosynthetics in Railway Track Structures (2013)
30. Silver Jubilee Celebration (2013)
31. Directory of Geosynthetics in India (2013)
32. Applications of Geosynthetics in Infrastructure Projects (2014)
33. Geosynthetics India 2014
34. Three Decades of Geosynthetics in India – A Commemorative Volume (2015)
35. History of Geosynthetics in India - Case Studies (2016)
36. Proceedings of 6th Asian Regional Conference on Geosynthetics (2016)
37. Coir Geotextiles (Coir Bhoovastra) for Sustainable Infrastructure (2016)
38. Proceedings of the Geosynthetics Applications for Erossion Control and Costal Protection (2018)
39. Geosynthetics Testing – A Laboratory Manual (2019)

Indian Journal of Geosynthetics and Ground Improvement

The Indian Chapter of IGS has taken the initiative to publish Indian Journal of Geosynthetics and Ground Improvement (IJGGI), on half yearly basis (January – June and July-December), since January 2012.The aim of the journal is to provide latest information in regard to developments taking place in the relevant field of geosynthetics so as to improve communication and understanding regarding such products, among the designers,manufacturers and users and especially between the textile and civil engineering communities.The Journal has both print and online versions.

Events Organised/Supported

1. Workshop on Geomembrane and Geofabrics, September 1985, New Delhi
2. Workshop on Reinforced Soil, August 1986
3. International Workshops on Geotextiles, November 1989, Bangalore
4. National Workshop on Role of Geosynthetics in Water Resources Projects, January 1992, New Delhi
5. Workshop on Geotextile Application in Civil Engineering, January 1993, Chandigarh
6. International Short Course on Soil Reinforcement, March 1993, New Delhi
7. Short Course on Recent Developments in Design of Embankments on Soft Soils, Nov./Dec. 1993, New Delhi
8. 2nd International Workshop on Geotextiles, January 1994, New Delhi
9. Short Course on Recent Developments in the Design of Embankments on Soft Soils, January 1994, Kolkata
10. Workshop on Role of Geosynthetics in Hill Area Development, November 1994, Guwahati
11. Workshop on Engineering with Geosynthetics, December 1994, Hyderabad
12. Short Course on Recent Developments in the Design of Embankments on Soft Soils, May 1995, New Delhi
13. Seminar on Geosynthetic Materials and their Application, August 1995, New Delhi
14. Short Course on Recent Developments in the Design of Embankments on Soft Soils, October 1995, New Delhi
15. Short Course on "Ground Improvement with Geosynthetics", October 1995, New Delhi
16. Workshop on "Environmental Geotechnology", December 1995, New Delhi
17. Workshop on "Role of Geosynthetics in Hill Area Development", February 1996, Gangtok
18. Workshop on "Engineering with Geosynthetics", March 1996, Visakhapatnam

19. Workshop on “Ground Improvement with Geosynthetics”, March 1996, Kakinada
20. Workshop on “Engineering with Geosynthetics”, May 1996, Chandigarh
21. International Seminar & Technomeet on “Environmental Geotechnology with Geosynthetics”, July 1996, New Delhi
22. Seminar on “Fields of Application of Gabion Structures”, September 1997, New Delhi
23. First Asian Regional Conference “Geosynthetics Asia’1997”, November 1997, Bangalore
24. Short Course on “Waste Containment with Geosynthetics”, February 1998, New Delhi
25. Symposium on “Rehabilitation of Dams”, November 1998, New Delhi
26. Training Course on “Geosynthetics and their Civil Engineering Applications”, September 1999, Mumbai
27. Seminar on “Coir Geotextiles-Environmental Perspectives”, November 2000, New Delhi
28. Second National Seminar on “Coir Geotextiles – Environmental Perspectives”, April 2001, Guwahati, Assam
29. National Seminar on “Application of Jute Geotextiles in Civil Engineering”, May 2001, New Delhi
30. International Course on “Geosynthetics in Civil Engineering”, September 2001, Kathmandu, Nepal
31. Workshop on “Applications of Geosynthetics in Infrastructure Projects”, November 2003, New Delhi
32. Geosynthetics India 2004 – “Geotechnical Engineering Practice with Geosynthetics”, October 2004, New Delhi
33. Introductory Course on Geosynthetics, November 2006, New Delhi
34. International Seminar on “Geosynthetics in India – Present and Future” (in Commemoration of Two Decades of Geosynthetics in India), November 2006, New Delhi
35. Workshop on “Retaining Structures with Geosynthetics”, December 2006, Chennai
36. Special Session on “Applications of Geosynthetics” during 6th International R&D Conference, February 2007, Lucknow (U.P.)
37. Workshop on “Applications of Geosynthetics – Present and Future”, September 2007, Ahmedabad (Gujarat)
38. International Seminar “Geosynthetics India’08” and Introductory Course on “Geosynthetics”, November 2008, Hyderabad
39. Special Session on “Applications of Geosynthetics” during 7th International R&D Conference, February 2009, Bhubaneswar (Orissa)
40. Seminar on “Applications of Geosynthetics”, July 2010, New Delhi
41. International Seminar on “Applications of Geosynthetics”, November 2010, New Delhi
42. Geosynthetics India’ 2011, September 2011, IIT Madras
43. Seminar on “Slope Stabilization Challenges in Infrastructure Projects”, October 2011, New Delhi
44. GEOINFRA 2012 – A Convergence of Stakeholders of Geosynthetics, August 2012, Hyderabad
45. Seminar on “Ground Control and Improvement”, September 2012, New Delhi
46. Workshop on “Geosynthetic Reinforced Soil Structures - Design & Construction”, October 2012, New Delhi
47. Seminar on “Landfill Design with Geomembrane”, November 2012, New Delhi
48. Seminar on “Slope Stabilization Challenges in Infrastructure Projects”, November 2012, New Delhi
49. Seminar on “Applications of Geosynthetics in Infrastructure Projects”, June 2013, Bhopal
50. Seminar on “Applications of Geosynthetics in Railway Track Structures”, September 2013, New Delhi
51. Silver Jubilee Celebration, October 2013, New Delhi
52. Seminar on “Applications of Geosynthetics in Infrastructure Projects”, July 2014, Agra
53. Geosynthetics India 2014, October 2014, New Delhi

54. Seminar on Geotextiles: A Big Untapped Potential, September 2015, New Delhi
55. Three Decades of Geosynthetics in India – International Symposium Geosynthetics - The Road Ahead, November 2015, New Delhi, India
56. North Eastern Regional Seminar on “Applications of Geosynthetics in Infrastructure Projects”, June 2016, Guwahati
57. Workshop on “Applications of Geosynthetics in Infrastructure Projects”, June 2016, Thiruvananthapuram
58. Training Course on Geosynthethics, November 2016, New Delhi
59. Workshop on Coastal Protection, November 2016, New Delhi
60. 6th Asian Regional Conference on Geosynthethics, November 2016, New Delhi
61. Training Course on "Geosynthetic Reinforced Soil Structures", February 2017, New Delhi
62. Training Course on “Applications of Geosynthetics”, December 2017, Dharwad (Karnataka)
63. Workshop on “Design and Construction of Pavements using Geosynthetics”, January 2018, New Delhi
64. IGS Educate the Educators Program, February 2018, IIT Madras
65. Training Course on “Applications of Geosynthetics”, February 2018, Trichy (Tamil Nadu)
66. Training Course on Design and Construction of Pavements with Geosynthetics and Geosyntheics Reinforced Soil Slopes and Walls, 15 June 2018, New Delhi
67. Seminar on Slope Stabilization Challenges in Infrastructure Projects, 21-22 June 2018, New Delhi
68. Training Programme on “Applications of Geosynthetics in Dams & Hydraulic Structures”, August 2018, Bhopal
69. Training Course on “Slope Stabilization Challenges in Infrastructure Projects”, October 2018, Dehradun
70. Seminar on “Geosynthetics Applications for Erosion Control and Coastal Protection”, October 2018, Bhubaneswar
71. Workshop on Natural Hazard Mitigation with Geosynthetics, January. 2019, Thiruvananthapuram, (Kerala)
72. Symposium of International Association for Computer Methods and Advances in Geomechanics (IACMAG) – Special Session of Indian Chapter of IGS, March 2019, IIT Gandhinagar
73. Seminar on Geosynthetics for Highway Infrastructure with Marginal Materials and Difficult Soils, September 2019, Jaipur
74. Workshop on Testing and Evaluation of Geosynthetics, September 2019, Jaipur
75. Workshop on Best Practices for Implementation of Geosynthetic Reinforced Soil Walls. January 2020, Jaipur
76. Webinar on Challenges in Developing Codes of Practice for Geosynthetics for Durable Infrastructure Development, 14 September 2020
77. Webinar on Challenges in Geosynthetic and Geotechnical Testing, 15 September 2020
78. Virtual Training Sessions on Erosion Control, 28 July 2021
79. Virtual Training Programme on the Failure of Reinforced Soil Walls: Lessons and Remedies, 29 September, 2021

DID YOU KNOW?... GEOSYNTHETIC NETS HELP REMOVE PLASTIC WASTE FROM WATER

An estimated 23 million metric tons (Mt) of waste plastic enters our rivers, lakes and oceans every year. This could grow to 90 Mt by 2030.

Much of the plastic in aquatic systems is due to mismanagement of single-use consumer products such as the 500 billion plastic bottles produced annually worldwide. Once discarded, these plastics may enter our waterways via urban drainage systems.

Geosynthetic nets can be used as ‘trash traps’ to catch plastic waste in drainage systems. The nets trap solid waste carried by stormwater into drainage networks. Once trapped, the collected waste can be recycled or safely disposed of.

A net safely captures waste plastic from a drain

Geosynthetic solutions should be fully investigated on every infrastructure project to ensure they meet the needs of the present without compromising the ability of future generations to meet their own needs.

Find out more about how geosynthetics are making a difference by downloading the IGS Sustainability eBook or visiting our Sustainability.

IGS LANDSLIDE PREVENTION PAPER FEATURES IN OPEN ACCESS JOURNAL

A paper on the power of geosynthetics to prevent landslides is available in an open access journal by the International Consortium on Landslides (ICL).

Sustainability of geosynthetics-based landslide stabilization solutions’ features in the ICL’s Open Access book series Progress in Landslide Research and Technology Volume 1, Issue 1 2022. Members of the IGS Technical Committee on Soil Reinforcement (TC-R), chair

Pietro Rimoldi, vice-chair Yoshihisa Miyata, and Secretary Ivan Puig Damians co-authored the piece with former IGS Vice-President Nathalie Touze and IGS Executive Director John Kraus.

The article outlines the various types of geosynthetics for landslide prevention, and the sustainability benefits of choosing geosynthetic materials over traditional methods. It also discusses ‘MIVES, the Spanish Integrated Value Model for Sustainability Assessment which is used for evaluating slope stability remediation alternatives.

Established in 2002 and headquartered in Kyoto, Japan, the ICL aims to promote landslide research and education, and offer expertise in landslide risk and mitigation. In 2020, the IGS was among signatories to the Kyoto Landslide Commitment, supporting 10 priority actions to mitigate the environmental and human costs of landslides.

To read the full paper, visit the IGS Digital Library, where you can also find a wide variety of resources on geosynthetics.

PETER LEGG TO GIVE FIRST KELVIN LEGGE LECTURE

Water sustainability in Africa will be the subject of the inaugural Kelvin Legge Lecture at the 4th GeoAfrica conference next month.

Solid waste management specialist Peter Legg has been chosen to give the address at the 4th African Regional Conference on Geosynthetics (4th GeoAfrica), which runs February 20-23. His talk titled ‘The role of geosynthethic barriers for the future of African water resources’ will explore how properly engineered geocomposite barriers can mitigate the pollution impact of waste disposal to protect the continent’s precious water resources.

The Kelvin Legge Lecture was one of four new lectures created last year by the IGS Recognitions Task Force to honor some of the industry’s most impactful practitioners.

Mr Legg said: “I am extremely honoured and feel privileged to have been invited to deliver the inaugural Kelvin Legge Lecture at GeoAfrica 2023. I have known Kelvin Legge for the past 30 years and have a great admiration for his knowledge and passion for protecting our water resources.

“Having been involved in the design of many waste disposal facilities in South Africa and elsewhere in Africa over the past 30 years, I have been encouraged to see the increased development of properly engineered landfills and mineral waste disposal facilities incorporating geosynthetics in various functions including basal barriers, landfill final covers, filtration and reinforcement.

“My lecture will briefly consider the impact of uncontrolled waste disposal in Africa and the increased use of engineered barrier systems incorporating geosynthetics in various functions. Several case studies will be presented as well as guidance for the design of engineered barrier systems.”

Mr Legg is the owner of Peter Legg Consulting Geo-Environmental Engineers. He specialises in all aspects of civil and geotechnical engineering associated with solid waste management and pollution control facilities. He is a Past President of IGS South Africa and a former Treasurer of the IGS. He was also chairman of the organising committee for the first GeoAfrica in 2009, held in Cape Town.

For GeoAfrica4 hosted by IGS Egypt, delegates will gather at the Cairo Marriott Hotel in Cairo, Egypt, for a packed program exploring the theme ‘Geosynthetics in sustainable infrastructures and mega projects’. The event will include talks from seven eminent speakers including J.P. Giroud, Richard Bathurst, Jorge Zornberg, Chungsik Yoo, Daniele Cazzuffi, and Malek Bouazza.

Mohamed Salah Morsy, secretary general of the GeoAfrica4 organizing committee, said: “The interest in the conference is very high with all the exhibition booths now sold and healthy registration numbers showing an increased attention towards geosynthetic opportunities in Egypt and the Middle East. As well as a comprehensive technical program, prestigious keynote speakers and IGS local chapter awards, we will be hosting a gala dinner in a marvellous spot over the banks of the Nile. We look forward to welcoming everyone soon.”

DID YOU KNOW… GEOSYNTHETICS REPRESENT A MODEL FOR THE RESPONSIBLE USE OF PLASTICS?

One of the most important issues surrounding plastics is their destiny once their functional application and use comes to an end. Many products have short service lives and a physical and chemical persistence in the environment once they are not considered useful anymore. This is the case for packaging, sanitary products, plastic bottles and similar commodities.

Unfortunately, a significant fraction of plastic waste is released into the environment thanks to poor human behavior. Even when plastic waste is collected, treated and recycled, these activities need energy, and have an impact on the environment. So, the number one priority with waste is its reduction.

The circular economy provides the guidelines to mitigate this problem, from eco-design to end-of-life. One of the pillars involves the length of the functional life of a product: the longer the utilization, the lower the impact.

Although the long-lasting persistency of plastics is a problem when we have to manage waste, it represents a great opportunity when involving long term applications. It is up to us to maximize the durability of plastics and put it to the service of our sustainable development goals.

In the construction industry most of the works are intended to last as long as possible, and mankind has traditionally used very durable materials such as concrete, stones, gravel and sand to build roads, railways, dykes, and other infrastructures and buildings.

The use of geosynthetics enables the substitution or dramatic reduction of the need for aggregates, making it possible at the same time to offer increased longevity to the related construction works.

This in turn allows a reduction in greenhouse gas emissions during the construction process, better wear and seismic resilience and landscape preservation because of a reduced need for excavations, and many other reduced environmental impacts due to the significant reduction of construction traffic.

On top of all these environmental benefits, geosynthetics offer durability of our geotechnical works with a service life which is virtually as long as the physical life of the materials.

Geosynthetic solutions should be fully investigated on every infrastructure project to ensure they meet the needs of the present without compromising the ability of future generations to meet their own needs.

GEOAMERICAS 2024 SEEKS SESSION, SHORT COURSE, AND TRAINING LECTURE PROPOSALS

GeoAmericas 2024 is the 5th Pan-American Conference on Geosynthetics. The event, being held under the theme "Connecting State of the Art and State of Practice," will take place April 28 – May 1, 2024 in Toronto. The organizers welcome proposals for Short Courses, Training Lectures, and Sessions.

IGS members are encouraged to Get Involved! Answer the Call!

Major topics at GeoAmericas 2024 include Sustainability, Energy, Mining, and Transportation Infrastructure. The conference themes page outlines a number of expected contributions under these topics. Additionally, the Technical & Education Committees welcome course, training lecture, and session topic offers for these topics.

Proposals are requested by January 31, 2023. Contact info@igs-na.org with questions.

Highlights of GeoAmericas 2024

The program for GeoAmericas 2024 is designed to provide everyone with opportunity for professional growth in the technical program, networking, and trade show. Highlights include:

- First GeoAmericas to be held in Canada
- 2nd Zornberg Lecture (An exciting announcement forthcoming!)
- Celebrations of IGS Journals Geotextiles & Geomembranes (40th anniversary) and Geosynthetics International (30th anniversary)
- Celebration of ASTM International Committee D35 on Geosynthetics (40th anniversary)
- "GeoJeopardy" event for student teams incorporated into conference plenary sessions
- Access to leading practitioners in the mining sectors and affiliated industries that are redefining the global mining focus
- Access to leading climate scientists and influencers in climate change response and sustainability
- Significant local projects with geosynthetics

IGS YOUNG MEMBER PHOTO CONTEST WINNERS REVEALED!

Breathtaking images of geosynthetics in action have won four young members prize money and free entry to an IGS regional conference.

During the summer, the IGS Young Members Committee invited members and non-members aged 35 and under to submit original images showcasing geosynthetics around the world.

The idea was to share the many inspiring ways geosynthetics technology and materials are used in a range of applications. Prizes included a gift voucher, donation to a charity of the winners' choice, and free entry to an IGS regional conference. Fifty-two photos were submitted by 21 entrants from around the world. Some 67% of entries were from IGS members and half of these were IGS student members.

Overall winner was Sergio Luiz da Costa Junior, of IGS Brazil, for his photo of a triangular geomembrane reservoir for irrigation water in Bahia, Brazil. His prize was $300, split between a gift voucher and charity donation, which he said would be going to an LGBT+ charity. His image also won 'Best Photo by an IGS Young Member', earning him an extra $150.

"Triangular Geomembrane Reservoir" Sergio Luiz da Costa Junior

> "Circular Geomembrane Reservoir" - Sergio Luiz da Costa Junior

The civil engineer specializing in geotechnical and geosynthetic engineering said he was delighted to win, adding: "It is wonderful to see two works, two challenges, two achievements recognized internationally. This helps to raise awareness about geotechnical works that involve geosynthetics, especially in countries with great challenges like Brazil."

Sergio also won the People's Choice award for his image of a circular geomembrane reservoir in Minas Gerais, Brazil, voted for on social media.

Second overall winner was IGS Brazil member Daniel Moreno Meucci, a commercial engineer in a geomembrane technical department. His photo showed a water reservoir in Luís Eduardo Magalhães city in Bahia state, Brazil, one of the largest irrigated areas in the country. It demonstrates the waterproofing function of geomembranes, which offer greater irrigation security to ensure plantations continue to thrive.

> "Water tank" - Daniel Moreno Meucci

Daniel, who received a $200 voucher/donation, said: "I'm very flattered that my photo was selected in second place with so many high level photos and projects submitted. There's no doubt that initiatives like this benefit the growth of the geosynthetics community. The donation portion of my prize will go to one of the charities my company Sapphire supports but that is yet to be chosen."

Third was Youchen Lee, who is a member of the Chinese Taipei chapter of the IGS, for an image of geogrid reinforced soil slopes in the mudstone badlands of Kaohsiung, Taiwan. Youchen received a $150 voucher/donation.

> "Geogrid Reinforced soil slopes in the mudstone badlands" - Youchen Lee

An award was also given for Best Photo submitted by an IGS Student Member. This was won by Julian Gomez, of IGS Colombia, for his image of the Villeta-Bogotá highway in Bogotá. This triumph also earned Julian free entry to the 12th International Conference on Geosynthetics (12th ICG) in Rome in September 2023. His photo showed erosion control using a turf reinforcement mat and a geogrid system with soil nailing.

> "Highway Villeta-Bogotá" - Julian Gomez

He said: "Winning was a nice surprise. Being able to attend the 12th ICG is a huge opportunity, and I look forward to taking part in one of the most important conferences in the geosynthetics world."

Dawie Marx, chair of the IGS Young Members Committee, said: "The 2022 IGS Young Members Committee Photo Competition was a great success. Initiatives like this help widen the understanding and awareness of geosynthetics among members and the wider public and we thank everyone who entered for sharing their impactful entries."

IGS Young Members membership is open to anyone aged 35 and under. You can find out more about the IGS

Young Members Committee here. Student membership of the IGS is free. For more about membership options, and to join the IGS, visit the webpage here.

+++ Finalists for the Best Young Member Paper competition at the 12th ICG will soon be revealed. The IGS Young Members Session will see 10 contenders battle for the top spot and a chance to win $1,000. All finalists will get free conference entry. The shortlist will be announced on January 23, 2023.

CIRCULAR ECONOMY EXPLORED AT ITALY CONFERENCE

Nathalie Touze receives a gift after her keynote lecture in Bologna from the IGS Italian Chapter officers

Cutting edge ideas on geosynthetics and sustainability were shared at the 32nd Italian National Geosynthetics Conference.

The regular event in Bologna is co-organized by IGS Italy, known as AGI-IGS, and the Italian Geotechnical Association (AGI), and is in association with the biennial SAIE 2022 construction trade show organized by BolognaFiere and SENAF. Keynote speakers this year included former IGS Vice-President Nathalie Touze, IGS Council member Francesco Fontana and IGS Executive Director and IGS Sustainability Committee member John Kraus.

Speakers at the conference, themed ‘Circular economy and resilient applications’, included:

- Nathalie Touze (President of the INRAE center at Jouy-en-Josas-Antony) – keynote speech on *‘The role of geosynthetics in sustainable development and the circular economy’*
- Francesco Fontana – *‘Opportunities and limits of recycling in the production of geosynthetics from a circular economy perspective’*
- John Kraus – *‘Microplastics – why geosynthetics are not the problem’*
- Antonella Senese and Beatrice De Felice (Milano University) – *‘Experimental studies on the impact of geotextiles in the alpine environment’*
- Valentina Grossule, also on behalf of her colleagues Raffaello Cossu and Maria Cristina Lavagnolo of Padua University – *‘The role of sustainable landfilling in the circular economy’*
- Quintilio Napoleoni (University of Roma ‘Sapienza’) – *“Sustainable design of landfills”*
- Filippo Crociati (Herambiente, Italy) – *‘The design parameters of geosynthetics for landfills in consideration of climate change issues’*
- Piergiorgio Recalcati (Tenax SpA, Italy) – *“An analysis of direct shear and inclined plane test results on different interfaces of landfill capping systems’*

John Kraus (far right) and Nathalie Touze during a break of the Bologna conference together with Daniele Cazzuffi (far left) and Francesco Fontana

IGS Italy President Daniele Cazzuffi said: “The event had important international participation and gave excellent results both in terms of the number of registered participants and the quality of the presented papers. Moreover, the context of the SAIE exhibition – the international reference point for the world of construction in Italy – enhanced the importance and impact of the geosynthetics presentations.”

Proceedings have been edited into a volume of articles by conference organizers Mr Cazzuffi, Nicola Moraci and Claudio Soccodato. It includes four articles in English and four articles in Italian with English abstract. The volume can purchased here.

During the conference, Pierpaolo Fantini (Huesker srl) received the IGS Chapter Service Award, while Nicolò Guarena and Andrea Luciani (both from Torino Politecnico) jointly won the AGI-IGS prize for the best PhD thesis on geosynthetics engineering discussed in the last three years in Italian universities.

The 33rd Italian National Geosynthetics Conference will take place in October 2024. IGS Italy is also preparing for the 12th International Conference on Geosynthetics, taking place in Rome, Italy, from September 17-21, 2023.

INDIAN JOURNAL OF GEOSYNTHETICS AND GROUND IMPROVEMENT

GUIDELINES FOR AUTHORS

This journal aims to provide a snapshot of the latest research and advances in the field of **Geosynthetics**. The journal addresses what is new, significant and practicable. **Indian Journal of Geosynthetics and Ground Improvement** is published twice a year (January-June and July-December) by IndianJournals.Com, New Delhi. The Journal has both print and online versions. Being peer-reviewed, the journal publishes original research reports, review papers and communications screened by national and international researchers who are experts in their respective fields.

The original manuscripts that enhance the level of research and contribute new developments to the geosynthetics sector are encouraged. The work belonging to the fields of Geosynthetics are invited. **The journal is expected to help** researchers, technologist and policy makers in the key sector of Geosynthetics to improve communication and understanding regarding geotextiles, geomembranes and related products among designers, manufacturers and users The manuscripts must be unpublished and should not have been submitted for publication elsewhere. There are no **Publication Charges**.

1. Guidelines for the preparation of manuscripts for publishing in "Indian Journal of Geosynthetics and Ground Improvement"

The authors should submit their manuscript in MS-Word (2003/2007) in single column, double line spacing. The manuscript should be organized to have Title page, Abstract, Introduction, Material & Methods, Results & Discussion, Conclusion, and Acknowledgement. The manuscript should not exceed 16 pages in double line spacing.

Submission of Manuscript:

The manuscript must be submitted in doc and pdf to the Editor as an email attachment to **sunil@cbip.org.** The author(s) should send a signed declaration form mentioning that, the matter embodied in the manuscript is original and copyrighted material used during the preparation of the manuscript has been duly acknowledged. The declaration should also carry consent of all the authors for its submission to **Indian Journal of Geosynthetics and Ground Improvement**. It is the responsibility of corresponding author to secure requisite permission from his or her employer that all papers submitted are understood to have received clearance(s) for publication. The authors shall also assign the copyright of the manuscript to the Indian Chapter of International Geosynthetics Society.

Peer Review Policy:

Review System: Every article is processed by a masked peer review of double blind or by three referees and edited accordingly before publication. The criteria used for the acceptance of article are: **contemporary relevance, updated literature, logical analysis, relevance to the global problem, sound methodology, contribution to knowledge and fairly good English**. Selection of articles will be purely based on the experts' views and opinion. Authors will be communicated within Two months from the date of receipt of the manuscript. The editorial office will endeavor to assist where necessary with English language editing but authors are hereby requested to seek local editing assistance as far as possible before submission. Papers with immediate relevance would be considered for early publication. The possible expectations will be in the case of occasional invited papers and editorials, or where a partial or entire issue is devoted to a special theme under the guidance of a Guest Editor.

The Editor-in-Chief may be reached at: contact@geosyntheticsindia.org