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Three Decades of Geosynthetics in India

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ABSTRACT*: With the recent emphasis on infrastructure development, geosynthetics in India have received a tremendous boost. Apart from the consistent use in pavements of the east-west and north-south corridors and golden quadrilateral of the NHDP projects being executed by the NHAI, reinforced soil walls in urban flyover approaches have become common, due to their distinct advantages over conventional reinforced concrete walls. These apart, the use of high strength geotextiles and geocell mattresses for foundation of high embankments on soft soils has also proven to be feasible even in black cotton soil areas. Increasing emphasis is being given to the development and use of natural fibre (particularly, jute and coir) geotextiles for civil engineering applications. The paper traces many of these developments and summarizes the key issues to be taken note of for utilizing the vast potential geosynthetics offer, in India's march to development.*

KEY WORDS : Basal reinforcement, erosion, Geosynthetic reinforced walls, landslides, pavements

1. INTRODUCTION

The journey with Geosynthetics has started in India in the year 1985, with the first Workshop on Geotextiles and Geomembranes conducted by the Central Board of Irrigation and Power, at New Delhi. The earliest applications in India have been documented in a publication entitled "Use of Geosynthetics in India – Experiences and Potential" brought out by the Central Board of Irrigation and Power (Venkatappa Rao and Saxena, 1989). Based upon the early experiences in testing and evaluation and the need for highlighting the design and construction with geosynthetics – a publication entitled "Engineering with Geosynthtics" was brought out in 1990 (Venkatappa Rao and Suryanarayana Raju, 1990). In the early years indigenously made geotextiles had a very narrow range and they lacked the diversity. Also, bringing in foreign manufactured goods was very cumbersome if not impossible.

The author has earlier (Venkatappa Rao, 1996) presented an overview of the scenario in India and the potential that geosynthetics offer. The opening of the Indian market to the entry of foreign materials and technology and the awakening of the people and Government to the dire need of infrastructure, the realization that this development cannot be done without adaptation of new technology to make the structures cost-effective and durable has brought forth another aspect for serious consideration amongst Indian civil engineers. This is a major breakthrough in the Indian environment helping in soil and resource conservation. After three decades, geosynthetics have found a firm place in civil engineering construction in India. This is particularly so because they have enabled good cost-effective alternatives to conventional design. This paper traces the developments in their use and brings out the key issues that need to be taken note of, to use geosynthetics to their full advantage in the large infrastructure projects in the country.

2. GEOSYNTHETIC REINFORCED SOIL STRUCTURES

Geosynthetic Reinforced Soil Retaining Walls

The first geosynthetic reinforced soil structure was constructed on National Highway No. 1, near Ludhiana in the mid-eighties for a road over rail bridge approach, wherein geostrips have been used as a reinforcing element and precast concrete panels were used as facia (Fig.1). With a maximum height of 8 m, the saving achieved was more than 15% depending on wall height. The speed of construction was also faster when compared with RC walls. Similar construction was later carried out at Phagwara in Punjab.

Fig. 1 First Reinforced Soil Wall in India – Ludhiana, Punjab 1986

A few years later at the Visweswarayya Setu (Road over rail bridge) in Delhi, the Public Works Department, Delhi Administration successfully constructed a 59 m length of geogrid reinforced wall with 15 cm thick precast concrete facia elements with average height of 6 m using fly ash as the fill material. This wall was built on a rigid biaxial basal reinforcement geogrid wherein Fly Ash was used. With all these novel features, this was the first construction of its type in India and the overall savings were over 20%.

Since then hundreds such structures have been built in the megacities, notably in Chennai, Delhi, Hyderabad, Mumbai and in many National Highways in different parts of the country using a variety of geosynthetics, geogrids, geotextiles, geostrips, metallic rods and ribbed metallic strips with precast anchor blocks and facia elements of precast concrete panels of different shapes, segmental concrete blocks and also gabion facia. Many more are in the offing.

Several structures have also been built on soft soils and also deep black cotton soils. Figures 2, 3 and 4 depict the scenario for a Road over bridge approach over a canal, at Eluru, Andhra Pradesh, with high water table, black cotton soil and limited space for construction. Part of the foundation soil has been replaced with sand reinforced with basal reinforcing geocomposite, in several layers.

Fig.2 Site condition at Eluru

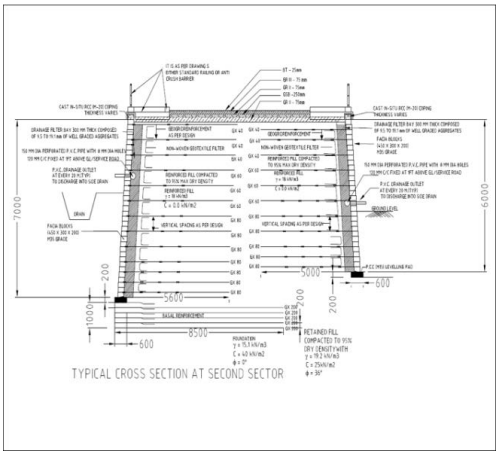

Fig. 3 Typical geosynthetic layout for Eluru Geosynthetic Reinforced soil Wall

One typical wall (at Patna)was built on stone column foundation, with soil as fill material, whereas another one at Gangavaram Port, Visakhapatnam was built with partial stone column foundation and basal geocomposite with flyash as fill material.

Fig.4 The Block faced wall at Eluru

Tiered reinforced soil walls provide an increased opportunity to take advantage of the superior economy and ease of construction afforded by reinforced soil wall technology. Geosynthetic reinforced soil walls have proven to be an economical, reliable system for tall wall applications, with materials that meet the demands of greater loading while maintaining flexibility and ease of construction. Figures 5 and 6 depict reinforcement arrangement and finished structure 42 m high 4 tiered reinforced soil wall, at Vijayawada, A.P. In another land mark development the first 45 m high reinforced slope with gabion/wraparound facia, has been constructed for the Runway of the Pongyong Airport, in Sikkim.

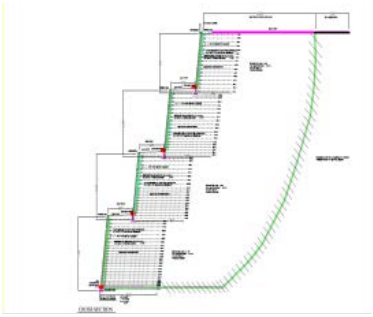

Fig.5 Typical Cross-section of 42 m high GRS Wall

Embankments On Soft Soils

Many high embankments are coming up on soft soil regions. Experience has been gained in use of high strength geotextile as basal reinforcement in the Port Connectivity Project and Airport projects at Visakhapatnam. Also, geocells with high strength geotextiles or with geogrids in construction of bridge approaches over deep seated black cotton soils, at Vasishta Godavary and Gautami Godavary at Rajahmundry and Palakol have been found to be successful (Figs. 7 and 8).

Fig.6 GRS Wall at Vijayawada

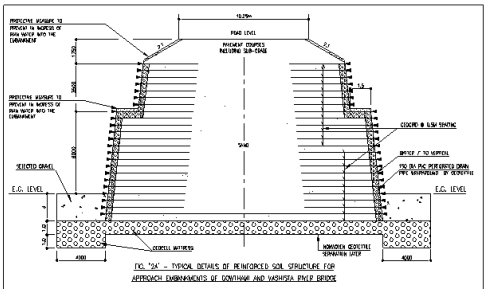

Fig. 7. Arrangement of Basal Mattress

Fig. 8 The Bridge Approach at Siddhantam, A.P.

Pavements

Ghosal and Som (1989) have reported the first major use of a non-woven fabric in a heavy duty construction yard in Haldia. It has been found to decrease the pavement thickness to the extent of 30 %.
Placement of geotextiles/geogrids at the interface between the subgrade and the sub-base course has been shown to improve the behaviour of pavements, under cyclic loading both in terms of permanent deformation (rutting) and resilient modulus. Also use of geogrids in a flexible overlay is found to improve the overall behaviour. A summary of these works is reported in Venkatappa Rao (1996). Non-woven geotextiles and bi-oriented geogrids have been successfully utilized in Maharashtra (1997) in the State Highways by the PWD for strengthening the road pavements in black cotton soil.

A number of field trials have been conducted using coir geotextiles and jute geotextiles in Rural Roads, in the length and breadth of the country, demonstrating the potential these materials have in the rural road network in the country, particularly in soft soils (Sanyal and Sur, 2003, Choudhary (2012), Sheela and Venkatappa Rao (2012)). Ghosh et al (2012) have developed a Jute Asphalt Overlay fabric.

3. GROUND IMPROVEMENT – PVD

More than a decade ago, prefabricated vertical drains were effectively deployed at Kakinada Port to consolidate soft submarine soils. They have been successfully used at Kandla, Visakhapatnam Ports and at Visakhapatnam Airport.

Both synthetic PVD's and natural fibre PVD's are manufactured in India.

4. GEOMEMBRANES

Use of thin LDPE liners has been recommended in the eighty's for canal lining and guidelines have been drawn by the Central Board of Irrigation and Power and the Central Water Commission, but with limited success. Particularly, in a major project eg., Indira Gandhi Canal in Rajasthan, because of puncturing and bursting, they did not take off in a big way. With engineered geomembranes, now being available, they are being for pond lining, as well as in landfill lining systems.

Today, in all the metro cities and major towns engineered municipal solid waste landfills are a common sight. Experience has also been gained in the construction of landfills for industrial waste notably at Hindustan Zinc Ltd. at Udaipur, Visakhapatnam and for Binani Zinc Ltd. at Kochi. Construction of an engineered landfill is in active progress at Ankleswar and Vapi. At megacities like Mumbai, Bangalore, Hyderabad MSW landfills have been constructed and maintained under a kind of BOT/Co-operative system under the aegis of the respective State Pollution Control Boards.

5. NATURAL FIBRE GEOTEXTILES

Jute, a bast fibre (coming from the stem of the plant, by retting process), has a tenacity of around 30 cN/tex with a low extension at break of around 1.0 to 1.8 % . The tenacity of coir fibres (coming from the husk of the coconut, retted or unretted – white coir or brown coir respectively) is much lower 15 cN/tex, but elongation at break is much higher having range of up to 45 % . The growth of micro-organism on vegetable fibres depends on their chemical composition, particularly the lignin content. Coir has about 35 % lignin content, making it extremely resisting against biodegradation, whereas for

jute it is only around 12 %. Volume swelling of jute fibre is excellent having value of 44.3 %. This makes jute a suitable raw material for making 'sheath filter' part of pre-fabricated vertical drain.

A simple machine was developed at Textile Technology Department of IIT Delhi (Banerjee, 1996, Banerjee et al, 2000) that uses coir and jute yarns to manufacture 100 % natural fibre strip drain. This drain differs from the other natural fibre drain in that it is manufactured in a single machine, and has capability of varying the width, thickness and mass per linear metre to suit different soil conditions.

6. EROSION CONTROL

India has about 25% of its geographical area under mountainous terrain. Over 80% of the annual rainfall occurs from June to October. This leads to flooding every year causing environmental degradation which in itself is caused by excessive grazing, road construction, mining and unscientific farming practices. This results in an estimated soil loss of the order 6 billion tonnes per annum. Thus the importance of erosion control need hardly be emphasized.

Not only the many rivers that crisscross the country, but the longest sea coastline and storms and hurricanes add to major concerns of degradation and particularly severe erosion around port and harbour works. As per a survey conducted by the Ocean Engineering Division of National Institute of Oceanography, Goa, India about 23 per cent of India's mainland coastline of 5 423 km is getting affected by erosion. As much as 1248 km of the shoreline is getting eroded all along the coast out of which about 700 km of coastline has been reasonably protected by construction of seawalls, groins, etc . With 480 km of the 569 km shoreline of Kerala is being affected by the phenomenon, in Karnataka, the erosion was marked over 249.6 km out of the state's total coastline of 280 km with the problem relatively more severe in south Kannada and Udupi coasts where about 28 per cent of the total stretch is critical. Again, the coastal erosion is marked over 263 km of the 652.6 km shoreline of Maharashtra while 107.6 km. Extreme wave conditions occur under severe tropical cyclones which are frequent in the Bay of Bengal during the northeast monsoon period. Andhra Pradesh coast has frequently been affected by cyclones and inundated by storm surges. Erosion is noticed at Uppada, Visakhapatnam and Bhimunipatnam. Erosion is noticed at Gopalpur, Paradip and Satbhaya in the neighbouring Orissa. Growth of long sand spits at Chilka lake indicates the movement of littoral sediment and subsequent deposition.

The various causes of erosion, the different geosynthetic solutions then available are detailed in "Erosion Control with Geosynthetics" published by the CBIP (Venkatappa Rao, 1995). Early experiences have been gained in the country in using polymeric geomeshes (at Ghaziabad byepass by UPPWD), gabion mattress underlain by needle punched geotextile (on Gandhar River Gujarat by GERI), grouted mattress (Kakarpar Canal, Gujarat) and in many other water ways and locations.

In 1988 as part of river training works in the Hooghly, to prevent erosion at Nayachara Island, over 30,000 m^2 of geotextile mattress was laid on the river bed. Denuded forest cover in hilly regions due to indiscriminate lime stone quarrying around Dehradun are controlled environmentally by use of jute geotextiles and other measures by CSCRI, Dehradun.

The ability of natural fibres to absorb water and to degrade with time are the prime properties which give them an edge over synthetic geotextiles for erosion control purposes.The "drapability" of natural geotextiles (due to their flexibility) allows them to conform closely to the terrain,and for intimate contact with the soil.

From literature one also notes that erosion control measures with jute based geotextiles had given a good response but the textile degraded after about one year. In the more severe situations, either because of climate or steepness of slope, a longer period of function by the geotextile is required. Coir based geotextiles provide both the advantages of biodegradable geotextiles and the longevity required where plant establishment might be slow (up to 3 years).

Several successful case studies have been reported by the Central Road Research Institute, New Delhi and others in use of jute and coir matting for erosion control in different hill regions of the country. A successful use of jute open weave geotextile in mine dumps is depicted in Fig.9.

Fig. 9 Erosion control by Jute Geotextile in mine dumps (Photos courtesy Sri T.Sanyal)

Fig. 10 Control Of Coastal Erosion By Geocontainers (Photo Courtesy : M.Venkataraman)

Fig. 12 Indigenous geotube for coastal erosion

Fig.11 Use of sand bags (geocontainers) in erosion protection at River Sarada

This apart, simple solutions like use of geocontainers - as small as bags(1 m x 0.6 m)(Figs.10 and 11) or as large as 20 m diameter geotubes (Fig.12) have been successfully tried in several projects in India.

7. MANUFACTURE IN INDIA

The manufacture of geotextiles is not new to India. Since 1985 many textile manufacturers ventured into the then unknown potential of geotextiles. Now, M/s. Garware Wall Ropes, Pune and Techfab India,Silvasa are well known industrialists in the manufacture, design and construction with geosynthetics. M/s Meccaferri Environmental Systems, Pune, Strata Geosystems (India) Daman and Skaps Industries (India), Ahmedabad have their manufacturing facilities and also provide design assistance. M/s.Ten Cate India and Heusker Geosynthetics have their presence in India through their distribution network and design assistance.

Extensive manufacturing facilities exist for both Coir Geotextiles (notably M/s Charankattu Coir Industries, Alappuzha,Kerala) and Jute Geotextiles (notably M/s Glocester Jute Mills, Kolkata, and many others notified by National Jute Board) in the country. As already mentioned the National Jute Board, Kolkata and Coir Board, Kochi, support research and development of natural fibre geotextiles in the country.

India manufactures many types of Geosynthetics to International standards

- *Non-woven geotextiles*
- *Woven geotextiles*
- *High strength Woven geogrids*
- *Geostrips*
- *Glass grids*
- *Geonets*
- *Geomembranes*
- *PVDs*
- *Woven and Non-woven Coir and Jute Geotextiles*
- *Erosion Control Mattresses (RECBs)*

Jute and Coir Geotextiles are being manufactured as Rolled Erosion Control Products in various weights and in various configurations such as woven nettings, meshes and blankets for different applications requiring varying degrees of protection. More varieties were developed at Indian Institute of Technology, Delhi, at CCRI, Kalavur and IJIRA, Kolkata.

8. THE FUTURE

Hitherto an attempt was made to project an overview of the early attempts made to bring in the much needed new technology of geosynthetics into the civil engineering fold and one can say with confidence that a platform has been made, with an estimated annual consumption of over 100 million m^2. But this is just the beginning, a tip of the iceberg. The following describes the future prospects.

I) Railways

Indian Railway system with a network of 60,700 km route length is the largest system in Asia. Out of this, nearly 60,000 km is of broad gauge (1676 mm gauge). The line capacity utilization of existing major trunk routes like Delhi- Howrah, Chennai-Howrah, Delhi-Chennai have exceeded the 100 % capacity and hence have become critical. In improving these systems Dedicated Freight Corridors are being established which use modern technology and are on fast track. Some of the critical stretches go through the high swelling black cotton soils or marine soft soils. The field trials with geosynthetics in the tracks are in progress, to establish the quantum of improvement. Rockfall prevention and land slide mitigation has been ably accomplished in the Konkan Railway, on the Western coast of India. These and other issues were highlighted by the author in a recent book (Venkatappa Rao, 2013). In addition, a major field study is being undertaken by the RDSO, Ministry of Railways in order to develop Specifications and construction procedures for use of Geosynthetics in a variety of track conditions.

About 7 000 km of the Indian Railway track is founded on weak formation, causing ballast penetration, resulting in multiple losses like extra maintenance cost to track and rolling stock, speed restrictions, higher fuel

consumption, and passenger discomfort. Rehabilitation/strengthening of such track can help to eliminate speed restrictions.

Apart from this, the construction on the country's ambitious 3,300 km Dedicated Freight Corridors (DFCs) on the eastern side from Ludhiana to Dankuni – a distance of 1,839 km ,and the western flanks from Dadri to Mumbai – a distance of 1,500 km is set to start shortly. The entire project is envisaged to cost around Rs.950 Billion (around US$ 15 billion). The construction of the 640 km of the western corridor (Rewari to Palanpur) – being funded by the Japanese International Co-operations Agency (JICA) may cost around Rs.65 billion. The 343 km of the eastern corridor (Kanpur to Khurja) being funded by the World Bank is likely to cost around Rs.33 billion.

In this context, it is now well known that there are major technical benefits of using geosynthetics in the construction of rail-tracks as well as their maintenance. Geosynthetics can be an economic aid in improving train load carrying capability.

ii) Highways

The Highway Network in India is very vast and vital to the development of the country. The Government of India gives top priority to the road development through its many schemes, either through the National Highway Authority which in a way controls the significant portion of the 71,770 km of National Highways or through its many development programmes to develop the State Highways whose length is around 150,000 km. The National Highways comprise only 1.7 % of the total Road network, but carry 40 % of the traffic and has only 24 % of it with 4 or more lanes. Hence, continuous development of these roads goes on either through strengthening roads and/or widening, for its ever increasing traffic. A significant component of these are the Road Underbridges and Road overbridges, which call for Geosynthetic Reinforced soil structures. Whereas the use in pavements is yet to pick up ground improvement procedures through PVDs or reinforced Embankments are becoming increasingly common, particularly in providing access to Ports.

iii) Inland Water Transport

An Inland Water Authority was set up in India in 1986 for developing waterways for navigation. There are already some waterways declared along the major rivers like Ganga, Brahmaputra and Godavari with a total length exceeding 5,000 km. Apart from river bank protection and provision of permanent and floating king jetties, they are required to maintain minimum draft of 1 to 2 m throughout the year.

iv) Interbasin Water Transfer

In view of the vast area of hinter land and uneven distribution of river waters, a significant amount of water goes waste into the sea. Many plans are afoot to conserve this water by novel schemes such as Inter Basin transfers, which may connect even large rivers like Godavari and Krishna, to utilize staggering water resource. The NWDA web site, lists the status of 14 such projects. A few of these are already successful, but many are being planned for immediate development. As these are surely to pass through hills and over soft soils, hence landslides, ground improvement, elevated canals are all going to call for efficient use of geosynthetics.

v) Landfills

Solid Waste Management be it Municipal Solid Waste or Chemically active/hazardous waste is required to be dealt appropriately by constructing and managing Engineered Landfills as per Statutory Guidelines issued for the said purpose, which includes use of natural soils as well as Geosynthetics generally following International norms. Further details are contained in Venkatappa Rao and Sasidhar (2009). With 9,00 t Municipal Waste being produced every day out of the India's capital Delhi, the landfills are expectedly huge and finding alternate sites is quite cumbersome. According to the Master Plan of Delhi, the city requires an additional land area of 1500 Hectares. Thus the need for Engineered Landfills grows by the day not only in metropolitan cities but also in large towns. Though continuous efforts are being made to segregate and also develop energy out of waste, still the task is Herculean.

vi) Landslide Mitigation

Most hill regions in the fragile Himalayas be it in Uttar Pradesh, Himachal Pradesh, Jammu and Kashmir, the North-eastern Hill States or the Nilgiri Hills in Tamil Nadu, land slides pose a recurring problem. They damage the highway structures as well as endanger the thickly populated hill towns. There are many classic examples of recurring problems, say, on the Jammu-Srinagar National Highway, Highways in the North East Region as well as the Konkan Railway.

It is possible to use this technique in many other problematic areas. For instance, in many of the water resources projects as well as new railway projects, considerable (sometimes indiscriminate) blasting results in instability of the region, exposure of fresh rock face, appearing like an eye sore. In such cases geosynthetics offer convenient economic and permanent, green solutions.

9.CONCLUDING REMARKS

- Use of Reinforced Soil Structures proved to be a feasible and economical solution in India.
- In many roads and railway system on poor sub-soils there is a need for remediation through use of geosynthetics.
- Coupled with the fact that many port structures are likely to be located on soft soils, there is a great need for ground improvement through PVDs.
- For the upcoming MSW and hazardous waste land fillsthe requirement of geosynthetics is huge.
- Methods of controlling the severe erosion on embankments, hill slopes and flood banks need rational geosynthetic system.
- The durability of geosynthetics is not established in the Indian context caused bylarge variations in the climatic conditions, terrain and the soil.
- Jute and coir have tremendous potential in India as well as the rest of the world for environment friendly applications.
- Bulk waste materials like Fly Ash can be used in GRSW. Their designs need to be standardized and doubts eliminated.

10. THE GOAL

Global geosynthetics market is expected to reach US$ 27 billion by 2022, according to a new study by Grand View Research, Inc. Construction industry growth in India, China and Middle East, on account of rising expenditure on infrastructure development is expected to be a crucial driving factor for geosynthetics market growth.

Suffice it to mention that, as India continues to march towards development of world class infrastructure and the increased need for the development felt by the people, the need for the use of geosynthetics is synonymous with development, in view of the confidence with which the materials have been used in the country.

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