Use of Geosynthetics for Protection of B-Dyke in Dhakuakhana along the River Brahmaputra, Assam -A Case Study

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Abstract. The Assam state in the north-eastern India annually bears the brunt of floods. Displacement of people on the banks of rivers due to erosion is another major issue. The meandering characteristic of Brahmaputra River is so dynamic that Brahmaputra-dyke (B-dyke) from Sissikalghar to Tekeliphuta takes the shape of a bow for nearly 5 km. To protect this area, Geotextile tube and Geotextile mattress were deployed for the first time in the history of India in the year 2010. This 5 km embankment became a part of the B-dyke which is 27.15 km long. Now, to further provide protection to B-dyke at vulnerable reaches from Lotasur to Tekeliphuta from the erosion of River, Geosynthetics materials were used to protect existing embankment to prevent floods and erosion in Dhakuakhana, District Lakhimpur. Such application is being rapidly deployed to achieve maximum benefit to the community, typically through the use of on-site materials, innovative Geosynthetics materials and construction techniques, where construction is to be completed in a limited time during the flood. The scheme benefits approximately 5 lakh thickly-populated villages and protects 10,117 hectares of cultivated and homestead land. The paper briefly presents the problem and protection works carried out along the vulnerable reaches.

Keywords: Geosynthetics, Protection, Dyke, Flood, River.

1 Introduction

River Brahmaputra is the lifeline of northeastern India since ages. After the great earthquake in 1950, flow split into more than one channel causing severe flood and erosion problem. Formation of number of braided channel has disturbed the original equilibrium of the river. The flood plain area has to lose a huge quantity of cultivation and agriculture land due to periodic flood, which is now aggravated by climate change also. Most of the existing embankment around the Brahmaputra River were constructed between fifties and seventies and crossed their designed life and got weakened due to wear and tear over the years. Failures of embankment at different region have caused major destruction to thousands of villages, affecting lakhs of people. New areas are being affected by erosion every year. Fertile land is reducing due to erosion, which has a very negative impact on the rural economy of the state. Embankments system needs to be fortified in phase wise with new technology and strategies. Geosynthetics application has found its place as midterm measures. One application described in section 6 and 7 of the paper is the use of geotube mega container and geotubular mattress in the Dhakuakhana area of Lakhimpur District. Located by the side of the river Brahmaputra, Matmara area was disturbed by flood 20 times in between 1964 to 2009. 90 % of its paddy land was silted by the flood and 50 % rendered homeless. To save the area from the devastating flood of river Brahmaputra, for the first time in the history of India, construction of embankment using geo fabric tube technology for five km was used as a flood protection measure. The annual benefit cost ratio of the project then was 7.09: 1. The work was completed in 2010 under Flood Management Programme (FMP) [1]. Similar work was again taken-up in 2015 for the remaining reaches under FMP sanctioned by the Ministry of Jal Shakti, Govt. of India with the benefit cast ratio of 3.47: 1. Such applications of new technology and determination of the Government gave boost to the geosynthetics material in flood control and anti-erosion work. Subsequently many projects were completed under FMP in Ganga and Brahmaputra Basin with the support from Central Water Commission (CWC), Ganga Flood Control Comission (GFCC) and Brahmaputra Board (BB) in their respective jurisdiction.

2 Problem in Brahmaputra Basin

2.1 Geology and Seismology of Brahmaputra Basin

The Brahmaputra basin is considered as a tectonic sedimentary basin, 80-90 km wide and 720 km long, underlain by recent alluvium about 200-300 m thick consisting of clay, silt, sand and pebble. Because of young sedimentary deposit, river carries the second highest sediment load of all the rivers in the world. While the riverbed is largely formed by the coarser sediments, especially sand and more upstream gravel largely mobilized during the high flood season, the floodplains are built from finer silts and clay. Due to its location very near to colliding Eurasian plate boundaries, the Brahmaputra valley is seismically very unstable, falling in severe seismic intensity zone V. Active seismicity of the North Eastern region has caused extensive landslides and rockfalls, subsidence and fissures of ground in the valley. This has led to changes in the course & configuration of Brahmaputra River and its several tributary. Because of which there is significant impact on the hydrologic regime and morphology of the basin resulting in flood hazards, especially after two great earthquakes of 1987&1950.

2.2 Flood and Bank Erosion Problem

Brahmaputra River is one of the largest alluvial rivers exhibiting an unusual degree of meandering and braiding characteristics. According to the Water Resource Department, Assam, the Brahmaputra has shown an alarming picture of widening trend during the last century i.e., 4000 km^2 in the 1920s, expanded to 5000 km^2 in early 1970s, and 6000 km^2 in 2008. Width of the river within Assam varies from 6 km to 18 km [2]. The flood plains of Assam have the highest drainage density in the world and shelter a huge population. Successive floods in Brahmaputra valley have become routine every year and have damaged the economy, more particularly the agro-economy of the floodplains. Approx. 4.27 lakh ha. of land has already been lost since 1950 which accounts to 7.4 % land area of Assam state [3]. The primary reason for this is the erosion and channel migration by mighty Brahmaputra. In recent decades, river bank erosion has become a serious threat to the fertile land and huge population residing in the flood plains of Assam. A large part of this landmass has been already lost and the process is still continuing.

This causes enormous problem for the people and the Government. Due to population increase along the bank of rivers, large number of township, villages, human dwellings, number of important installations and line of communications are under sever threat. The impact of erosion is unbearable and imposes permanent irreparable loss to human being.

2.3 Siltation and Water Logging Problem

Large scale silt deposit in the Brahmaputra River is the main factor for bank erosion. It is therefore essential to either check arrival of silt into the river or de-silt when it has entered into the river. But this is a challenging task, as qty and area is widespread. To streamline the flow and moderate flood, raising & strengthening of embankment is generally undertaken to increase the depth of basin.

Deposition of silt load eventually leading to widening of river and increases frequency of flood. Rise of bed act as barrier to free flow creating drainage congestion and water logging. Water logging has also become the recurring phenomena with the increase in flood. As a result, there is land-use change as well as occupational change influencing the livelihood pattern. Twice cultivation in a year (double cropping) is not been possible as most part of the area remain under waterlogged situation during entire kharif season. The land holding of majority of population being small is inadequate to sustain the livelihood with single crop. The economic vulnerability of the people can be improved, provided the waterlogged scenario of the area is mitigated. Malakar, J., 2013 [4] has studied water logging problem of flood affected area of Morigaon district, Assam.

2.4 Impact of Climate Change

Erratic pattern in monthly average rainfall and incidents of unpredictable flood at several clock of time is the phenomenon, which the region never experienced in the past is the explicit onset of climate change.

Sorry part is that, with the new warning like climate change appearing, time is running out fast. Already, floods have occurred in recent years in areas that are normally not a flood prone. There is changing pattern of runoff, discharge & flow regime thereby increasing risk of flooding in the region. The potential change due to climate change that would seriously impact would be the river hydrology of the Brahmaputra valley, due to glacial melt and regression of the Himalayan glaciers [5]. The major glacier fed rivers of North East India, having substantial impact on the environment and mankind of the people are the Brahmaputra (256,928 km^2), Lohit (20,720 km^2), Dibang (12,950 km^2), Manas (31,080 km^2) and Subansiri (81,130 km^2) [6], as well as a vast web of other springs, streams and tributaries. It is therefore necessary to connect climate acclimation and mitigation measures with those dependence on natural resources and magnified risk they face due to the climate change.

3 Importance of Geosynthetics Materials in its Various Forms

Because of huge quantities of soil involved, it is the primary construction material for embankment. Scarcity of suitable material near the project site and compromise in quality may bring instability in embankment, which increases the chances of erosion, breach and flooding. In order to overcome above limitation, geosynthetics materials in various forms like geobags, geomattress and geotubes are not only used for strengthening old embankment, but are also used for new construction known as Geo-dyke.

Further, conventionally used boulders for protection works has become scarce. In recent years, sand filled geobags in various forms, size and shape has emerged as

perfect replacement for boulders and causes less environmental damages. Application of geotextile bags is gradually increasing in the country.
The location and topography of a large number of roads, alongside hilly terrain and upper reaches of rivers are subjected to flooding, landslides, rock falls and other natural disasters like earthquakes. If required quality of sand near river or good quality of stones at hilly terrain is available, either can be made useful in protection works. Sand filled geotextile bags or stones/boulders encased in a gabion box can be used for protection works. There is also increase in rock fall protection like cable nets, barriers and fences which are deployed along the vulnerable places as a protection layer to control and guide movement of falling rock at the toe of the slope.

Satisfying the filter and drainage criterion for conventional graded design is extremely expensive, difficult to obtain, time consuming to install and involves problem of segregation during placement. The conditions can easily be achieved using a single layer of Geotextile filter media. Such materials opening size and permeability is defined which retain soil particles, prevent erosion while at the same time allow water to pass freely. Buildup of hydrostatic pressures in protected slopes is prevented, thus enhancing slope stability. A single layer of Geotextile fabric can replace a graded filter comprising two or three layers. Geosynthetics material with so many advantages and application, its use may rapidly increase in the future.

4 Life Expectancy and Future Scope of Geosynthetics

Geosynthetic products may have expected life in the range of 5-10 year [9] when directly exposed to UV radiation. This expectancy may vary and depends largely on various considerations like polymer composition at manufacturing stage, installation method, exposed condition, climate condition, application and function etc. They may be applied in the form of strips, fabrics, container, in a composite form or in a three dimensional structure in contact with earth materials to enhance engineering performance. They are made up of polymeric material, so they are durable, non-corrodible, non-biodegradable and stable in both acidic & alkaline environment over pH range of 4 to 11. Since they are factory manufactured high quality can be assured. Also, uniformity in material specification can be maintained throughout project.

Realizing the importance of geosynthetics material in the last decade and to fill the gap (where conventional material cannot be applied due to shortage or shortcoming in application), there is a very good scope of geosynthetics material depending upon the complexity (flood & erosion problem, stability problem and time constraint) of the problem. Geotextiles as filter media, geobags for erosion control and geotubes for flood and coastal protection are the established applications where various sizes and lengths are customized to form revetment, launching apron, temporary reefs, groynes, erosion control works, breakwaters etc.

Government of India, sensing the importance of technical textile in engineering application has supported the growth of technical textile industry since 2007. To boost its usage it has also launched the National Mission for Technical Textiles and has given a special importance to technical textile. Various handbook and manual prepared by Government of India (GOI) to promote the use of geosynthetics [7-10] are presented in Table 1. India as a developing country is much more likely to see a sustained programme where solutions with geosynthetics products will increase immensely over the next decade and beyond. Therefore, the role of quality control and assurance should be strengthened to ensure that the Geosynthetics materials being used meet the minimum qualifying criteria.

Table. 1. Various handbook and manual prepared under GOI

Sr	Guidelines and Handbook	Year	Organization
1	Handbook for flood protection, anti erosion & river training works	2012	CWC, M/o Jal Shakti
2	Handbook for Geosynthetics	2013	M/o Textiles
3	Guidelines for use of geotxtiles, geotextile bags, geotextile tubes in construction of flood management works	2016	GFCC, M/o Jal Shakti
4	Practice manual for use of technical textiles in water resources works	2019	R&D Division, M/o Jal Shakti

5 Importance of Flood Management Programme and Benefits

With the development of the new scenarios around the world regarding climate change and other complex issues like submergence area, downstream impact assessment, interstate & intra region disputes, forest & environment protection, tribal protection, rehabilitation & re-settlement, it appears that building a dam and reservoir is having a little opportunity in coming future. While long-term measures are always helpful in multipurpose development, short & medium-term measures are essential for immediate relief from flood and erosion. GOI brought Flood Management Programme (FMP) as a central assistance schemes during the XIth (2007-2012) & XIIth (2012-2017) five year plan. This plan schemes covers the works of flood control & management, anti-river bank erosion, anti-sea erosion, restoration work, flood proofing and drainage development. Considering the critical and emergent situation to complete the work within scheduled time financial approval of individual schemes was given by empowered committee. The schemes under FMP are monitored by CWC, GFCC and BB in their respective jurisdiction. During XIth & XIIth plan, more than 520 works were approved and Rs 4873.07 Crores [11] was released under FMP. Various states including Ganga and Brahmaputra basin, facing flood problems were benefitted by this scheme.

Two such schemes, implemented in Dhakuakha area of Lakhimpur District, Assam are presented below in section 6 & 7. The area was disturbed by the flood 20 times before 2009. The major breach of 5 km was completed in 2010 and remaining reach of the embankment was strengthened in 2015. Flood protection work is performing well till today and no breach has been taken place after completion of work. Above work were completed in a tactful manner using innovative geosynthetics technology.

6 Protection of B-dyke in Dhakuakhana along the River Brahmaputra in District North Lakhimpur under FMP

During the 11th five year plan, above scheme was successfully implemented using geotube mega containers and geotubular mattresses for construction of embankment in Matmara of Dhakukhana. The purpose of using geosynthetics product was feasible because materials available for earthen embankment especially on the northern Brahmaputra bank are sandy soil, which often do not possess required cohesion and stability. However, geotubes made of geotextile materials with sufficient tensile strength was the new emerging concept in India.

The use of geosynthetics has revolutionized the practice of geotechnical engineering all over the world. Although, its application started in Europe in 1960s, its use in India started only from 1990s but were seldom applied for flood management and erosion work. The credit goes to the Water Resources Department, Assam for taking up new initiative in 2009 with geotube mega containers and geotubular mattresses in Matmara area of Dhakuakhana.

6.1 Root Cause and Flood Problem at Matmara, Dhakuakhana

Matmora [1] is located in the portion of Sissikalghar-Tekeliphuta B/dyke at Dhakuakhana in District Lakhimpur. The Dyke length of 27.15 km was constructed in 1955-56 keeping bank margin 3 km from the river. But during course of time Brahmaputra River formed a bank-ward spill channel at Matmora after 1950's Earthquake. The channel eroded the bank and caused subsequent sequence of breaches, requiring closure works each time. Effect of flood & erosion in Matmara [12] are shown in Table 2.

Table 2. Effect of flood and erosion

	Flood and Erosion Problem
1	Annual flood affected area 6,252 Ha Land area eroded (1967-2008) 3,640 Ha (Bank line length 13 km)
2	Rate of erosion 69.2 m/year (Highest erosion rate is observed in 2007-08 at 161.86 m/year)
3	Number of household lost 199 nos. (Last 10 years) Number of household affected 2,186.

During the flood of 2007, matmara area was disturbed due to a major breach on the flood embankment causing enormous damages in Dhakuakhana division. Due to non-availability of good quality of soil, the embankment breached at many locations. The entire stretch of land area is covered by river sand & silt and construction of bund extending a length of 5 km is not sustainable. Figure 1 shows the breach and flood problem before construction of Geo-dyke. Basically the materials available for earthen embankment especially on the northern bank area of the River Brahmaputra consist of vast track of sandy & silty soil, which often do not possess required cohesion and stability. However, these materials form an excellent filler material for use in geo-tubular mattresses, geotube containers and geotextile bags.

Fig. 1. Breach and Flood problem before execution of Geo Dyke

6.2 Solution Implementation

For flood and erosion control work, variety of protection works can be adopted to reduce the erosive force of water. But reducing the erosive force is not the complete solution, as river water fluctuates between LWL and HFL and over a period of time structure may fail due to build-up of water pressure. To overcome the problem of non-availability of good quality material and bring new technology for carrying out the protection work, it was decided by the Water Resources Department, Assam to use polymeric geotextile in the form of geotube containers and geotubular mattresses with the available river bed material as filter material.

Geotubular mattress, geotubes and geobags made of geotextile materials with sufficient tensile strength were used in the protection work during the 11th five year plan in Matmara of Dhakuakhana to protect Majuli and Dhakukhana area against flood caused by Brahmaputra River. The protection work was carried out with different components. The purpose of each component is presented in Table 3.

Table 3. Components of the protection works

Components	Purpose
A) Construction of embankment using geotube mega containers (Dia. 2.5 m) as core.	This is the main body of protection work, constructed with respect to high flood level to prevent flooding on the country side.
B) Construction of revetment using geotubular mattresses on slope of embankment	To protect the slope from getting damaged from erosion, rain cuts etc. The apparent opening size of geomattress allows water to gradually flow out and at the same time retain soil particle within the embankment. This does not allow pore water pressure to buildup in the structure during receding flow.
C) Construction of scour apron using geotube mega containers (Dia. 0.9 m)	Scour apron is constructed with respect to low water level. It prevent scour of the riverbed materials during flood. Scour occurring towards the outer bank of meandering river is of great concern to the designers.
D) Construction of Filter Media	To support the phreatic line well within the embk, 0.15 m thk filter media is provided at left side toe for a length of 7.42 m.

The slope of the embankment was prepared as stable as possible with slope of 3H: 1V. To support the phreatic line well within the embankment, 0.150 m thick filter media was provided at left side toe for a length of 7.42 m. The work was started in March 2009 and structure was physically completed in December 2010 and thereafter resisted number of floods event without any major damage to properties and loss of land. This is regarded as a first project of its kind in the country. Typical cross section [13] of protection work showing all the component is presented in Figure 2.

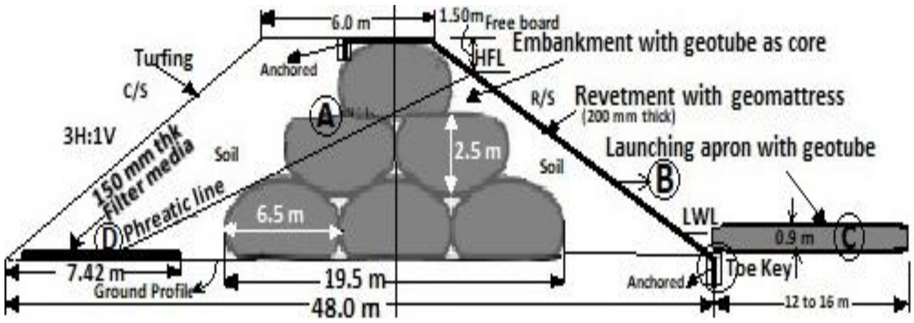

Fig. 2. Typical cross section of protection work using geotube and geotubular mattress

6.3 Construction of Embankment, Revetment and Scour Apron

Construction of Embankment using Geotube as Core (Geo-Dyke): Good quality of soil for embankment construction was not available in the vicinity of the project. Hence geotextile in the form of geotube mega containers filled with sand/silt was used in the core of the embankment with adequate soil cover to provide a trapezoidal shape having stable slope of 3H:1V as shown in Figure 1.This is the main body of protection work. The formation of geotube dyke for closing the breach of 5 km length consisted of mainly 6 tubes i.e. 1 over 2 over 3 nos. Geotube installed for a length of 5 km embankment was 200 nos. per line and therefore total nos. of geotubes for 6 lines consisted of 1200 nos. The length of geotubes used were 25 m long with fill height of 2.5 m. Minimum 3 stages were required to complete the tube filling. In every stage, pumping of slurry inflated the tube to its full capacity, then pumping was stopped until the water comes out from the tube. Such stages continued until the fill height achieved is 2.5 m. The height of the embankment was kept 7.5 m, consisting of 3-2-1 formation of geotubes stacked one above the other to form the required slope as shown in Figure 3 [1]. Height of embankment is selected with respect to high flood level to prevent flooding on the country side.

Fig. 3. Installation of geotubes (1:2:3) as core of the embankment

Construction of Revetment using Geotubular Mattress: For providing revetment, slope of the embankment on the river side is dressed atleast up to low water level (LWL). Geotubular mattress filled with sand (200 mm thickness) is laid on the slope to protect the slope from getting damaged due to the rain cuts etc., and due to flood water. It also served the dual purpose of preventing bank erosion and bank sloughing due to seepage of country side water which is filtered out by the sand filled mattress. Geotubular mattress is anchored at crest and bottom toe (near LWL) of embankment slope by bending the mat into the trench of size 1.5 m x 1.0 m and filled with earth materials. Trench at the bottom slope also acts as toe-key for the revetment and apron. Revetment work [1] is shown in Figure 4.

Fig. 4. Installation of Geotubular mattress as revetment

Construction of Scour Apron using Geotube: Construction of scour apron is carried out near LWL using geotube mega container of dia. 0.9 m. It is filled in place by pumping sand water slurry, allowing the geotube to fit the contour of uneven river bed. It is placed on the river side ground and extends from embankment toe-key towards the river for a length of 12 to 16 m as scour apron to prevent scouring of the river bed. The structure also protects the scouring of embankment toe-key by dampening the velocity of the flow approaching towards it. Figure 5 shows the installation [1] of geotube as scour apron at Matmara geo-dyke.

Fig. 5. Installation of Geotube as scour apron at Matmara geo-dyke

Here, revetment is part of slope protection work while scour apron & toe key is a part of bed protection work. Slope protection followed by a suitable bed protection can be considered as the key success for any flood protection work. This is regarded as a first project of its kind in the country in the year 2010.

7 Protection of B-dyke in Dhakuakhana along the River Brahmaputra in District North Lakhimpur under FMP

After successfully completing 5 km breach portion with Geo-dyke at matmara in the year 2010 as discussed above, Dhakuakhana WRD implemented similar work in the year 2015-16 under FMP with nomenclature “Protection of B/dyke from Sissikalghar to Tekeliphuta at different reaches from Lotasur to tekeliphuta from the erosion of River Brahmaputra with annual benefit cost ratio of 3.47:1. Out of 27.15 km B-dyke, strengthening of remaining portion was started in 2015. Protection of B-dyke was done using geotubular mattress all along the length on river side and geotube mega containers, each 0.9 m fill height and 10 m length was applied in the critical portion. Geotubular mattress was installed on the slope of the embankment as revetment [1], as shown in Figure 6 and geotube mega container was installed at the toe portion as scour apron. Geosynthetics materials for above scheme were evaluated for their quality at CSMRS, New Delhi [14-15]. The protection work was started in 2015 and completed in 2019.

Fig. 6. Installation of Geotubular mattress

7.1 Material Design

Geotubular Mattress: The geotubular mattress is a double layered composite geotextile fabricated to form a tubular mattress when filled with sand and used at design slope of affected reach. The upper layer of the mattress is directly exposed to sunlight, temperature, abrasion etc., where UV degradation could be the greatest. The upper layer is therefore made from heavy-duty polypropylene (PP) woven geotextile, needle-punched with a formulated mixture of UV stabilized green fleece forming an engineered composite geotextile fabric. This layer provides excellent durability in terms of abrasion and UV resistance. The lower layer of the mattress is also made up of heavy-duty UV stabilized PP woven geotextile fabric without any substrate. Both the layers of engineered fabrics are stitched together at regular interval to form a containment product, which when filled with sand form a three dimensional tubular structure. The net result is completely flexible revetment and can replace concrete slabs, block, rip-rap revetments etc.

Geotube Mega Container: The geotube fabric is made up of woven geotextile to sustain filling pressure by sand pumps. It also has a suitable apparent opening size to retain sand fill material from flowing out during pumping. When applying geotubes with pumping sand-water slurry, the major design considerations/problems are related to the integrity of the units during filling. The geotube container having high strength woven geotextile allow the river water to permeate through it by providing flexible structure which absorbs the stresses against erosive forces free from pore water pressure and brittle failure. Closer view of geosynthetics materials is shown in Figure 7.

Fig. 7. Closer view of geosynthetics materials

7.2 Material Specification

Geotube mega container and Geotubular mattress are designed for high strength, robustness, special pore size, excellent abrasion resistance and UV resistance etc., for the vulnerable reaches to be protected.

An evaluation of specialized product for a specific application needs proper selection of testing program and conduct of the various tests as per test procedures. The detail specification adapted from WRD, Assam for geotube mega container and geotubular mattress are presented in Table 1 and Table 2 respectively.

Table 4. Specification of Geotube Mega Container

Properties	Test Method	Unit	Minimum values
Tensile Strength (Warp & Weft)	ASTM D 4595	kN/m	> 55
Elongation (Warp & Weft)	ASTM D 4595	%	< 20
Apparent Opening Size, O_{95}	ASTM D 4751	mm	< 0.18

Seam Strength	ASTM D 4884	%	> 70
Abrasion resistance (Retain tensile strength)		%	> 75
UV Resistance (Strength retained)	ASTM D 4355 @ 500 hrs	%	> 80

Table 5. Specification of Geotubular Mattress

Properties	Test Method	Unit	Minimum values	
			Upper layer	Lower layer
Mass per unit area	ASTM D 5261	g/m^2	≥ 650	≥ 400
Tensile Strength	ASTM D 4595	kN/m	> 42	>76
Apparent Opening Size, O_{95}	ASTM D 4751	mm	< 0.35	< 0.35
Abrasion resistance (Retain tensile strength)	ASTM D 4886	kN/m	> 35	
UV stability (Strength retained)	ASTM D 4355 @ 500 hrs	%	≥ 80	≥ 80
Resistance to oxidation (Strength retained)	ISO/TR 13438 @ 100° C for 28 days	%	≥ 80	
Sewing thread: High tenacity polyester (tensile strength is 200 N, elongation at break ≥ 20 %				

8 Conclusion

The paper presents the problems and the remedial works carried out along the vulnerable reaches of Brahmaputra River. Erosion and Flood at the Dhakuakhana Division was completely controlled with the permeable measures using geosynthetics materials. The completed project under FMP schemes benefitted vast track of land having 200 nos. of villages and approx 5 lakh populations, definitely enhancing the social-economy of the flood affected area of Lakhimpur District. Protection and strengthening of B-Dyke using geosynthetics materials stands as a sustainable protection measure against flood by the mighty Brahmaputra. 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.

With the effect of climate change and glaciers melting, erosion and flood has become an endemic problem. To deal during emergent condition, WRD, Govt. of Assam in its initial phase has set-up a bank of buffer material at Guwahati and Majuli as a central storage to store 2.50 lakhs geosynthetics bags including other jumbo and empty cement bags along with 10,000 members of PSC porcupine bars. Geotextile materials in large quantity are also stored as buffer material at district level. To monitor the continuous status of long chain of embankment, WRD has also brought out mobile app application named "PANEE (People Application for Noticing Embankment Erosion)" where citizen can participate, so that quick steps for repair can be done in the field for erosion and flood management.

Floods were previously considered as purely natural phenomenon, but after the implication of climate change and melting of glaciers, it is no longer a natural phenomenon. Damage due to increase in flood is associated with not just increased in precipitation but also with increasing infrastructure residing within flood plains due to rise in population size and density. With the increase in green house gas, alteration of green cover/forest land into urban area/agriculture land and utilization of low-lying land & wetlands areas to meet the resources required to support the increased population. All these environmental disturbances in clock have gradually given rise to surface flow, diminution in surface storage & infiltration capacity and climate changes. From the nature's reaction, it appears that flood-erosion problem and climate change adaptation will be new normal for future. Today, there is a profound need that the communities of the river bank & coastal areas at local level is very much part of the entire process of mitigation measures. On a more pragmatic note there is always a scope of improvement with development of technologies/strategies to ensure efficient protection measures. Since good initiatives and best technologies has already been put in place. Future management, development and hazard mitigation have to be planned keeping in mind the effect of climate change and present state of the river along with the existing embankments.

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