Use of Geosynthetics in Restoration and Bank Protection from Dhola-Hatiguli to Rohmoria along the River Brahmaputra - A Case Study

Suresh Maurya
Central Soil and materials Research Station,
Ministry of Water Resources, New Delhi, India

Manish Gupta
Central Soil and materials Research Station,
Ministry of Water Resources, New Delhi, India

Nripendra Kumar
Central Soil and materials Research Station,
Ministry of Water Resources, New Delhi, India

Abstract- 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 studies where Geosynthetic are used as erosion control measures and their effectiveness at two different reaches (Rohmoria & Dhola-Hatiguli) 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 Geosynthetics materials.

Keywords – Flood, Bank Erosion, Geosynthetics, Quality Control

I. INTRODUCTION

A. 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.

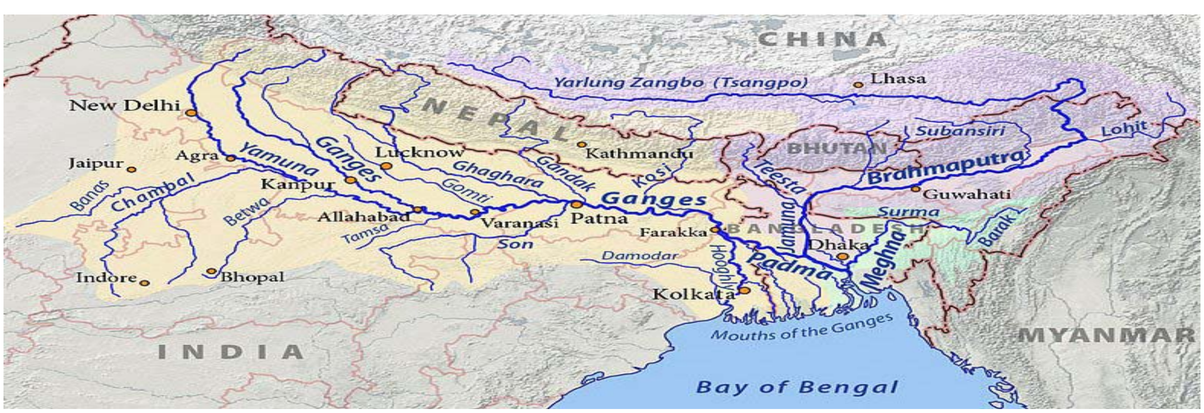

Figure 1. Brahmaputra River System

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 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.

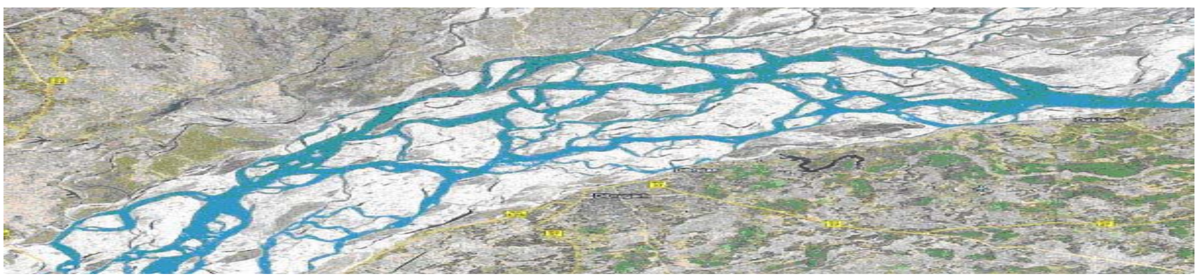

Figure 2. Braided channels of Brahmaputra Rive

B. 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

C. Flood and Bank erosion problem of 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 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.

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**

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.

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**

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.

II. FLOOD MANAGEMENT ACTIVITIES USING GEOSYNTHETICS IN RESTORATION AND BANK PROTECTION

In order to provide protection to the people, short & medium term measures were taken up by the Brahmaputra Board, Ministry of Water Resources and 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 and to mitigate the problem of combined discharge near Dhola-Hatigulu in Tinsukia district from two rivers resulting in gradual widening of the channel and bank erosion, 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 Geosynthetics 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 of testing woven and nonwoven geotextiles, filters, geomembranes, geonets, geogrids, glass fibre paving mat, G.I wires, polymer rope gabions and geocomposite that are used in drainage, earthwork, erosion control and soil reinforcement applications.

A. Rohmoria Project, Dibrugarh, Assam –

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.

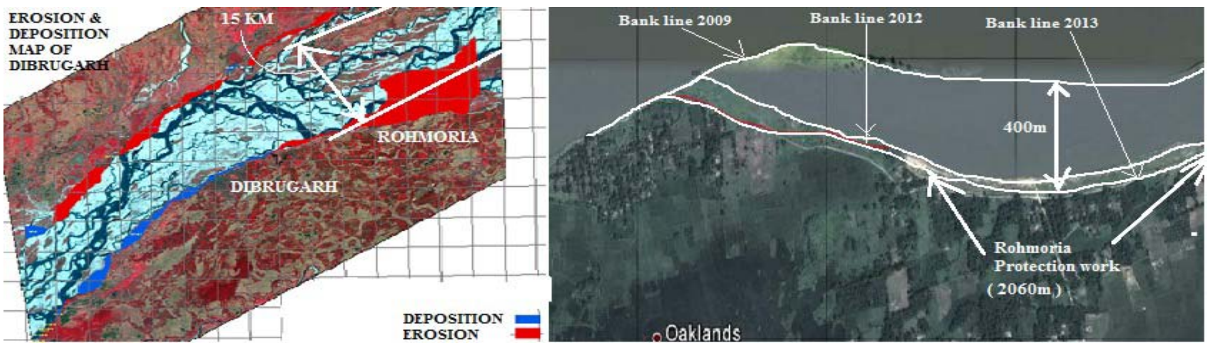

Figure 3. Bank Erosion & Rohmoria protection work

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 slope at an inclination 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 Geotextile bags placed on geotextile filter layer. 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. Figure 4 shows typical design section of anti-erosion work.

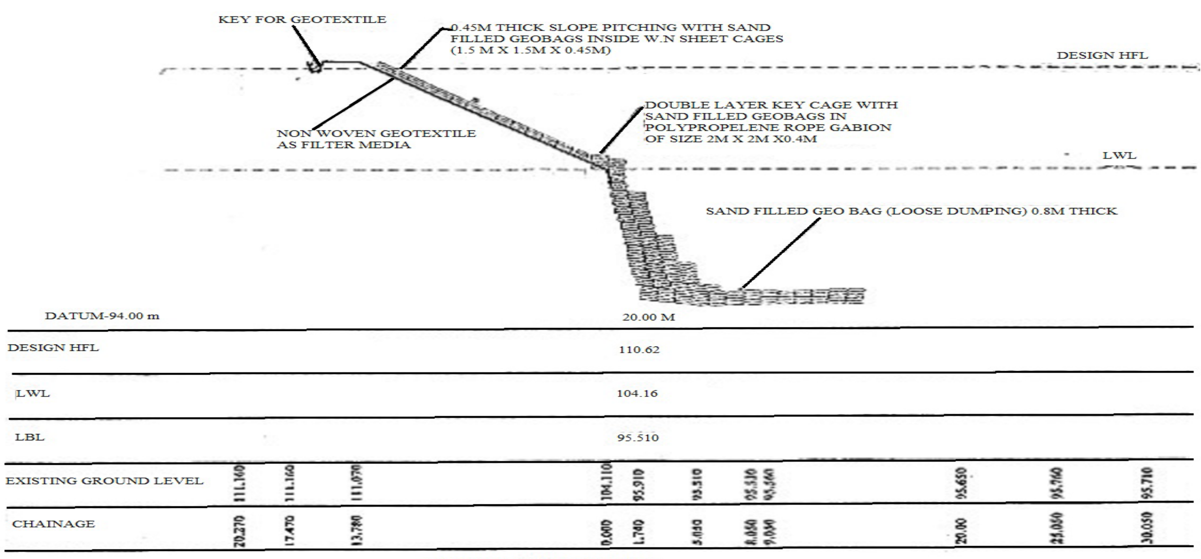

Figure 4. Typical design section of anti-erosion work

Laboratory Investigation –

As part of the quality assurance, 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/m^2/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**

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 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 introduced 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.

Figure 5. Placement of filter media, Geobags & PP Gabions

Figure 6. Bank condition during flood

Figure 7. Silt deposit on bags after flood

B. Dhola-Hatiguli Project, Brahmaputra Board, Assam –

Dhola-Hatiguli project in the upper portion of the Rohmoria area is designed to push the direction of Lohit and Dibang rivers northwards which would reduce the pressure of the river on the southern bank which is Dibrugarh and Rohmoria. At the junction of Lohit and Dibang, the width of the river is almost 12 km.

Problem Description –

The combined flow of Dibang and Lohit Rivers was originally falling into Dihang (Brahmaputra) River at about 25 km downstream of Dibru-Saikhowa National Park at Kobo. Avulsion of left bank of River Lohit occurred at confluence of Lohit with Dibang near Dhola-Hatighuli located in Dumdooma of Tinsukia district in the year 1989. As a result,River flow of Lohit diverted towards south. The breach was plugged in the year 1990.The breach erupted again. Initially, the breach developed in a length of 1 km in the year 1992 and then increased to 1.3 km in the year 1993. This problem was further aggravated due to pushing of flow of Lohit towards south by River Dibang, flowing from north to south direction and joining Lohit from the opposite direction as shown in Figure 8. During the year 2001-02, offshoots channel of Lohit and Dibang was carrying to the extent of 90 % of their combined discharge and falling into Brahmaputra at North Balijan instead of Kobo. This resulted in formation of a channel of about 1 km wide and 55 km long, eroding away large area of agriculture and homestead lands along with tea gardens in the way. Gradual widening of the channel with time was threatening existence of more areas of Tinsukia and Dibrugarh

District of Assam, situated all along the newly developed channel. Thousands of hectares of rich cultivated land of 49 villages were eroded away before the year 2002. An approximately 48,000 people of the area are adversely affected. By the end of year 2010, length of breach portion increased to 3.6 km.

Solution Description –

The quick and economic preventive measure adopted by the department was to implement non-woven geotextile bags in flood protection work. The scheme was to restrict the flow of River Dibang in its original course and to avoid pushing of Lohit River toward bank & habitat area. Constructing artificial barrier of 2070 m in length, overall width of 15 m including apron width of 6 m and maintaining top height of bund at RL+129.5 m with respect to HFL of 128.8 m. Pitching of Tie bund and launching apron with multiple layer of geotextile bags was a part of preventive measures. This was followed by well dressed tie-bund at a stable inclined slope of 1V:1H. The Tie-bund construction was a part of flood protection work while launching apron was part of bed protection work as shown in Figure 9. Tie-bund barrier followed by a suitable bed protection can be considered as the key success for protection work. 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.

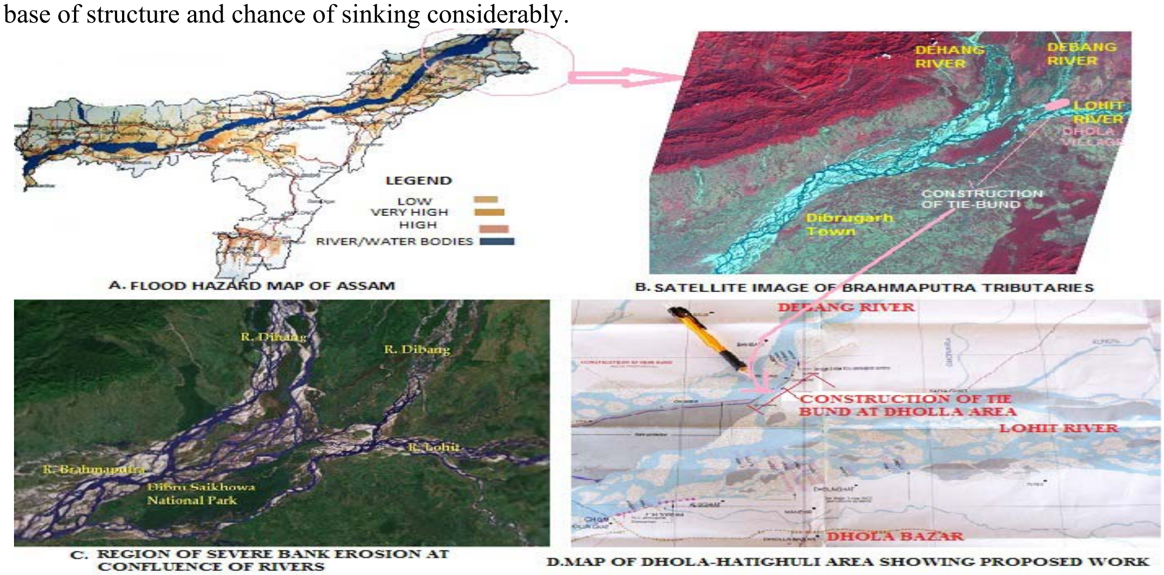

Figure 8. Map showing location of River Brahmaputra tributaries

Laboratory Investigation –

As part of the quality assurance, CSMRS, New Delhi carried out extensive testing for evaluating the properties of non-woven geotextile bags. The Geotextile bags of Type – A (Size 1.03 m x 0.7 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 were specified. The Laboratory tests such as apparent opening size, mass per unit area, tensile strength & elongation (wrap), tensile strength & elongation (weft), CBR Puncture strength etc were carried out on the non-woven geotextile bags 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 6.

Table 6 Range of results of Laboratory tests carried out on nonwoven geotextile bags.

Properties	**Range of Results**
Mass per unit area, g/m^2	**405 to 425**
Tensile Strength (MD), kN/m	**20.5 to 21.9**
Tensile Strength (CD), kN/m	**20 to 20.5**
Tensile Elongation (MD), %	**53 to 85**
Tensile Elongation (CD), %	**43 to 89**
CBR Puncture strength, N	**3910 to 3950**
Apparent Opening Size, mm	**0.075 to 0.150**

Solution Implementation –

Non-woven Geotextile bags were filled with sand to the specified height to ensure that appropriate density is achieved by filling. At a given stretch, number of bags were filled and stacked suitably for checking and verification. This was a part of quality assurance and compliance procedure that was followed during the installation activities. 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 the construction was placing of sand filled Geobags in multiple layer for launching apron, key construction and placement of sand filled Geobags in multiple layer on the bund. Construction of launching apron and key was carried out partly underwater. This was carried out using suitable vessels and appropriate placing methods. Further, the tie- bund was dressed to the inclination of 1V:1H and over this a multiple layer of non-woven geotextile bags filled with sand was laid. Figure 9 shows implementation of non-woven geotextile bags at various stages.

Figure 9. Implementation of Non-woven Geotextile bags.

On an average, 100 labors were deployed for filling, stitching, loading and placing of bags. Around five numbers of boats were used to transport filled bags from filling area to installation location. Total quantum of geotextile bags for the protection works was approximately 2,00,000 numbers and these were placed at the rate of 1,000 numbers of bags per day. The work was completed in 8 months from December 2012 to August 2013, with an average placement of 25,000 numbers of bags per month.

C. Solution Performance and conclusion –

The erosion protection measures constructed with Composite Geosynthetics solution at Rohmoria as Emergent works served the purpose & protected the banks and flood protection work carried out in Dhola-Hatiguli has restricted the flow of River Dibang in its original course and also avoided pushing of Lohit River toward bank & habitat area during the flood of June 2013. 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.

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.

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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.

[8] CSMRS (2013), “Report on Laboratory testing for Brahmaputra Board”, Guwahati.