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A Research Paper on Performance of Jia Bharali River Bank Protection Measure using Geotextile Bags

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ABSTRACT

River bank erosion is one of the major natural disasters being faced by the state of Assam, located in the North-eastern part of India. With the increasing popularity of geotextile materials in construction industry several pilot projects to control bank erosion of major rivers of Assam have recently been executed with the application of geotextile bags, geotextile tubes. But very little scientific study on the post-construction performance of these works is available. In this paper the findings of a study on the post construction performance of one of these recently completed bank protection works is presented. In order to ascertain the erodibility of the bank soil characterisation of geotechnical properties of the bank soil is carried out. The bore log obtained by adopting a simplified method of boring suitable for this investigation is presented along with detailed laboratory test results and analysis. The change in river flow pattern near the bank after installation of the bank protection work and the resultant siltation is studied in this work. In order to predict progressive development of sand bar due to the induced siltation during the first 1 year after installation of the protection work the siltation area is surveyed and the contours are prepared. The resultant flow pattern is reasonably determined from the siltation area contours. Satellite images of the study area for a period of 3 years after installation of the protection work are analysed and presented before arriving at a final conclusion on the performance of the protection measure.

I. INTRODUCTION

Stream bank disintegration is one of the significant catastrophic events being confronted by the condition of Assam, situated in the North-eastern piece of India. In the course of the most recent 100 years compelling waterway Brahmaputra, which runs 740 km through the State of Assam, has demonstrated a general pattern of enlarging wiping out more than 4500 towns. The Brahmaputra which possessed around 4000 km2 in 1920 has extended to around 6000 km2 in 2010 along the surge fields of Assam [1]. Brahmaputra and the vast majority of its tributaries in its north bank have begun for the most part from the Himalayan range. A sudden lessening in slants of these streams as they enter its surge fields in Assam result in a lot of dregs statement, offering ascend to improvement of plaiting example of the waterway. With the initiation of surge season, the silt transport in these waterways increment, the thalweg begins to change position and geometry and area of mid-channel bars change. As the stream subsides, affidavit over the bed happens as bars and islands. The waterways stream in a few twisted directs in the middle of these sandbars.

Kotoky et al. from their review on nature of bank disintegration of the interlaced Brahmaputra waterway channel confirm noteworthy disintegration on both banks amid the period 1914–1975, while amid 1975–1998 the stream saw a prevailing period of statement.

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Jiyabharali and Subansiri are two noteworthy tributaries of Brahmaputra in its northern bank. Both the two tributaries have started from the Himalayan range and have comparable plaiting trademark in the surge fields of Assam. Subansiri has drawn more consideration of scientists than Jia Bharali because of its hydro-electric power potential. Gogoi and Goswami in their investigation of bank-line movement example of Subansiri stream utilizing satellite symbolism of 1995 and 2010 found that the aggregate disintegration (82 km2) on both banks is twofold that of statement (43 km2) amid this 15-year time of study. The Subansiri stream is portrayed by substantial stream amid surge season, tremendous volume of dregs load, constant change in channel morphology, bankline relocation and horizontal changes in channels which additionally causes extreme bank disintegration prompting an impressive loss of good fruitful land each year. The immense seismic tremor that hit Assam in 1950 bothered the harmony between dregs supply and transportation of Subansiri waterway and this extra residue brought about mid-channel bar development, bank disintegration and broadening. The normal suspended silt heap of Subansiri and Jia Bharali are accounted for as 1776 and 2013 ha m, individually.

Development of goads, utilization of porcupines and stone pitching of banks are the normal measures taken up to contain bank disintegration in these waterways of Assam. Government organizations take up the essential duty of executing and keeping up these security measures. With the expanding fame of geotextile materials in development industry a few pilot activities to control bank disintegration of significant waterways of Assam have as of late been executed with the utilization of geotextile sacks, geotextile tubes, and so on.

Mondal et al. through a contextual analysis on bank rupturing in Moyna waste bowl range of West Bengal, India, examined the physical, mechanical and geotechnical properties of the dike material and assessed existing outline system for dike dependability examination. As locally accessible soil was utilized as a part of development of the earthen banks the review found that the geotechnical properties of dike materials should have been enhanced by utilizing added substances or strengthening materials like soil–cement, characteristic or geosynthetic fiber. It was additionally recommended utilization of geotextile packs, bond composites with support for dike incline assurance.

Geotextile tubes, Geotextile packs are likewise being tested in chosen extends of banks of waterway Brahmaputra and its real tributaries. Maurya et al. have given a definite record of the current surge security and against disintegration works composed and executed utilizing geotextile to give insurance of the overnight boardinghouse disintegration of the Brahmaputra stream. Bank security taken after by a reasonable bed insurance was completed utilizing geotextile packs put on geotextile channel layer. Steel Gabions loaded with geotextile sacks were put at standard interims to confer assist steadiness to the scour assurance measure. Maurya et al. concentrated the material properties of the geosynthetics utilized as a part of stream preparing works of waterway Dibang, a tributary of Brahmaputra, and talked about the benefits of utilizing these geotextile packs over regular materials and techniques.

Very little study on the post-construction performance of these bank protection measures using geotextile bags in flood plains of river Brahmaputra is available in literature. In this work a study on the effects of Jia Bharali river bank protection work, executed by Water Resources Department of Assam under one of its pilot projects using geotextile bags, on the induced siltation and flow pattern of the river is taken up.

Research has shown that differential physical properties of cohesive and non-cohesive bank materials result in marked differences in erosion rates, erosion processes and failure modes. Although fine-grained materials are resistant to fluid shear, they tend to have low shear strength and are susceptible to mass failure. To acquire appropriate understanding of mass failure problem like erosion the characterization geotechnical properties of the bank soil is also undertaken in this work.

II. THE STUDY AREA

A stretch of western bank of Jia Bharali river near Tezpur town of Assam had continuously been subjected to erosion every year during the floods since last several years. The progression of the river into the land due to erosion resulted in breaching of an existing embankment and was perceived as a threat to the Tezpur Central University, situated about 1.5 km away. The Water Resource Department, Assam, in the year 2012, had taken up a pilot project for protection of this stretch of the river bank. The measure consisted of installation of a launching apron up to low water level (LWL) and boulder pitching of river bank above LWL. Application of geotextile was made in the form of geotextile bags for construction of the launching apron. A satellite map of the location is shown in Fig. 1.

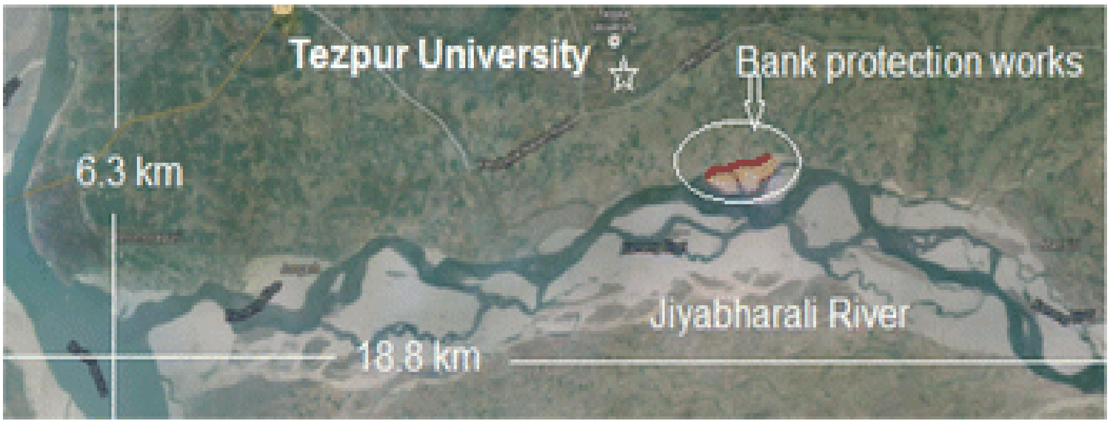


Figure 1

Length of this bank protection work is 650 m, located from Lat. 26°42′53″ Long. 92°51′2″ to Lat. 26°43′21″ Long. 92°50′58″, about 12 km upstream from the point of confluence of this tributary and river Brahmaputra.

III. FIELD AND LABORATORY STUDIES

Portrayal of geotechnical properties of the stream bank soil is embraced in this work in a geotechnical examination of the Jia Bharali waterway bank soil at an area close to the insurance work under review.

The field work constituted of field soil examination up to ground water table amid the dry season. Since the profundities of disappointments because of disintegration are by and large shallow the dirt stratification in fine detail should have been gathered for suitable incline strength examination. Both wash exhausting and twist drill drilling, the most usually received subsurface drilling strategies, give very aggravated soil tests and it is hard to distinguish more slender strata of subsoil. Keeping in mind the end goal to acquire the dirt stratification information in better detail an option and rearranged system was received in this examination. In this strategy an empty aroused iron pipe of 2.5 m length, 70 mm inward measurement and 3 mm thickness was utilized and the borehole was brought around rehashed upward–downward development of the pipe into soil with the assistance of manual exertion. The pipe was removed from the borehole after each 30 cm entrance and the dirt was deliberately removed from the pipe by tenderly tapping its external body. Tests of soil were than gathered, fixed in checked holders and transported to the geotechnical designing research center of the Dept. of Civil Engineering, Tezpur University for research facility testing. The technique could be viably used to gather soil tests for profundities up to ground water table. The in situ shear quality of the bank soil at various profundities were measured utilizing field vane shear instrument. The test strategy was taken after as set down in Indian standard code of practice.

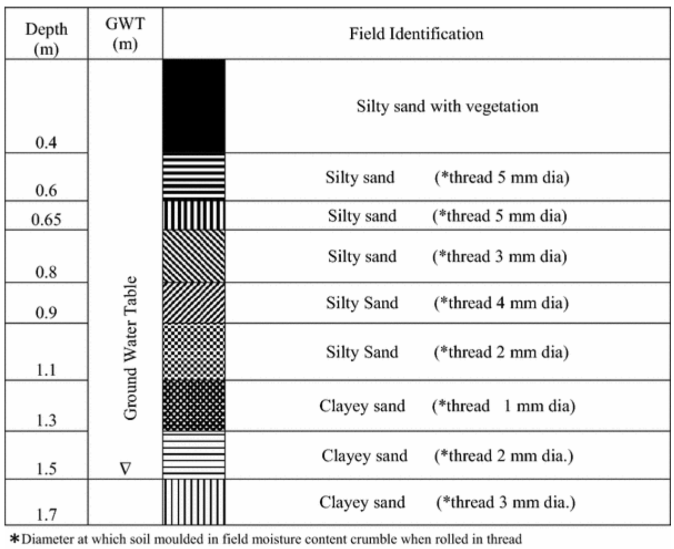
The soil samples collected from field were tested in laboratory for determination of the geotechnical properties of the river bank soil. The shear strength was determined from laboratory testing of remoulded samples prepared at field density. For determination of the shear strength direct shear test was conducted under undrained condition.

IV. FIELD SURVEYING

In the principal year after establishment of the assurance measures new siltation was seen in the review zone shaping sand bars. Keeping in mind the end goal to concentrate the example and degree of this instigated siltation and arrangement of the sand bars field reviewing was done in the siltation range. Electronic Theodolite was utilized as a part of this looking over work. The study zone was partitioned into 20 m × 20 m matrix and diminished levels at the lattice focuses were resolved with a point of setting up a form drawing of the sand bars.

V. PROPERTIES OF THE RIVER BANK SOIL

The borehole log obtained from the field borehole is shown in Fig. 2. It shows a surface layer of silty sand soil up to a depth of 0.9 m beyond which the soil is predominantly clayey sand.



The ground water table was encountered at 1.46 m depth. The stratification of the bank soil could be obtained in finer detail due to adoption of the simplified method of boring.

Table 1 gives the geotechnical properties of the bank soil obtained from laboratory testing of the soil collected from field at different depths.

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Table 1
Geotechnical properties of the river bank soil at five different depths

Depth from ground level (m)	Dry Density (g/cc)	Atterberg limits			Specific gravity	% Finer than (particle size)		Classificati
		LL	PL	PI		2 mm	0.075 mm	
0.3	1.33	22.8	19.8	3.0	2.70	100	30	Silty sand
0.6	1.26	36.1	30.6	5.5	2.71	97	21	Silty sand
0.8	1.45	29.5	23.3	6.2	2.76	98	33	Silty sand
1.1	1.45	32.9	23.3	9.7	2.76	92	34	Clayey sand
1.6	1.50	31.0	24.1	6.9	2.75	93	30	Clayey sand
2.7	–	–	–	–	–	–	–	–

VI. DESCRIPTION OF THE RIVER-BANK AND INSTALLED BANK PROTECTION WORKS

The detail of the protection work designed and installed at the river bank by the Water Resources Department (WRD) is shown in Fig. 3 and Table 2.

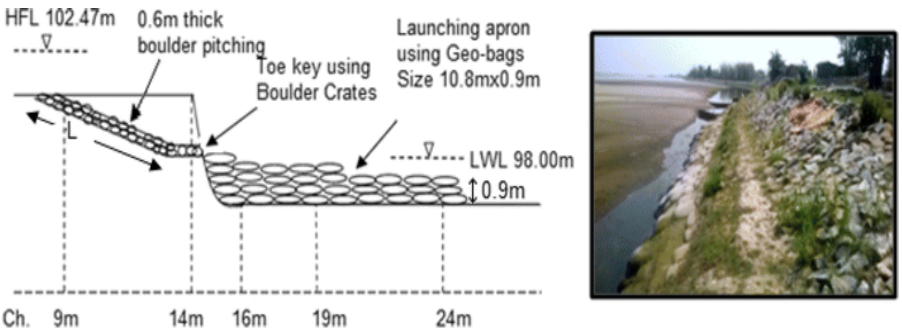


Figure 3

Table 2
Technical details of the bank protection work installed by Water Resource Department, Assam

Site: Jiyabharali river embankment at Dikoraijan near Tezpur University Length of mitigated area: 650 m Type of mitigation measures: boulder rip-rap and geotextile bags Year of work: 2012–2013	
Boulder pitching	*Launching apron with geotextile bags*
Slope of pitching: 2H:1 V	Length of launching apron: 10.80 m
Pitching thickness: 0.60 m	Thickness of apron: 0.90 m (3 layers of geotextile bags each 0.3 m thick)
0.075 m of thick metal filter bed	Geotextile bag filling: local sand packed to density 1.90 g/cc.
Average pitching length (*L* in Fig. 3): 5.4 m	

VII. PROPERTIES AND PHYSICAL CONDITION OF GEO-TEXTILE BAG MATERIAL

Tests of unused geotextile sacks from a similar parcel of packs utilized as a part of the above venture were gathered for testing. A couple geotextile sacks, sand-filled in the year 2012, were discovered unused in the filling site in the waterway bank and were gathered for surveying their physical condition following 3 years of presentation to handle condition. The geotextile materials were tried in the research center for assurance of mass per unit territory, thickness, rigidity and cut quality. The cut quality and rigidity were tried in the CBR instrument utilizing 50 mm distance across plunger. The CBR test setup was reasonably altered as appeared in Fig. 4 to do these tests. The elasticity of the geotextile and resist disappointment were resolved from the CBR cut test utilizing the accompanying relations [14].

Figure 4 CBR Tssting

$$\text{Tensile force per unit width} = \frac{\text{CBR puncture breaking force}}{2 \times \pi \times \text{radius of CBR puncturing plunger}},$$

$$\text{Strain at failure} = \frac{(x - a)}{a} \times 100\ \%,$$

where x = diagonal length of the geotextile at failure; a = horizontal distance between the outer edge of the plunger and the inner edge of the mould.

The geotextile material used in the project is of nonwoven type. A general inspection of the used and unused samples of the geotextile showed that the geotextile, after 3 years of exposure to field condition, has not shown any significant deterioration. The laboratory test results are shown in Table 3.

Table 3
Results of laboratory tests carried out on the geotextile bag materials

Properties	Test results of the geotextile bag material used in the project[a]	
	Unused material samples (stored in room condition)	Material used in field in the year 2012 (3 years of field exposure)
Mass per unit area (g/m²)	326	300
Thickness (mm)	2	2
CBR puncture strength (N)	1400	1200
Tensile strength (kN/m)	8.9	7.6
Strain at failure (%)	33	27

[a]Project executed in year 2012–2013 and materials tests conducted in March 2016

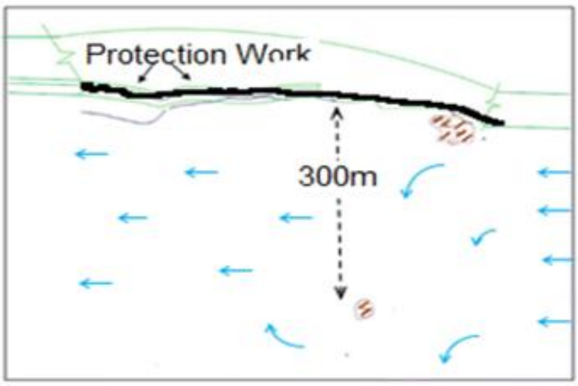
The results show that the nonwoven geotextile bag material used in this work, even after 3 years of field exposure, has not shown signs physical deterioration with only 15 % drop in its strength.

VIII. EFFECT OF THE PROTECTION MEASURES AND SILTATION AND FLOW DEFLECTION OF THE RIVER

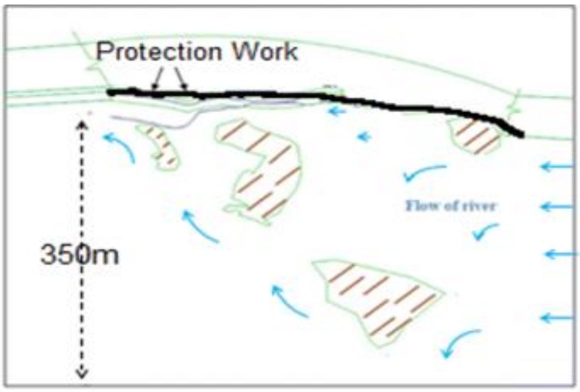
The waterway Jiyabharali in the year 2012 ruptured around 500 m of an earthen dyke built in the western bank. The dyke was basically in charge of security of the Tezpur University and its abutting territories from waterway Jiya Bharali surge. The WRD, alongside works for shutting the rupture of the dyke, completed a stream bank insurance work utilizing geotextile packs in the area. The adjustment in waterway stream design close to the bank because of the bank security work and the resultant siltation was considered in this work.

Because of establishment of the starting cover in the waterway bed the speed of stream gets diminished close to the bank and sediment testimony begins. With the expansion in volume of the residue store the standard stream heading of the waterway continuously makes tracks in an opposite direction from the bank and siltation territory gradually augments. As the water level retreats after surge the ranges encountering most astounding residue store seem first as a sand bar over the waterway water surface. Stream water keeps on streaming around these little sand bars. As the water subsides advance the following level of sediment store zones develop over the water surface. More siltation zones develop as the waterway water level keeps on subsiding until it achieves LWL. In this way, the diverse ground heights of bars in the waterway speak to various phases of their arrangement concerning time. The profile of this dynamic development of sand bars subsequently of actuated siltation can by implication be utilized to evaluate the adjustment in stream example of the waterway after establishment of the bank assurance works.

In order to estimate the extent of this progressive sand bar formation contour drawing of the char area was prepared through detailed ground surveying. The sand bar which was formed after installation of bank protection measures in 2013 was surveyed in January 2014 in this work. The surveying was done using digital theodolite by dividing the entire area into 20 m grids. The contour map was drawn adopting the method of interpolation with a contour interval of 25 cm. Contours at elevations 99.25, 99.00, 98.75, 98.50, 98.25 and 98.00 m (LWL) are shown in Fig. 5a–f.



(a) Sand bar having elevation > 99.25 m



(b) Sand bar having elevation > 99.00 m

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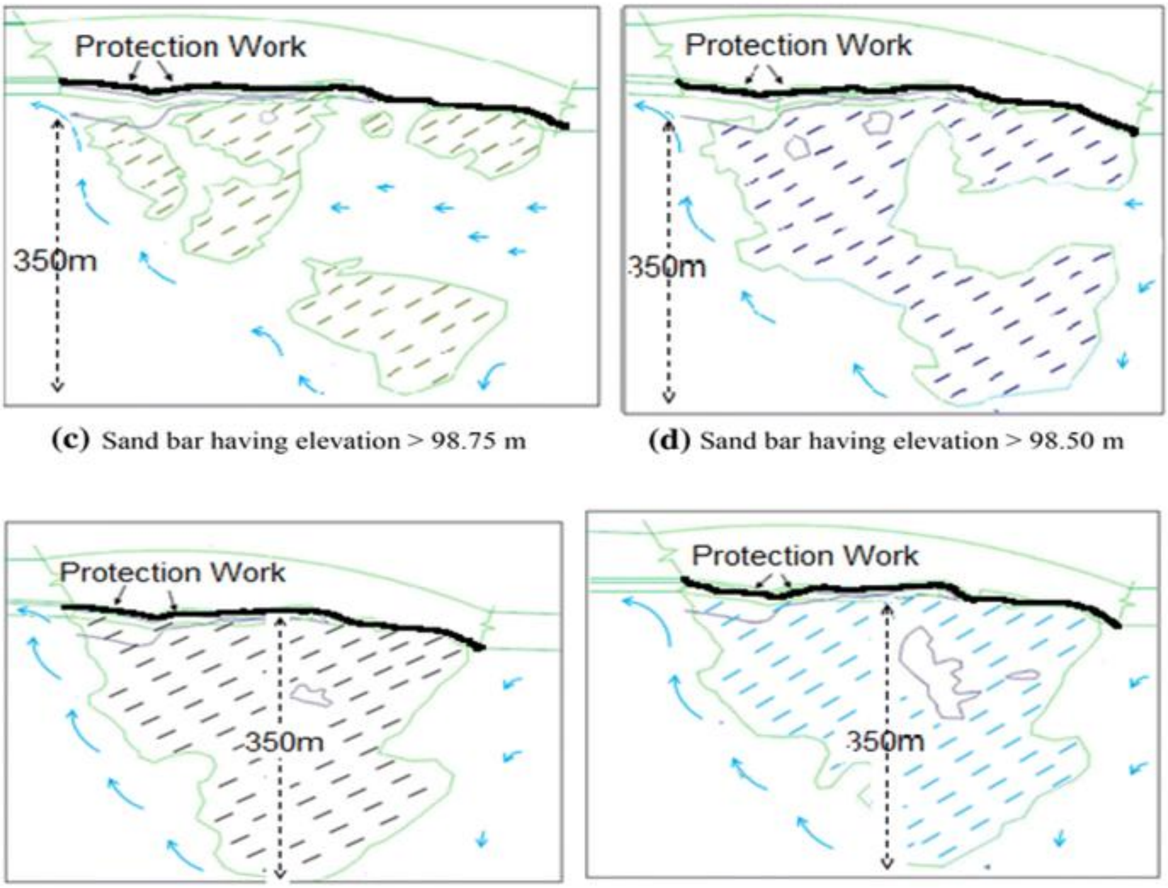

(c) Sand bar having elevation > 98.75 m

(d) Sand bar having elevation > 98.50 m

(e) Sand bar having elevation > 98.25 m

(f) Sand bar having elevation > 98.00 m

Fig. 5 Sand bar having elevation a >99.25 m; b >99.00 m; c >98.75 m; d >98.50 m; e>98.25 m; f >98.00 m

IX. CHANGE IN RIVER FLOW DIRECTION AFTER INSTALLATION OF PROTECTION MEASURES

The adjustment in stream example of Jia Bharali waterway in the review territory amid the period after establishment of the insurance measure is considered with the assistance of satellite photographs of the waterway accessible in Google Earth. With the assistance of Google Earth satellite photographs taken in March 2013 and March 2015 the stream example of the waterway stations and the sand bars as existed in March 2015 and March 2013 are followed out in Fig. 6a, b, individually. A correlation of Fig. 6a, b indicates new disintegration amid the period together with development of new sand bars. The degree of the zones influenced by crisp disintegration because of alter in stream course of the waterway channels and new siltation zones amid the period from 2013 to 2015 are resolved and appeared in Fig. 6c. The matrix in the figures demonstrates the latitude–longitude of the review range.

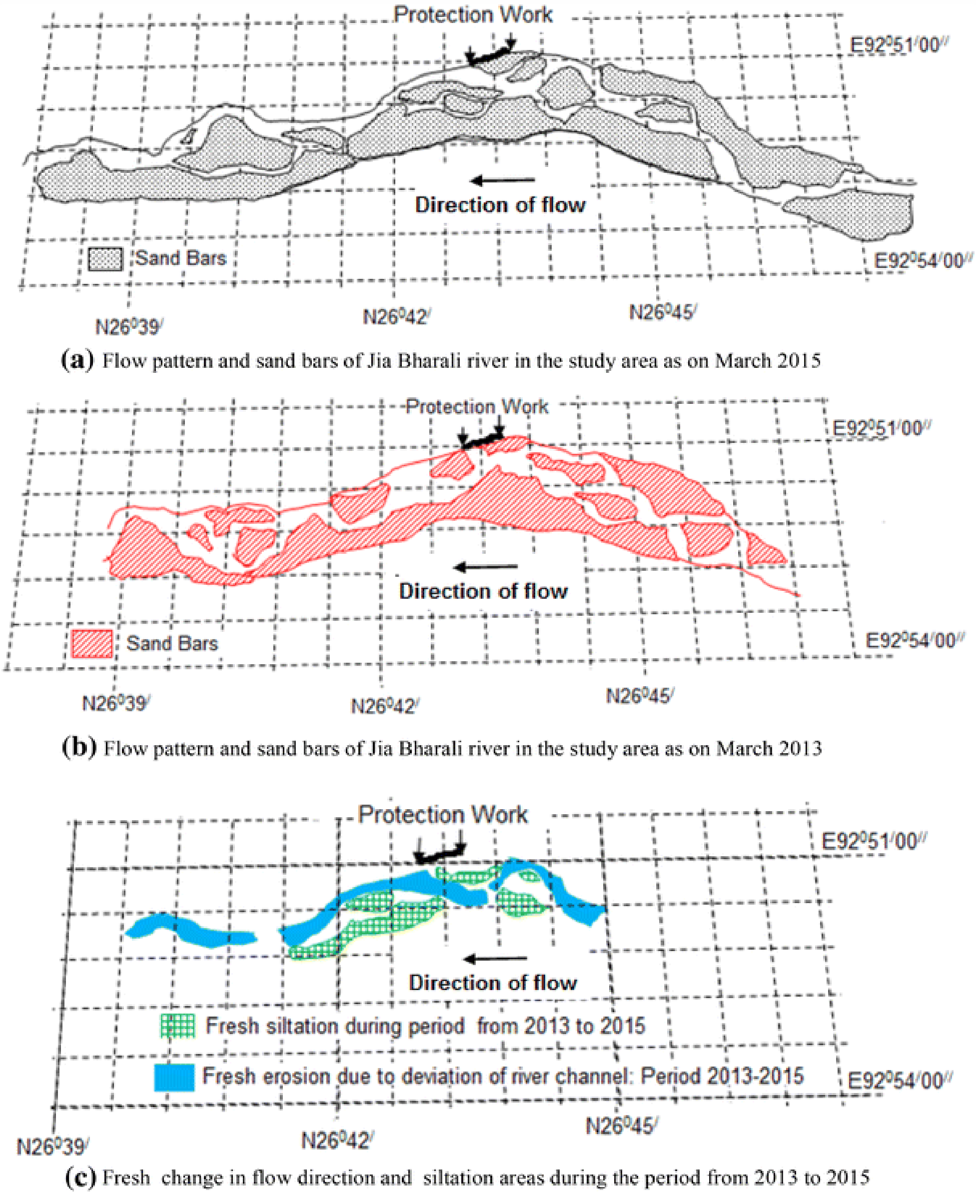

Fig. 6

Flow pattern and sand bars of Jia Bharali river **a** in the study area as on March 2015; **b** in the study area as on March 2013. **c** Fresh change in flow direction and siltation areas during the period from 2013 to 2015.

X. DISCUSSION

Two essential parts of stream bank material quality are erodibility and shear quality of the bank soil. Bank soil with low union and low versatility list (PI <15) are more vulnerable to disintegration [15]. The bank under review is constituted of soil having low PI (<10) and attachment esteem making it erodible. The shear parameters are likewise observed to be low. The in situ vane shear tests indicate marginally higher shear quality. The purpose behind this might be loss of quality because of remolding of the dirt example. The vane shear quality record demonstrates a sharp fall in the shear quality as the dirt winds up noticeably immersed. This shows the sharp loss of strength of the bank soil in the submerged condition amid surge occasions.

As the speed of stream is diminished after establishment of the bed cook's garment the primary indication of siltation is seen close to the upstream end of the bed smock (Fig. 5a). Figure 5a likewise demonstrates start of mid-channel siltation at an area around 300 m far from the bank showing redirection of the waterway stream bearing far from the insurance work. As the surge water retreats the siltation territory develops around the underlying mid-channel sand bar and furthermore close to the downstream side of the starting smock (Fig. 5b–d). It demonstrates progressive redirection of the waterway water stream channel far from the bank. Figure 5 demonstrates that the zone of impact of the bed assurance work through propelling overskirt stretches out up to remove 350 m from the bank into the stream which is about 30 times that of the 10.5 m width of the starting cover.

As the surge water subsides the stream of water is bit by bit diverted far from the bank, the reroute additionally starts siltation in the upstream of the assurance measure and the sand bar logically grows much past the upstream end purpose of the insurance measure.

Figure 5e, f demonstrates that in spite of the fact that the starting smock effectively redirected the stream water stream channel far from the bank close to the upstream end of the insurance measure and brought about advancement of another sand bars no siltation happens quickly past the downstream end of the assurance measure and the waterway channel returns strongly towards the bank just past the downstream end of the bed cook's garment. Since the bank soil is erodible, as obvious from the geotechnical testing, this sharp stream of the waterway towards the bank downstream of the security work has made it profoundly powerless against impinging stream disintegration.

Figure 6 plainly demonstrates that the waterway channel has strongly returned into the bank. This channel has begun new bank disintegration in the prompt downstream of the insurance work.

Jia Bharali stream, after establishment of the assurance measure in the western bank, has logically come nearer to a similar bank in the downstream of the security work. It, consequently, has additionally expanded the powerlessness of the bank to disintegration in quick downstream of the security measure. In this downstream segment of the stream, amid the time of 2 years from 2013 to 2015, the waterway has changed course towards the western bank bringing about bank disintegration and arrangement of mid-channel sand bars. This has made an earnest need to ensure the waterway bank facilitate downstream of the assurance work under review.

XI. CONCLUSION

The study on the effect of installation of river bank protection measure along with bed protection using geotextile bags in river Jia Bharali has revealed the following important conclusions:

1. The protection work has successfully diverted the river from the protected bank and resulted in siltation creating a sand bar extending to a distance nearly 30 times that of the width of the launching apron.
2. Although flow of the river is diverted from the bank in the protected stretch the diverted steam has sharply come back towards the bank just beyond the downstream end of the protection work, thus, rendering the bank downstream of the protection work vulnerable to erosion.
3. The poor geotechnical properties of the bank subsoil has made it further susceptible to erosion.
4. The protection work in its downstream has adversely affected the very river bank causing erosion and gradual shifting of the major stream of the river into the bank within a period of 3 years.

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From this review it is presumed that short length bank security measures with bed overskirt utilizing geotextile packs, albeit viable in ensuring a planned zone, has the capability of driving the disintegration issue towards the downstream zone of a similar bank. Such venture arranging needs to incorporate measures to lessen downstream bank disintegration especially if the geotechnical properties of the bank soil in the downstream extend are observed to be poor.

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