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# Use of Geosynthetics as a Soft Structural Measure to Mitigate Flood Hazard and Bank Erosion Problem

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**Abstract.** Conventional structural measures can directly reduce the magnitude of flood hazards to some extent, but are not always efficient or cost effective. However, impacts of floods can also be mitigated to a certain degree by adopting appropriate soft structural measures. This paper focuses on the soft structural measures using geosynthetics as an immediate measure to mitigate the flood hazard and bank erosion problem. Over the years, significant progress in the use of geosynthetics as a short term and localized flood mitigation has been witnessed. This paper is based on some of the key advances over the past years in improving understanding of the geosynthetics products and methods of construction techniques. Various case studies at vulnerable reaches along the River Brahmaputra, Swan, Ranganadi, Dibang, Ganga and Sarda has been discussed thereof and conclusion arrived at. Considering the advantages of geosynthetics materials, its use may rapidly increase in future and the importance of material evaluation and their frequency should therefore be emphasized to ensure that the geosynthetics materials meet the qualifying criteria**.**

**Keywords:** Geosynthetics, Structural, Flood, Mitigate, River

## 1 Introduction

Conventional structural measures like boulders and concrete revetments are often used on slope of river banks to prevent soil erosion. These armoured systems, when placed directly on the soil, have reduced the magnitude of flood hazards to some extent. River water fluctuates between low water level and high flood level. This causes seepage in and out of the bank slopes. If the seepage is blocked by placing impermeable protection materials, it leads to development of pore pressure which further destabilizes the bank slope. Further seepage water also removes the fine soil particles especially with receding flows. This leads to undermining the armoured protection, leading to failure of bank slope. Similarly, armoured protection is also required on river bed close to the bank toe portion. The armoured layer for protection of river bed also called as apron may consists of crated geotextiles bags or boulders in case of availability. During high flows, the discharge intensity increases, causing erosion of river bed even when it is protected. Fine particles may get removed from between the voids of the armoured layer. Hence a properly designed armoured layer and filter media is to be provided on the bank revetment, toe-portion and apron area as per IS 14262 [1].

Satisfying the filter & drainage criterion for conventional graded design is extremely expensive, often difficult to obtain, time consuming to install and involves problem of segregates during placement, thus compromising its filter ability. Many of the shortcomings of traditional filter can be overcome using geosynthetics to perform both drainage and filtration. The purpose of geosynthetics filter is to allow water to flow through it while preventing fine soil particles from being washed away. The design of filter is based upon the particle size distribution of the soil on the bank. Similarly, the armoured layer/apron provided on river beds also needs filter below it to prevent removal of soil fines of the bed materials

The Central Soil and Materials Research Station, New Delhi has provided quality control support in evaluating geosynthetics material properties to numerous projects. Geosynthetics materials in the form of geobags, geotextile filter media, geomattress, geotubes, geobags filled PP rope gabions etc have been implemented in various projects to mitigate flood hazard and reduce bank erosion, are discussed below.

## 2 Application of Geosynthetics in Managing Flood and Bank Erosion Problem along various Rivers

### 2.1 Restoration and Bank Protection Works along the Rohmoria Reach of River Brahmaputra

Rohmoria area is about 20 km northeast of Dibrugarh town on the south bank of Brahmaputra in Dibrugarh district of Assam. The area has witnessed erosion for the last sixty years and more than 25 villages have been wiped out by erosion. During the 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 non-woven geotextile filter materials and geobags (see Fig. 1).

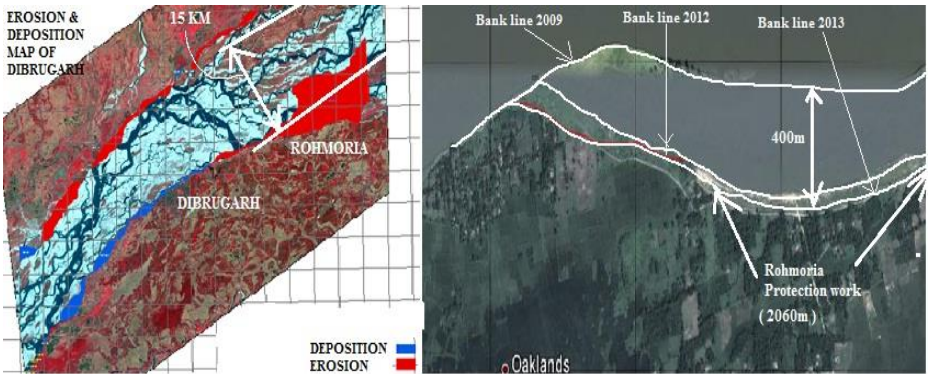


**Fig. 1.** Bank Erosion & Rohmoria protection work

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. The bank and bed protection were carried with multiple layer of non-woven geotextile bags placed over non-woven geotextile filter layer along the bank length of 2600 m. Strips of steel gabions and polypropylene rope gabions filled with non-woven geotextile bags were placed at regular intervals to impart further stability to the scour protection measure. Figure 2 shows placement of the filter media, Geobags & Polypropylene Rope Gabions [2].


**Fig. 2.** Placement of the filter media, Geobags & Polypropylene Rope Gabions

## 2.2 Engineered Anti-Erosion Works along the Banks of River Brahmaputra in Sonitpur District, Assam

The project is located in the Sonitpur District of Assam from Brahmaputra CH: 282 km (Silamari) to 373 km (Borgaon). The erosion in above said reaches is so severe that the river bank line migrates 300 to 400 m each year. At present, the difference between the dyke and the river at Bisawnath–Panpur reach is only 35 m at some locations. The river has already touched the only road used for plying vehicles to N.H-52. In Borgaon reach, River has migrated more than 5 km on its R/B for a reach of about 5 km during the last 10 to 11 years.

The quick and effective preventive measure adopted by the Tezpur Water Resources Division was to implement Geosynthetics materials & Gabions under Flood Management Programme. The scheme protected Biswanath-Panpur reach including upstream Silamari and far downstream Bhumuraguri to Borgaon against erosion of the River Brahmaputra. Figure 3 shows the cross section of launching apron; bank pitching and embankment work at CH: 10 m of Biswanath Reach [3].

**Bank Revetment with Launching Apron.** River bank of length 15600 m is dressed to the inclination of 1V:2H and over this a layer of non-woven geotextile of 400 gsm is laid as filter media, anchored at upper end and lower ends junction of bank & apron

to form a toe-key of gabion box filled with sand geotextile bags. After placement of geotextile filter, sand filled geotextile bags of Type-A (size 1.03 x 0.70 m) made of non-woven geotextile are placed all along the length of bank. Width of the apron is kept 20.80 m and top height of revetment is maintained with respect to HFL of 72.5 m. Thickness of slope pitching on bank is 0.45 m and launching apron is 0.90 m carried out with multiple layers of geotextile bags. Strips of zinc coated wire mesh Gabion box (size 2 x 1 x 0.45 m) filled with geotextile bags are placed along the length in toe-key of the bank revetment and also at specified intervals across the length of launching apron to impart further stability to the scour protection measure. Total qty of filter material applied is 1,67,650m$^2$, geotextile bags for the protection works is approximately 38,08,147 Nos. Gabion box used in apron and toe-key is 49428 Nos.

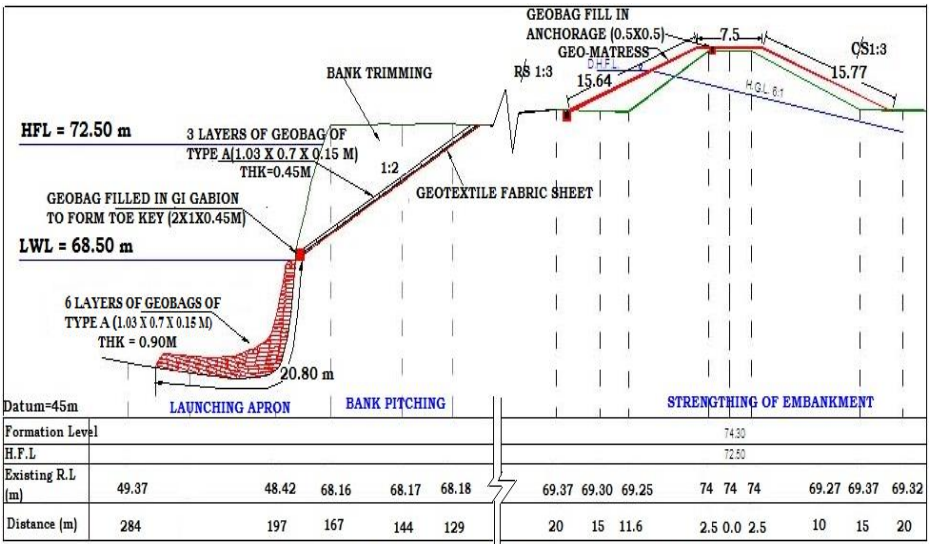


**Fig. 3.** Cross section of apron, bank pitching and embankment work at Biswanath Reach.

**Raising and Strengthening of the Embankment.** It is carried out for the total length of 8758 m. Crest width is kept 7.50 m and top height is maintained at RL 74.30 m with respect to HFL of 72.50 m with freeboard of 1.80 m. Filling of earthwork is done in uniform layers not exceeding 22.50 cm thick with profiling to achieve a slope of 1V:3H. Country side slope is protected by turfing with grass sods and river side slope is protected by a sand filled geo-mattress. It is a double layered composite geotextile fabricated to form a three dimensional mattress after filling sand through pump at design slope of affected reach, the upper layer of the mattress is made from polypropylene woven geotextile needle-punched with a mixture of U.V. stabilized green fibers and cut tape yarns and the lower layer of the mattress is also a U.V stabilised polypropylene woven fabric. Geo-mattress is anchored at upper and lower ends of embankment slope by bending the mat into the trench filled with sand filled geotextile bags. Total quantity of geo-mattresses is approximately 161737 m$^2$. Figure 4 shows the implementation of Geotextile bags, Geo-mattress and PSC Porcupine works.


**Fig. 4.** Implementation of Geotextile bags, Geo-mattress and PSC Porcupine works

### 2.3 River Training Works along the Banks of River Swan, Himachal Pradesh

Swan River originates from Joh-Marwari Village near Daulatpur Chowk in Tehsil Amb of District Una and flows through the inter mountainous valley of Una District. Swan River is known as "Sorrow of District Una" as it creates havoc during monsoon almost every year due to floods. Approximately,10,000 ha. of agricultural land is effected by floods in Swan River and nearly 2000 ha. of fertile land is not being cultivated due to fear of floods.

In the Phase-1st the main Swan River has been provided with embankments on its both banks from Jhalera Bridge (RD 19160) to Santokhgarh Bridge (RD 2500) in a length of 16.67 km. The work of this phase was started in year 2000 and was completed in year 2009. In this phase 2260 hectares land has been reclaimed.

In the Phase-2nd the main Swan River has been provided with embankments on its both banks from Gagret Bridge (RD 47500) to Jhalera Bridge (RD 19160) in a length of 28.34 km. The work of this phase was started in year 2008 and was completed in year 2012. In this phase 5000 hectares land has been reclaimed (Fig. 2). Channelization work is extended from downstream of Santokhgarh bridge upto Himachal boundary in Phase-3rd. Keeping in view encouraging result of Swan Channelization Phase-1st and Phase-2nd the State Govt. decided to extend the Swan River Flood Management Programme in Phase-4th to cover balance reach of main Swan River from Daulatpur bridge (RD 58390) to Gagret bridge (RD 47500), total 10.89 km in main Swan River along with 55 Nos. major tributaries which are joining the main Swan River from Daulatpur bridge to Santokhgarh bridge so as to get the full benefits of the flood protection scheme. Figure 5 shows the executed and proposed Swan River Flood Management Projects [4].

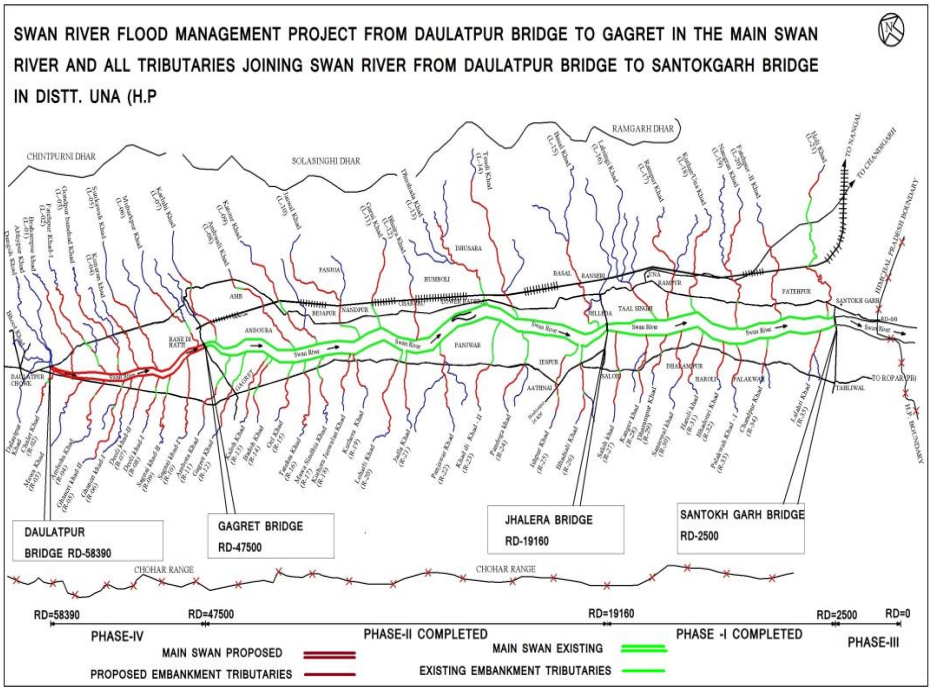


**Fig. 5.** Executed and proposed Swan River Flood Management Projects

**Embankment and Apron.** Low height heterogeneous type of embankment with Central clay core for seepage control is dressed to an inclination of 1V:1H and local sand/river bed material in outer core of embankment is dressed to a slope of 1V:2H. The height of embankment is on the basis of HFL with free board of 1.5 m in Main Swan River and 0.75 m in tributaries. Figure 6 shows the completed embankment in Phase-II.

**Fig.. 6.** Completed embankment in Phase-II

Geotextile fabric filter forms an integral part of protection works. It is provided below the wire crated apron filled with stone pitching and below toewall to prevent soil erosion. This filter material now replaces traditional granular material used in the past.

## 2.4 Anti-Erosion and River Training Works along the Banks of River Ranganadi

The River Ranganadi is an aggrading and meandering type of river by nature. As a result, it creates sand chores in one bank and causing erosion at the other bank. In addition to gradual rise of river bed, it is a matter of great concern that during every flood season, due to increase in the inflow of water from the upper catchment areas, the surplus/excess discharge have to be allowed to spill over the Ranganadi Dam of the NEEPCO hydel power project which ultimately increases the discharge at the downstream reaches. Due to combined effect of increase in the river discharge along with gradual rise in the river bed, flood lift occurs in the River Ranganadi within a very short period and threatens both the banks embankment system. Every year the rise in flood lift decreases the free board and cause overtopping. Now, for safety of the embankments against the anticipated flood lift, the embankment system at both the banks of River Ranganadi is raised by North Lakhimpur Water Resources Division under the Flood management scheme. It consists of raising & strengthening of embankment, bank revetment & launching apron. Figure 7 shows the installation of geotextile mattress at various stages [5].


**Fig. 7. Installation of Geotextile mattress at various stages**

**Bank Revetment with Launching Apron.** Construction is carried out for left and right bank of Ranganadi River at various vulnerable reaches for a total length of 7200 m where the river bank is dressed to the inclination of 1V: 2H and over this a layer of geotextile tubular mattress of 0.3 m fill height is laid and anchored at the top and toe of bank slope by bending the mat into key trench of size 1.0 m x 0.75 m. Geotextile mattress is a double layered composite geotextile fabricated to form a three dimensional mattress after filling sand through pump at design slope of affected reach. Total quantity of geo-mattresses applied is 1061939 $m^2$.

Launching of apron of size 9 m width and thickness 0.9 m all along the left and right bank is carried out with six layers of sand filled non-woven geotextile bags which include two sets of three layers of sand filled geotextile bags of Type A (size 1.03 m × 0.70 m) in one layer of gabion box (size 2m × 1m × 0.45 m). At the junction of the bank and apron, toe-key is formed from two layers of strips of zinc coated wire mesh gabion box (size 2 m × 1 m × 0.45 m) filled with a sets of three layers of sand filled non-woven geotextile bags. Total quantity of Non-woven geotextile bags used for the protection works is approximately 20,45,583 nos. and total qty of gabion box applied is 82700 nos. Figure 8 shows the cross section of bank revetment and apron.

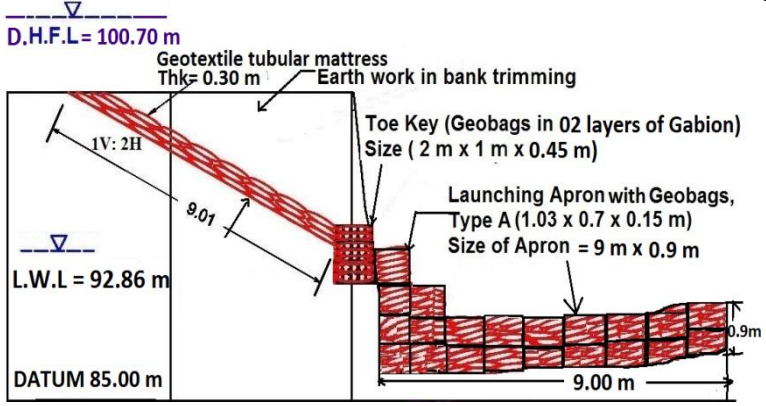


**Fig. 8. Cross section of bank revetment and apron**

## 2.5 Use of Geobags for restricting the flow of River Dibang

The combined flow of Dibang & Lohit Rivers was originally falling into Dihang 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, area of Tinsukia dist in year 1989. As a result, River flow of Lohit diverted towards south. The breach was plugged in the year 1990 but 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 the opposite direction (see Fig. 9).

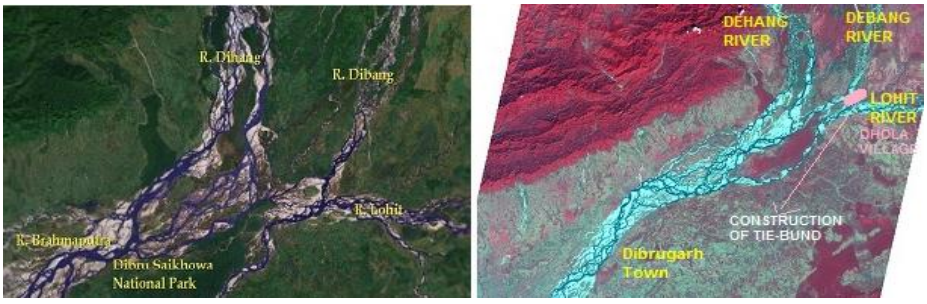


**Fig. 9. Confluence of Rivers and Location of Tie-bund**

Increased scarcity of available good quality stone aggregates & boulders led the Brahmaputra Board to implement flood management & erosion control works by using non-woven geotextile bags. The Tie-bund constructed, restricted the flow of River Dibang in its original course and avoided pushing of Lohit River toward bank & habitat area. Pitching of Tie-bund and launching apron with multiple layers of geo-textile 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 apron was part of bed protection work (see Fig. 10) [6].


**Fig. 10.** Pitching of Tie-bund and launching apron

## 2.6 Anti-Erosion Works at Farakka Barrage along the Banks of River Ganga

The River Ganga with its large mean discharge and a flat slope of about 1 in 20000 near Farakka, has been meandering through ages causing continuous bank erosion at different places. The Farakka Barrage across River Ganga is designed to serve the need of preservation and maintenance of Calcutta Port by improving the regime and navigability of river system. Jurisdiction of anti-erosion works has been extended 40 km u/s and 40 km d/s of barrage axis since 2004. The anti-erosion measures mainly involves laying of woven geotextile fabric filter under Tarza mat in water as well as on the land depending upon earth profile and over that boulder filled G.I. wire crates of 1.6m height (two layers of 1.0 m and 0.6 m each) along 34 m apron is laid to arrest scour due to high discharge intensities. These anti-erosion works were very effective in inducing siltation in 2007 proving the efficacy of the design (see Fig. 11). Lot of anti-erosion works with this design have since then been executed at vulnerable reaches during past years. Typical c/s of anti-erosion works is shown in Fig. 12 [7].

**Fig. 11.** Anti-erosion works at Farakka Barrage Project, West Bengal

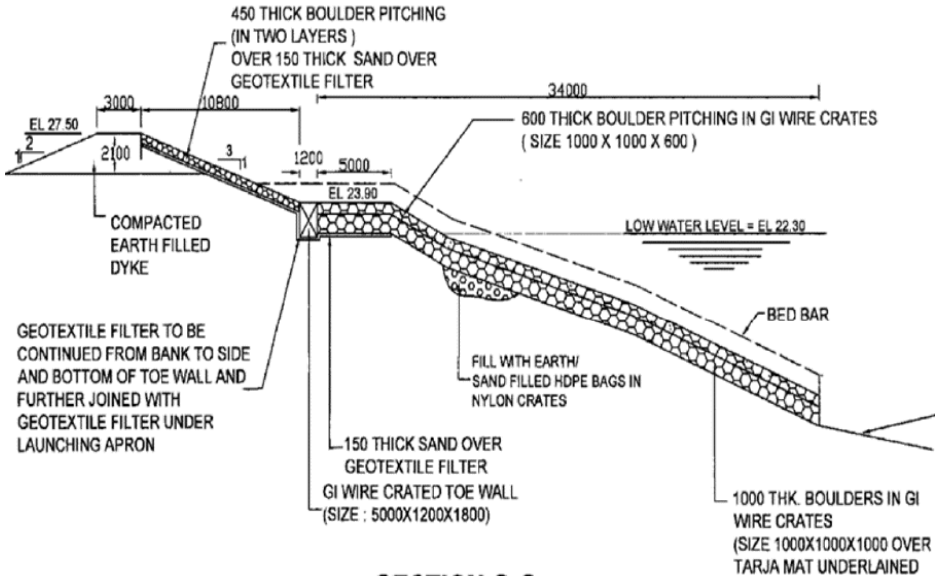


**Fig. 12**. Typical cross section of anti-erosion works at Farakka Barrage Project

## 2.7 Flood Protection works along left and right bank of River Sarada in District Lakhimpur Kheri

Flood protection work has been taken-up by Flood Division Sarda Nagar, UP to protect sensitive cluster of villages along left and right bank of river Sarda in district Lakhimpur Kheri at an estimated cost of Rs. 2504 lakhs in the year 2010-2011 [8]. In order to provide protection to the vulnerable reaches, high strength woven geotextile bags (Tensile strength 55kN/m) have been used in construction of Bank revetment and launching apron for a total length of 2410 m and PSC porcupines at 6o m c/c in three rows as an additional protection to the banks in order to reducing the velocity of flow. Such application is rapidly deployed to achieve maximum benefit to the community, typically through the use of on-site river bed materials, innovative woven geotextile materials and construction techniques. This scheme has benefitted population and protected 140 ha. of cultivated and homestead land including thickly populated villages, other public and private properties.

**Bank Revetment with Launching Apron.** River bank is dressed to the inclination of 1V:2H and over this a systematic pitching of sand filled woven geotextile bags of 200 gsm is carried out all along the length of 2410 m. Thickness of slope pitching on bank is 1.0 m. Construction of launching apron is carried out with the same geotextile bags filled with local river bed material. Width of the apron is kept 8.0 m wide and 4.0 m in depth and top height of revetment is maintained with respect to HFL of 129.34 m. Thickness of slope pitching on bank and launching apron is carried out with multiple layers of geotextile bags in staggered manner to ensure stability of protection works. Figure 13 shows the implementation of geotextile bags in revetment and launching apron.

**Fig. 13**. Implementation of geotextile bags in revetment and launching apron

## 3 Conclusions

The paper presents the problems and the remedial works carried out along the vulnerable reaches using soft structural measures. Such application replaces all other conventional methods (e.g. Boulders, RCC etc.) for immediate protection where flood is a regular phenomenon and construction is to be completed in a limited time period. The use of Geosynthetics materials permitted to carry out the protection works at a faster rate. The use of the mechanically zinc coated wire mesh Gabion box ensured the stability of the geotextile bags by providing the peripheral confinement to the bank structures. Such an arrangement can be rapidly deployed to achieve maximum benefit to the community, typically through the use of on-site river bed materials, innovative geosynthetics materials and construction techniques.

Considering the advantages of Geosynthetics materials, its use may rapidly increase in future and the importance of material evaluation should therefore be emphasized to ensure that the Geosynthetics materials and Gabions meet the qualifying criteria.

Protection work increase resistance of river banks to erosion and deflecting the current away. These generally shift the problem in the u/s or the d/s and necessitate further works to safeguard the land against erosion. Against this changing landscape it is no longer acceptable for flood management practices to simply focus on reducing flooding and reducing the susceptibility to flood damage. Wider opportunities need to be considered to eliminate root causes.

Progressive damage to river and floodplain s due to floods has increased substantially during the twentieth century. Climatic models also suggest that this trend will continue into the future [8]. Increased flood damage is associated with not just increased precipitation but also with increasing population size & density and increased infrastructure residing within floodplains.

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