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Erosion and scour protection of guide bund for a major river bridge on national highway in India and other applications using TechRevetment® technology

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ABSTRACT: This paper presentsa case studyof permanent erosion and scour protection works for a guide bund where TechRevetment® technology has been adopted. The river guide bund protection works were undertaken using Articulating Block (AB) concrete mattress for guide bund and embankment structures upstream and downstream of the location of a new bridge structure over Jia Bharali River in the state of Assam, India. At the bridge location, the river is characterized by a braided pattern with its width varying from 1 km to 7 km. The bed level elevations at the deepest point in the channel range from 72.5 m approximately 11.8 km upstream of the bridge, to 61.4m approximately 7.2km downstream. The average longitudinal slope of the river was estimated as 1m in 1709m. Hydrologic studies of the site and contributing catchment areas, along with records of historic monsoon seasons were used to develop a design discharge of 10,000 cubic meters per second (cumec) to represent a 100-year return period. The High Flood Level (HFL) induced water depth to vary from 2.5m to 7.5m across the channel width. Model studies were used to estimate that the mean and maximum velocity of flow along the guide bund varied between 1.766 m/s and 2.7 m/s respectively based on which the scour depth was estimated to vary between 17m to 25 m below HFL.

1. INTRODUCTION

Erosion protection is an important preventive measure that ensures stability of water-front infrastructure. TechRevetment® is a fabric formed concrete grouted mattress systemwhich is pre-engineered in the factory and used for permanent erosion protection works. Depending on project requirements, design considerations and specific application, the type of fabric form can be designed and prefabricated at the factory and delivered to job sites. This technology has been used to protect culverts, dams, dikes, roadway and railway embankments, bridge piers, spillways, underwater pipelines, dry and wet embankmentsand other hydraulic and marine structures from the forces of flowing water and wave action. It is also used to protect bridge abutments against scour, flood bank and bed protection of major rivers and waterways, lining of canals and for mining and industrial erosion protection and lining applications, to protect geomembranes and geosynthetic clay liners from mechanical damage in landfills, reservoirs, sewage lagoons, ash pits, cooling ponds, and other containment, capping and environmental applications.This system can be installed at rapid speed even under water without the need for dewatering.TechRevetment® is installed by positioning specially constructed fabric formwork over the areas to be protected followed by pumping high-strength, fine aggregate concrete into the formwork. The fabric formwork is placed in-situ and filled either underwater or in-the-dry. The high-strength, fine aggregate concrete is used in place of conventional concrete because of its pumpability, high-strength, impermeability, density, and absorption resistance. While the fabric formwork is designed for the in-situ casting of the concrete mattress, it does not serve as an integral part of the long-term stability and performance of the resulting concrete mattress system. As with most conventional concrete formwork, after the concrete has set, they have accomplished their purpose with the key difference being that the fabric formwork does not need to be stripped after setting of concrete. This paper presents a case study in which TechRevetment® was adopted for permanent erosion protection works.

2. PROJECT SETTING

The main project scope consists of four-laning a carriageway and constructing a new bridge structure over the Jia Bharali River. River training works were required upstream and downstream of the new bridge to

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protect the new structure from scour. The study involves design of erosion protection system on the bank of river Jia Bharali (Assam) for an approximate stretch of 18 km. Figure 1shows the site location. The guide bunds and embankments that were envisaged for protection in the project are classified into four sections:

1. Guide Bund:Length = 636 m
2. Embankment = 17,618 m

Figure 1. Site Location (Source Google Earth)

The guide bunds and embankments were intended to narrow the river flow channel to a width of 1200 m at the bridge location after completion of construction. Initial construction activity was focused on completing the Upstream Left Bund, from chainage 0+00 to 1+500 m and constituted Phase I of the project. The embankment heights in the Phase 1portion range from a minimum height of 5.8 m to a maximum of 10 m at the bridge location with the average height being 7.0 m. The embankments have a top width of 6 m with side slopes of 2H:1V with a horizontal bench near the middle of the slope.

2.1 Hydrologic Setting

At the bridge location, the river flow was characterized by a braided pattern with its width varying from 1 km to 7 km. The bed level elevations at the deepest point in the channel range from 72.5 m approximately 11.8 km upstream of the bridge, to 61.4m approximately 7.2km downstream. The average longitudinal slope of the river was estimated as 1m in 1709m.

2.2 River Flow Characteristics

Hydrologic studies of the site and contributing catchment areas, along with records of historic monsoon seasons were used to develop a design discharge of 12,196 cubic meters per second (cumec) to represent a 100-year return period. The High Flood Level (HFL) at the bridge site which is 73.76m has induced water depth to vary from 2.5m to 7.5m across the channel width. Model studies were used to estimate that the mean and maximum velocity of flow along the guide bund varied between 1.766 m/s and 2.7 m/s respectively.

2.3 Scour Depth

Based on this, the scour depth was estimated as 17m below HFL for the straight portion of the stream reach and 25 m below HFL for the curved portion of the stream reach. The scour depth calculations were performed in accordance with IS10751:1994 (Clause 5.6.3) and IRC 89 (Clause 5.3.7.4). The scour depths below HFL were converted to scour depth below channel bed level and then used to determine the length of Launching Apron required to protect the embankment from scouring.

Based on scour depth calculations, it was estimated that 22 m long Launching Apron was required to protect all guide bunds from scouring, except for the left downstream guide bund wherethe required Launching Apron length was estimated as 30 m.

3. HYDRAULIC ANALYSIS

Hydraulic analysis of Jia Bharali River was done by developing hydraulic model using HEC-RAS (Hydrologic Engineering Center – River Analysis System) software. HEC-RAS is a software that models the hydraulics of water flow through natural rivers and channels. This software allows user to perform one-dimensional steady flow hydraulics, one and two-dimensional unsteady flow hydraulics, quasi-unsteady and full unsteady flow sediment transport/mobile bed computations, and water temperature/water quality modelling.HEC-RAS designed to perform one-dimensional (1D), two-dimensional (2D), or combined 1D and 2D hydraulic calculations for a full network of natural and constructed channels. (Source User Manual).

Hydraulic modelwas developed for Jia Bharali River using HEC-RASto determine flow depth, flow velocity, and resulting shear stresses at points throughout the model. Two-dimensional unsteady flow model simulated using Digital Terrain Model (DTM) as an input to determine the design shear stress (τ_{des}), shown in Figure 2.

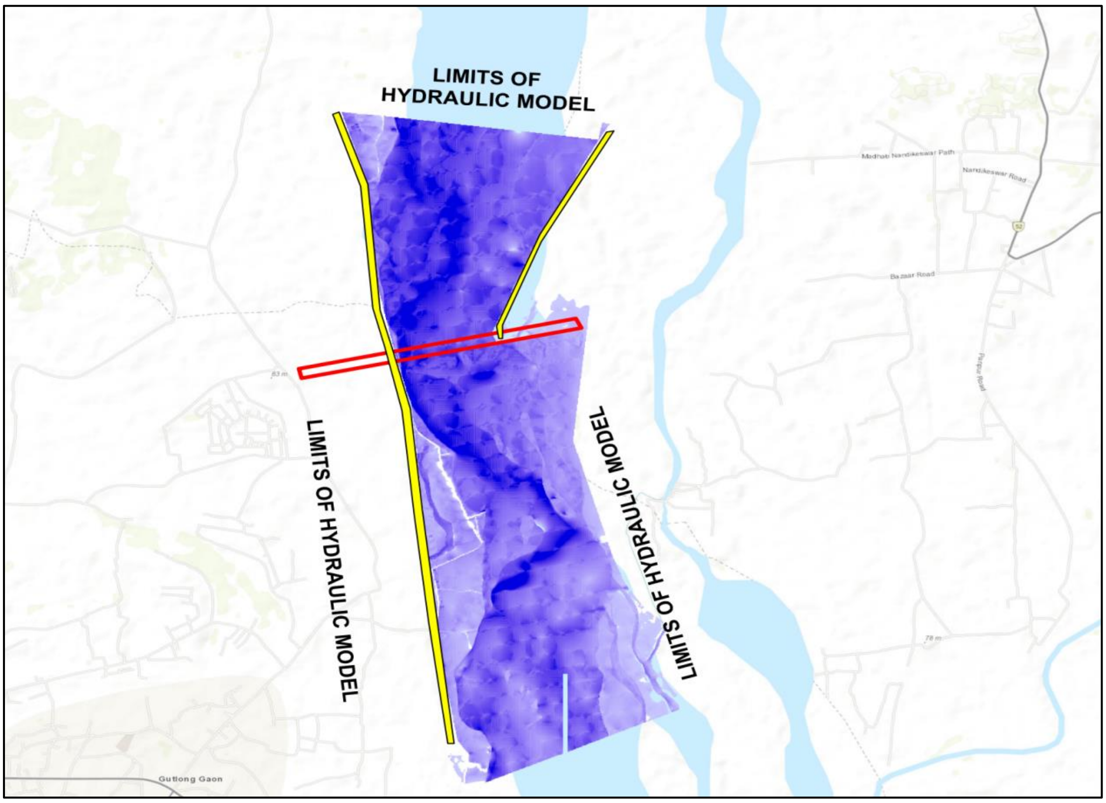

Figure 2. Modelling for calculation of design shear stress (Source HEC-RAS)

The model simulation had estimated the peak shear stress of 222.9 N/m^2. This peak shear stress value is considered for the design of TechRevetment®.

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4. DESIGN METHODOLOGY

Thedesign guideline adopted for our case study was published inHEC-23 which has Design Guideline 9 for Grout-Filled Mattresses for the estimation of thickness of mattress.The thickness of grout mat is selected such that computed factor of safety (F.S.) for the armor meets or exceeds the primary selected target value of Factor of Safety(SF_T).

Moreover, soil earth anchors are sometimes needed to increase the factor of safety against sliding and to provide the good stability to the mattress on the slope surface. During installation, the grout-filled mat shall exhibit the nominal properties shown in Table 1.

Table 1. Nominal Properties of Grout-Filled Mats (FHWA-NHI-09-112: HEC-23, 2009)

Property	4-inch Mat	6-inch Mat	8-inch Mat
Average thickness, in.	4	6	8
Mass per unit area, lb/ft^2	45	68	90
Mass per individual compartment, lb	88	188	325
Nominal dimensions of individual compartment, in.	20x14	20x20	20x26
Cable diameter, in.	0.25	0.312	0.312
Cable breaking strength, lbf	3,700	4,500	4,500

Once the thickness of grout mat is selected, the typical cross section of Jia Bharaliproposed for the installation of TechRevetment® technology is shown in Figure 3.

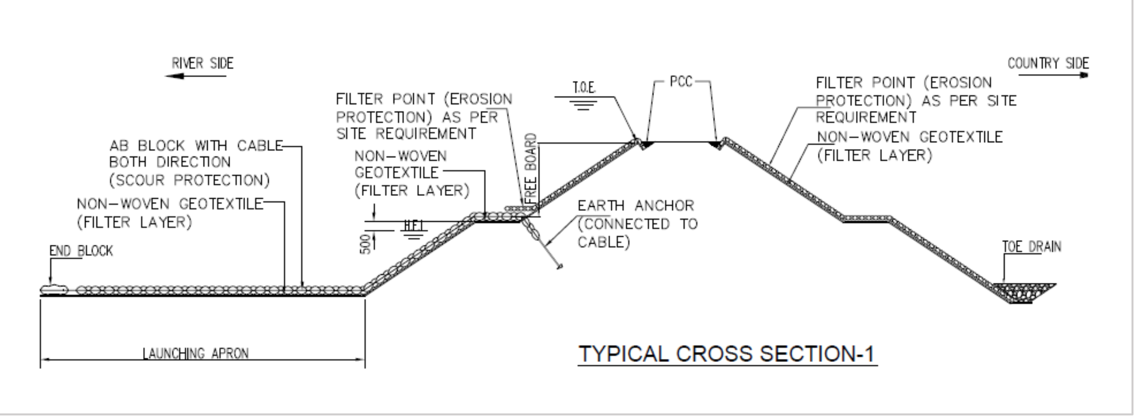

Figure 3.TechRevetment® Typical Cross Section proposed by Terre Armee India

5. RECOMMENDEDSOLUTION

Articulating Block Concrete Mattress was recommended for the protection measures along the guide bund embankment’s side slope (water side only) and launching apron. Beginning at the launching apron, the mattress thickness was 200 mm. As the mattress continues of the side slope, at an elevation 1.0 m above HFL, the mattress thickness transitioned to 100 mm, continuing to the crest of the embankment and into a trench at the top of the embankment. All mattresses comprised of a 6 mm diameter galvanized steel cable reinforcement in both directions. The tensile strength of the steel cable was 24 kN. Weep tubes were recommended to allow for rapid dissipation of water from behind the mattress in the event of rapid drawdown of water levels.

5.1 What is Articulating Block Concrete Mattress

Articulating Block Concrete Mattresses are cable-reinforced concrete block mattresses that are designed to resist erosive forces. They are often constructed where an embankment is exposed to river flows with high velocities and shear stresses and frontal attack by wave action. The Articulating Block fabric formwork are comprised of a series of compartments linked by an interwoven perimeter. Grout ducts interconnect the compartments, and high-strength revetment cables are pre-installed between and through the compartments and grout ducts. Once filled with fine aggregate concrete, the system becomes a mattress of rectangular concrete blocks with very high hydraulic stability.

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Figure 4. Articulating Block Concrete Mattress after installation at site

Figure 5. Articulating Block Mattress

6. WHY ARTICULATING BLOCK MATTRESS?

Fabric Formed Concrete Mattress systems combine the best features of different materials in such a way that specific applications are addressed in an optimal manner and at minimum cost hence maximizing the benefit/cost ratio. The Articulating Block Concrete Mattress system was recommended as the solution due to the following main advantages:

6.1 Flexibility

Articulating Block Concrete Mattress Systems are designed to enable flexibility while maintaining a stable matrix of armor units. The interwoven perimeters between the blocks provide an annular space designed to permit articulation. The high-strength revetment cables remain embedded in the concrete blocks to link the blocks together and serve as hinges to facilitate articulation.

Figure 6.Articulation of the concrete block mattress recorded at site

6.2 Permeability

The Articulating Block Concrete Mattresses System with interwoven filtration points can incorporate either a geotextile filter fabric for the release of water or geocomposite drainage layer for the collection and release of water. These blanket drains along with weep tubes can be used to ensure drainage and the relief of hydrostatic pressure. Geotextile filter fabric and geocomposite drainage systems are economical alternativesto conventional open graded aggregate, reduce installation time and design complexity and eliminate the need for heavy construction equipment.

6.3 Durability

Articulating Block Concrete Mattresses are resistant to damage due to rusting, vandalism and abrasion by trampling and stone impactunlike mattresses constructed using polymer or steelwire mesh.

6.4 Maintenance Free

Articulating Block Concrete Mattresses with high-strength revetment cable reinforcement are maintenance free.

7. CONCLUSION

This paper presents a case study of 600m length of permanent erosion and scour protection works for a guide bund where TechRevetment® technology was adopted. The river guide bund protection work was undertaken using Articulating Block (AB) concrete mattress for guide bund and embankment structures upstream and downstream of the location of a new bridge structure over the Jia Bharali river.It is observed during the project that for seamless construction and proper quality control, it is better that the fabric form is prefabricated at a manufacturing units only including assembling and installation of the steel cable reinforcement into it, and the fabric form is supplied in the form of tailormade panels (not in mill width only) to suit the site geometry and measurement and on-site stitching or sewing of material is avoided.In addition to the advantages offered by this system in terms of stability, flexibility, durability and no maintenance, the TechRevetment® technology is observed to have performed satisfactorily after installation thus making a strong case for its adoption in erosion control works along river front infrastructure.

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