Design, construction and monitoring of polymeric strip reinforced soil founded on soft soil

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ABSTRACT: Reinforced Soil (RS) wall structures have proved their importance in infrastructure development since last few decades in India. Walls reinforced with polymeric strips and segmental concrete panels as fascia are being extensively used due to its flexibility, economy, speed of construction and long term performance. This paper presents a case study of RS wall approaches of flyover structure for the green field access controlled expressway project. Vertical RS wall of height 16m was designed and executed on weak soil stratum. Clayey soil with low to medium plasticity in foundation strata was susceptible for settlement after construction of RS wall. This necessitated ground improvement by soil replacement along with high strength polyester geogrid as basal reinforcement to achieve required bearing capacity. RS wall for the approaches were planned at skew angle of less than 40 degree which added further complexity and challenges. Authority desired construction of RS wall to be completed in short span of three months which was made possible due to use of polymeric strip reinforcement, the perfect overall planning of project and meticulous construction. Structure wall was monitored from beginning to end of construction and till the flyover got opened for highway traffic.

Keywords: *Reinforced soil (RS) wall; Polymeric strip; construction*

1 INTRODUCTION

Soil, when confined, is strong in compression but weak in tension. Reinforcement in soil is provided to enhance stability and resistance to tensile strain. Interaction between soil and reinforcement is ensured by friction between soil and reinforcement and interlocking effect. RS wall system used in this project is MacRes which comprise of polymeric strips ParaWeb as soil reinforcement and segmented concrete panels as fascia. This system is proven and has been successfully adopted in adverse climatic condition across the globe and found suitable and efficient in terms of stability, construction speed and long term performance (Naughton et al 2005 and Kepmton et al. 2008) .

2 PROJECT SUMMARY

Uttar Pradesh Expressway Industrial Development Authority (UPEIDA) proposed development of Firozabad to Etawah access controlled expressway project in the state of Uttar Pradesh on engineering procurement and construction (EPC) basis. Total stretch contains 6 no's of Minor bridges over irrigation canals, 4 no's of flyovers and 2 no's of major bridges.

In this paper case study of minor bridge at chainage 88km is presented. Location was found to be critical as two numbers of ramps and one loop of road are intersecting the main alignment of the road. Minor bridge is having skew angle of 38 degrees, which added construction complexity to the project. Key Plan of the RS wall location is presented in Fig. 1 and 2.

In the total stretch of alignment of road, Chainage 88 found to be critical, as one Rail over bridge (ROB) at Ch. 88.415 and Minor bridge (MNB) at Chainage 88.757 are very close to each other.

Difference between finished road level and ground level is found to be in the range of 14 to 15m. There are total seven walls and one common wall for ROB and MNB which can be observed in Fig 2. Minor bridge is being constructed over an irrigation canal, which was another challenge to work in water logged area. It was decided to construct 16m complete vertical wall without any batter due to the constraint of right of way (ROW) availability.

RS wall was designed for maximum height of 16m with following soil properties. Geotechnical investigation was carried out for this area. For reinforced soil and retained backfill, cohesion less frictional fill was suggested having angle of internal friction ‘ϕ’ as 30 degree and Unit Weight ‘γ’ of 20 kN/m^3.

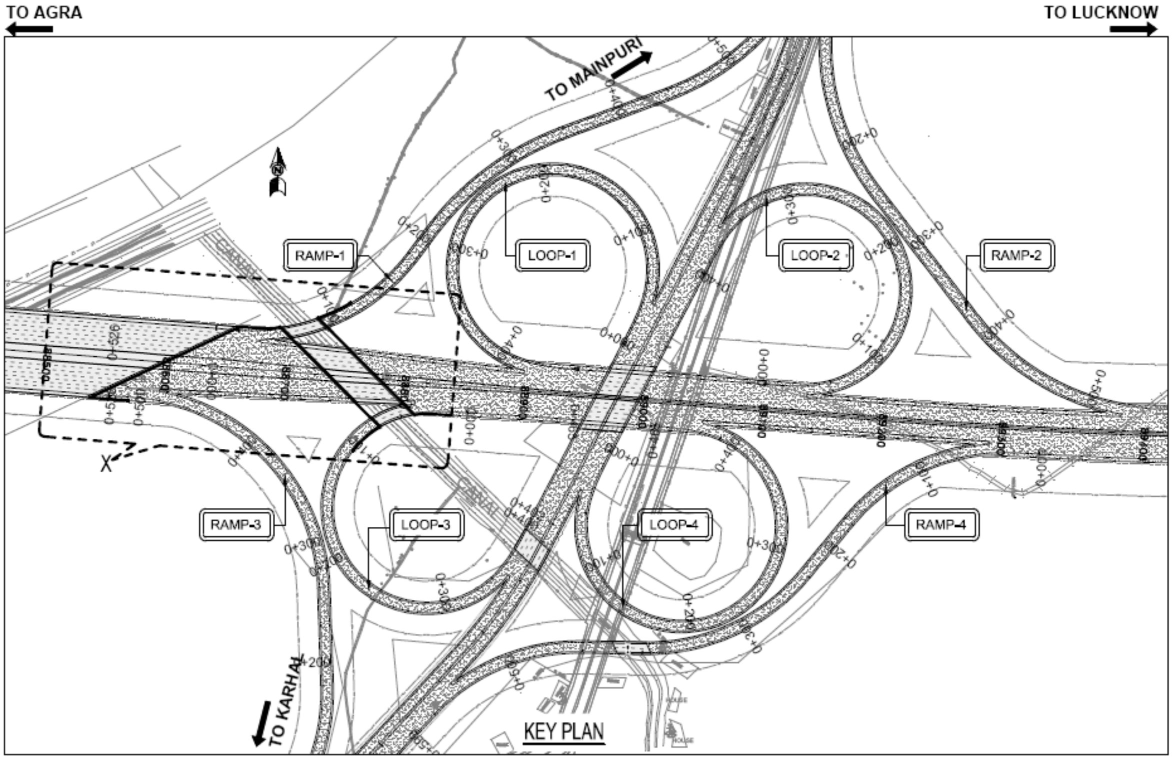

Figure 1 Key plan of Project site

Soil investigation was carried out in the pre monsoon dry month of May’ 2016. Soil investigation contains 2 no’s of boreholes with standard penetration tests (SPT) at depth interval of 1.5m interval along with laboratory tests on disturbed and undisturbed soil samples. The results of lab tests and bore log indicate that the stratum at the site is comprised of both non-cohesive as well as cohesive soil. The non-cohesive type soil is found to be either sandy silt ‘ML’ type soil or silty sand ‘SM’ type soil of Indian Standard (IS) classification and having 38 to 84 percent fines. However, the cohesive type soil comprises of either silty clay soil of low and medium plasticity and compressibility or clayey silt soil of low plasticity and compressibility belonging to ‘CL’, ‘CI’ and ‘ML’ group of IS classification and having 88 to 97 percent material finer than 75 micron.

As per Bore log charts prepared after soil investigation, SPT values obtained in the respective sandy layer region present are found to be in range of 10 to 38, indicating Loose to ‘Dense’ relative density. However, the SPT values obtained in the respective clayey layer region present are found to be in the range of 9 to 28, indicating ‘Stiff’ consistency.

Water table at the site was observed at a depth from 3.50 meter to 4.30 meter below ground level on the day of soil investigation during the fifth week of May 2016. However, the existing water table may rise by 2.00 meter to 2.80 meter in the post-monsoon period. Therefore, a water table at a depth of 1.50 meter below ground level was considered for analysis purpose.

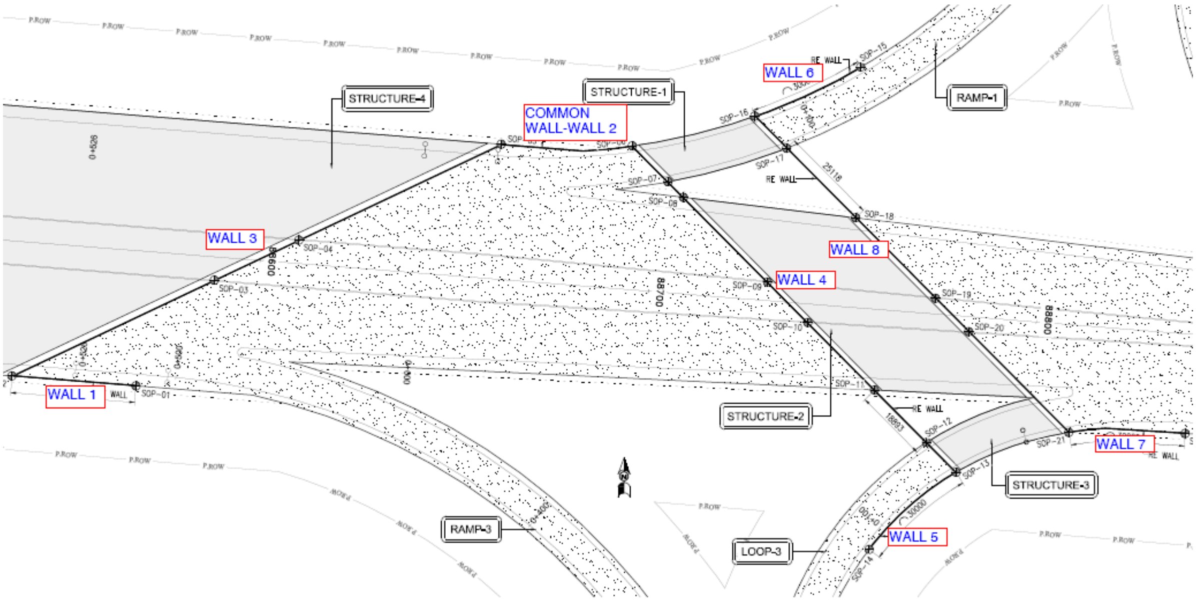

Figure 2 Proposed RS wall locations

As it can be observed from results, soil layers of low plastic clay, silty sand and medium plastic clay are found to exist up to 16 meter depth. Presence of clay and water table makes soil susceptible for consolidation settlement. Hence it was required to check soil for bearing capacity and consolidation settlement.

3 STABILITY ANALYSIS

The design of RS Wall follow the principles involved in conventional soil retaining structure, however, RS structures require additional consideration with respect to soil / reinforcement interaction. The design involves checks for external and internal stability (BS8006-1:2010). The external stability covers the basic stability of the reinforced soil structure as a unit, whilst internal stability analysis examines the effectiveness of the geosynthetic reinforcement to hold the reinforced soil mass together so that the geosynthetic layers and soil function as a monolithic block. Stability of RS wall was designed for global stability, external stability and internal stability (IRC-SP102:2014). Global stability analysis was performed using Maccaferri in house software MacStars.

The external stability is evaluated by assuming that the reinforced soil mass acts as a rigid body. It must resist the earth pressure imposed by the backfill retained by the reinforced soilmass and any surcharge loads. Potential external modes of failure considered are: Sliding, Overturning and Bearing capacity of foundation.

Internal stability considers two failure possibilities: i) rupture and ii) pullout of reinforcement. Initially the overall geometry of the wall is assumed based on standard guidelines as per standard BS 8006 part 1. There after necessary checks for external and internal stability are carried out using coherent gravity method. Based on the results the reinforcement layout is optimized. Live load of 22 kPa for traffic surcharge, 8 kPa load of crash barrier and pavement load of 13.5 kPa was considered in design. Vertical spacing between two reinforcement layers was kept 0.8m throughout the section. Horizontal distance between reinforcement ranges from 0.67m to 1m depending on design requirement. Reinforcement length was decided on the basis of requirement.

In addition to these checks, consolidation settlement analysis was performed. Clayey soil with high water table is prone to settle in consolidation.. Permissible settlement was limited upto 150mm for structure as RS structure is flexible and can bear total and differential settlements more than rigid RCC structures. Total consolidation settlement was coming more than 200mm. To limit total settlement to permissible limit, it was required to suggest suitable ground improvement.

Analysis was carried out by assuming replacement of top cohesive soil with cohesionless frictional fill. To limit the permissible settlement top soil was to be removed and replaced with cohesionless fill. To avoid differential settlement & slip failure high strength uniaxial geogrids i.e. Paralink were proposed in layers as basal reinforcement beneath RS wall which would act as a raft foundation (Fig 5). Maximum depth of replacement for highest portion of the wall comes out be 3m with basal reinforcement. Typical section of ground improvement can be noted in Fig 3.

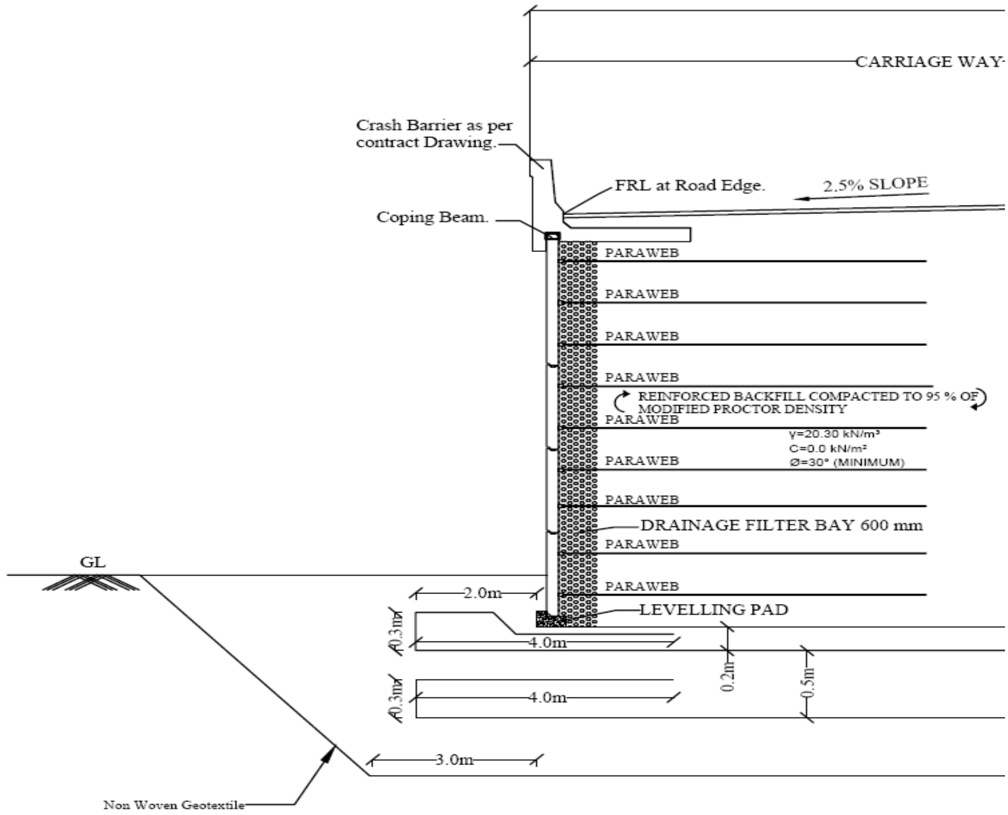

Figure 3 Cross section for ground improvement scheme

Figure 4 Ground improvement- Excavation in progress

Figure 5 Ground improvement-Laying of Paralink

4 CONSTRUCTION DIFFICULTIES

As per the proposed solution, it was required to excavate the ground upto 3m. Irrigation canal was running full while excavation was going on. Water table rose to 1m below ground level. Excavation was carried out upto 3m, but it was very difficult to dewater the excavated portion as water through canals were flowing continuously throughout the excavation and filling process. It was decided to use granular sub base (GSB) material for replacement having good frictional properties. It was difficult to compact the ground in ponding condition (Fig 4). Hence two water pumps continuously kept running during filling and compaction process. Full compaction could not be ensured as filling material was completely saturated. Compaction was carried out in layers and basal reinforcement was laid in two layers to ensure uniform distribution of the load. After finishing ground improvement RS wall construction was started. RS wall backfilling was done in stages with compacted soil layer having thickness of each layer 200mm. Structure was supposed to settle during and post construction. Hence, settlement of wall was monitored from beginning of construction.

Laying of soil reinforcement was difficult in the portion of corners where angle of skew was 38 degrees. At skews corners of RS wall, a full active wedge is not formed. Hence, active earth pressure values at corners are very less compare to straight portions. Special arrangement of reinforcement layout has been provided at skew locations, due to insufficient space available for reinforcement. Soil reinforcement layout as shown in Fig 6 has been laid.

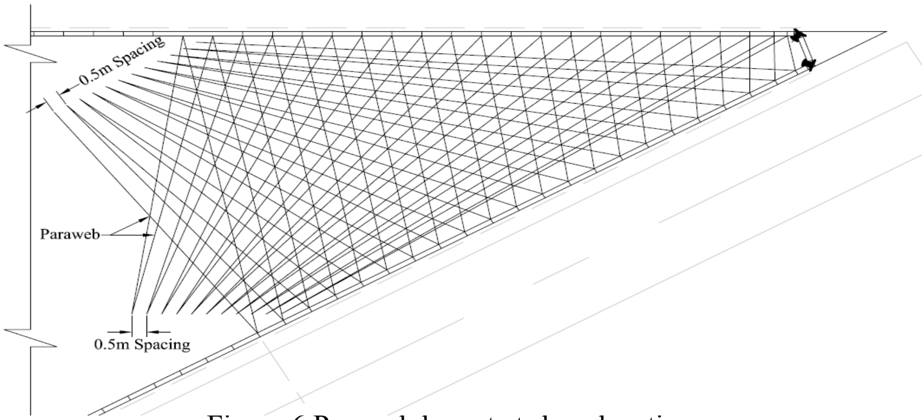

Figure 6 Paraweb layout at skew locations

5 PROJECT MONITORING

Construction activities have been monitored since the start of excavation up to completion of structure. It includes monitoring of gaps in adjacent fascia panels, wall batter checks, settlement etc. During construction of walls, marking was done on fascia panels of each wall and nearby piers to monitor settlements in walls. Level difference these marking were being measured by using level tube (Fig 8). Figure 7 presents variation of settlement with time.

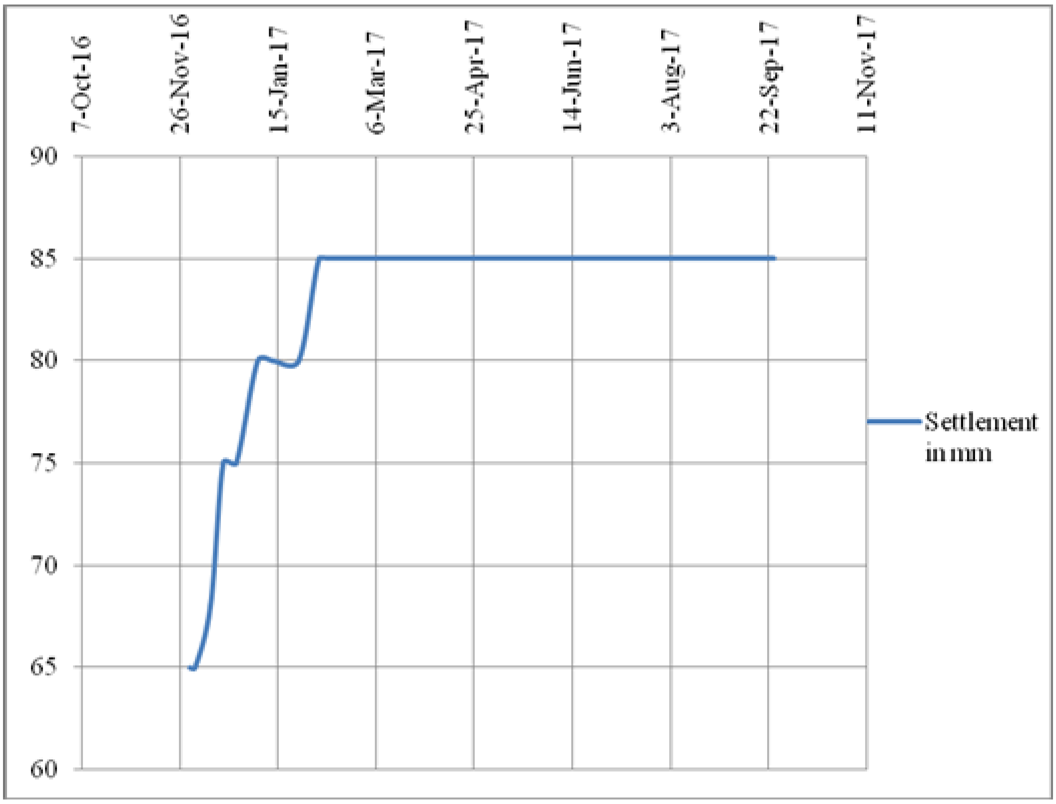

Figure 7 Settlement monitoring Record

Figure 8 Settlement monitoring example

Figure 9 Construction in Progress

Figure 10 Completed RS wall structure

Figure 11 Completed RS wall structure

6 CONCLUSION

Construction of the RS wall along with required ground improvement has been successfully completed in short period of three months of time, which is major achievement. Actual settlement at different locations after two months of completion of the wall was ranging from 45mm to 115mm which corroborated estimated settlement.

Wall batter was checked and there was no significant outward movement of the wall, which ensures proper performance of RS wall. High strength uniaxial geogrid ensured uniform settlement and no distress in panels noted. Placement of soil reinforcement in skew of 38 degree was possible due to polymeric strip which otherwise not possible. RS walls due to their greater flexibility found to be most preferable in road abutments in case of complex structures.

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