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Need for Relook at the Design Practice for Reinforced Earth Wall Foundations

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ABSTRACT

The next national plan caters to massive transport links with number of highways with thousands of Reinforced Earth Wall structures at crossings. Uses of reinforced walls (RE) of 20 m height are no longer rare. Design of RE walls/ slopes and foundations are based mostly on BS 8006:1995. The emerging design practices for foundation on the basis of BS code have been discussed. The paper justifies the need to relook at the theory, practice and predicted performance in light of Indian environment, economy and construction practices. It proposes to initiate observations, analysis and relook to evolve better practices in due course.

1. INTRODUCTION

The space constraint in urban centers in many countries justified RE Wall/Slope for flyover, bridge abutments which are cost effective. Reinforced rigid earth block (wall), transfers stresses to foundation. The design of foundation system is normally practiced on basis of BS-8006:1995 code. The design adopts limit state analysis with specified partial factors for load and properties of materials. The rigid block design is checked for external stability for sliding, overturning and ultimate bearing capacity of the foundation soil. Though the code only permits a non-cohesive compacted filling for RE block backfill and leveling of foundation pad by 1m to 2.5m thickness. Nowadays stabilized cohesive soils and industrial byproducts are also considered if they meet design soil parameters and durability criteria's. In cohesive backfills behind or below RE walls, on soft soils, a check of global slip stability analysis is required.

The code provisions and standard reference books for foundation have been examined in Indian scenario to arrive at a consensus on need to relook at theory and practice. This will be first step to derive our IS code latter.

2. CODAL STIPULATION / BS CODE REQUIREMENTS

The BS 8006:1995 code articles 1.3, 2.8, 5.1, 5.6, 6.5.6, 8.2, 8.4 and 9.4 and Fig.1(C) refers to foundation for RE wall in Fig.1. The important provisions are summarized/ reproduced below. The soil reinforcement's acts as structural element to support vertical load on weak soil giving immediate margin of safety to wall foundations. The provision of reinforcement at interface of fill and subsoil prevents lateral spreading of soil. The induced tension in basal reinforcement increases soil confinement pressure effect.

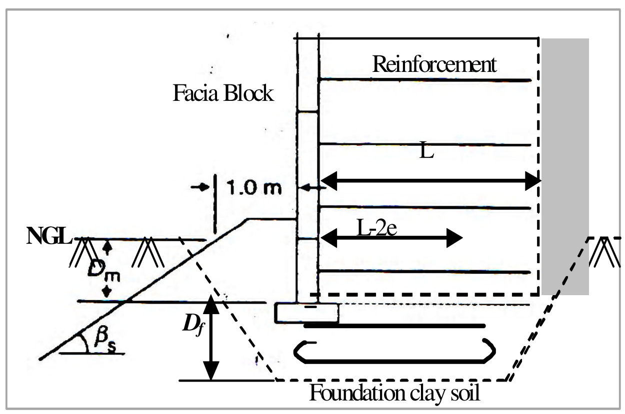

Fig. 1: Schematic Section of RE Wall, Dm: Depth of Embedment, D_f: Reinforced Foundation Pad

This gives a higher soil resistance in shear. For deep weak soil foundation (upto H/3 depth), basal reinforcement lengthens surface of slip i.e. the factor of safety (F.S) for slip will increase. For long term stability, when drainage consolidation has occurred, such reinforcement provided becomes redundant. Typical loads acting on reinforced earth block analyzed are shown in Fig. 2.

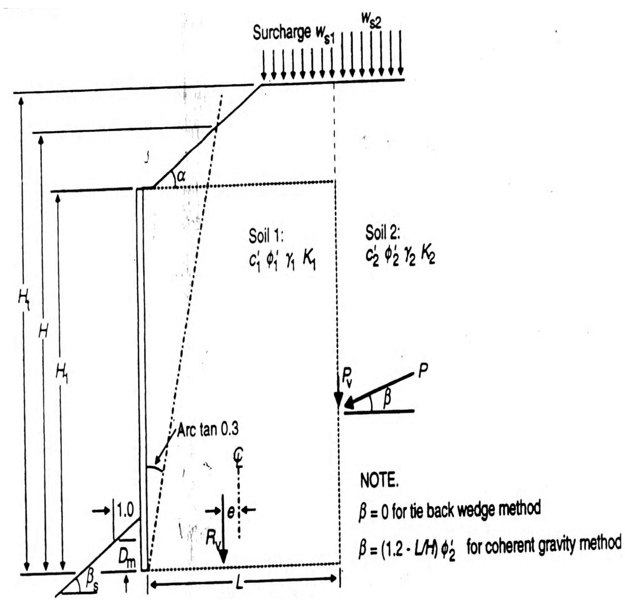

Fig. 2: RE Wall-Soil Properties and Principal Loads

The code categorizes failures as, a) ultimate limit state of collapse i.e. rupture or bond failure of reinforcement or b) Serviceability limits state i.e. excessive deformation of RE mass or excessive strain within reinforcement. The reinforcement is considered axially stiffer than soil. (Hausmann, 1990 Grid strength 16-120 kPa and Modulus 150-1225 kPa) For soil C=0; frictional resistance will be critical for bond resistance, whereas $\Phi_u = 0$ soil; critical will be the adhesive resistance. Polymeric materials (Hausmann 1990) shall have minimum load capacity of 70 kN/m and displacement < 25mm. Embedment depth of RE wall below G.L is 0.1 H (effective height of wall), life 70 year and surcharge 10 kPa is adopted if site specific data is not available. Depth of reinforced pad shall be designed on basis of soil profile upto depth 2 x width of RE block (L_e). (Typical layout shown in Fig.1).

The material prescribed for foundation pad shall be granular as per highway specifications. (Passing 600ìm; 0-25%, 63ìm; 0-12%). Cohesive or industrial byproducts fill meeting code specifications (Art 3.1.2.2, Table-2) are allowed. The mobilized shear in soil is influenced by axial tensile strain in reinforcement, chemicals in soil fluid, swelling, and strength. In basal reinforcement and cohesive soils, gain of soil strength is slow requiring consideration of stress relaxation. Creep in reinforcement is function of life of structure (BS: Table 12). The data of creep of polymeric materials with time, with all environmental aspects is critical for design. "The foundation settlements are computed by the conventional approach" (Art 5.5) considering creep of reinforcement.

The effect of short term loads (rains, flooding, heaving, and shrinkage) must be studied. The differential settlement tolerated by RE fill is higher. Both shear and settlement failures are considered using empirical analysis. Giroud & Noiray (1981) etc. have not considered deformation of all components. Finite element models, considering strain compatibility, are not convenient for routine design (Rowe 87, Otani et al 98), as parameters at the nodal points in reinforcement and soil are heterogeneous variable with time and composition of soil. The soft and compressible strata below the RE walls shall be suitably treated for improvement of UBC, reduction of settlements and its rate as explained in BS code art 7.1 and Fig. 59.

The fill materials in basal reinforcement, if considered as purely frictional (C=0) the shear parameters C_u - Φ_u, C'-Φ' predicted at end of life of structure are adopted. For over consolidated clay, residual Φ_{cv}, C_{cv} are used. In case of soils in wall undergoing small strain peak Φ'_p is representative. The shear resistance of fill on reinforced basal leveling pad is considered purely frictional (C =0). Φ_{cv} is used for non consolidated (C=0) soils. If basal reinforcement is expected to undergo large strain Φ_{cv} is adopted as shear resistance. Polymeric reinforcement for long life (120 Yrs) structures, the rupture strength decreases with time. For shorter life elements, creep will have significant role governing design parameters and economics.

3. PRESENT DESIGN PRACTICE

Geosynthetics by Shukla (2002) states "systems of shallow foundations are designed considering limited role of geosynthetics in improving bearing capacity on basis of different assumptions." Such empirical analyses do not consider deformability of all components in consideration. The design approaches consider, a) soil and reinforcement are modeled individually or b) both fill and reinforcements are unified. Former is widely used. If length of reinforcement is equal to width, it is assumed ineffective in improving bearing capacity. The bearing capacity improvement is possible by deep footing mechanism or wide slab mechanism, wherein reinforcement covers 3 x L area or more area.

The wall design is normally carried out by tieback method. Only if strain in reinforcement is less than 1%, coherent gravity method is adopted.

4. TYPICAL DESIGN ILLUSTRATIONS

The common design practice for RE wall is more or less based on following:

Generalized soil investigation for the overall site for major structures such as abutments is adopted for evolving design parameters for RE wall foundation.

Comment

Such exploration for the deep foundation will have merger test data for soil samples upto 4 to 5 m depth. They do not indicate special characteristics such as swelling, desiccation, collapsible soil and ground water variations. From this meger data, compilation of minimum C_u, Φ_u, density γ_d, Moisture Content w, type of soils, are statistically analyzed. Generally minimum c_u, & Φ_u and

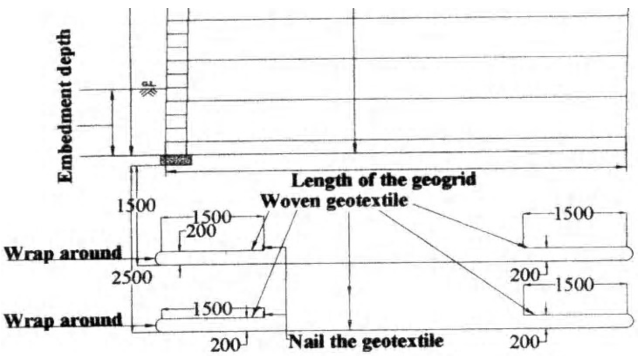

Fig. 3 : Typical RE Wall NH-8 Kamrej Soil Adopting Soil Improvement Depth 2.5 m, Geofabrics as Reinforcement.

Maximum γ_b, are adopted as design shear parameter. This data is for summer in general during the investigation phase. Through conservative, could lead to failure during construction stage.

Case study: Site on NH - 8: (Kamrej)

Parameters adopted for the depth upto 1 m, $C_u = 0.44$ kg/cm^2, $\Phi_u = 0°$, $\gamma_b = 16.8$ kN/m^3, is adopted giving ultimate bearing capacity of 240 kPa for a width L = 3 m. Parameters adopted for depth beyond 1 m are $\Phi_u = 0.62$ kg/cm^2, $\Phi_u = 11°$, $\gamma_b = 18.5$ kN/m^3, giving ultimate bearing capacity 620 kPa. for width of 3 m. As the soil is cohesive (Exploration in summer) the ultimate bearing capacity can be consider independent of width of foundation.

The RE wall analysis is carried out as per BS: 8006-1995 to find out bearing of 3 m height stress at the base of RE block using **Meyerhof** approximations. e.g. For the typical wall the value of bearing pressure is 113 kPa at 1 m and 63 kPa at 3 m depth. The corresponding settlement was found to be more than 110 mm.

Table 1: Foundation Analysis for RE wall Block.

Wall Height (m)	*Width of RE wall Base (m)*	*Depth (m)^4*	*Max. Bearing Stress (kN/m)^1*	*Ulti mate B.C^2.*	*FOS^4*	*FOS^3*
		1	191	238	1.2	–
6	4.7	2	150	**514**	3.4	152
		3	124	559	4.5	171

(1) The maximum stress (Meyerhof's method) due to RE wall. (2), Backfill UBC evaluated by Terzaghi theory adopting C = 3kPa, $\Phi = 32°$ for reinforced/non reinforced foundation zone. (3) Elastic settlement assuming soft cohesive subsoil to stressed depth ignoring variation of stiffness. (4) Factor of safety.

For height 1 and 2 m. the design factor of safety (FOS) (Ultimate Bearing capacity / Stress) varies from 2 to 8. The acceptable FOS is 3 in practice.

Walls upto a height of 3 to 5 m, requires foundation pad of 2 to 2.5 m thickness below the levelling pad of RE wall. This will be a replacement of clay in the foundation by selected, compacted backfill as per BS: 8006-1995.

For height 6 m the FOS (Table-1) being less than 1 upto 2.0 m depth. Depth of foundation pad is kept as 2.5 m.The excavated soil in foundation is replaced by reinforced backfill of specified materials, using a geogrid or geotextile.

Comments

Consider Ground water table or its variation and also effect of wetting of excavated cohesive soil for evaluating the bearing capacity analyzed. This being ignored in some cases could be disastrous, even during construction as soil report does not give environmental changes, around over the life of structures.

The soil strata below will have to be treated by Ground improvement technique adopting suitable economic method. Similarly typical designs recommended for flyover on cohesive subsoil at Surat is illustrated in Fig.4. Similar practice is seen in Fig. 5.

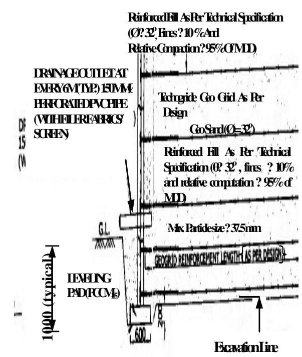

Fig. 4: Typical Sketch of Proposed Foundation for RE Wall for Flyover at Parle Point Surat (2010). Depth of Foundation 4 m Reinforced by Geogrids.

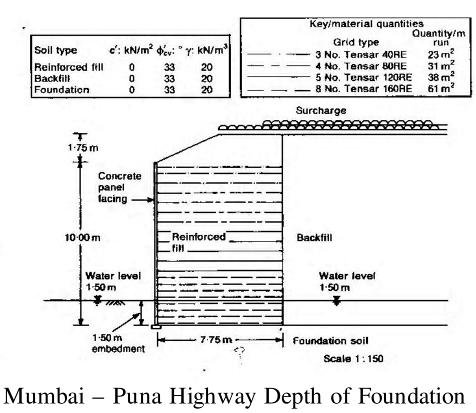

Fig. 5: RE Wall Mumbai – Puna Highway Depth of Foundation 1.5 m. (Netlon India, 2001).

The design bearing capacity ignores influence of reinforced earth mass for shear and settlement analysis which needs to be studied in light of high FOS for safe economical alternatives. Normally foundation pad constructed is checked for ultimate bearing capacity and settlement by 0.45 m diameter Plate Load Test at site.

It is not clear to the site engineers how to interpret this Load Test data for ultimate bearing capacity and settlement of prototype having a larger width. e.g. For a width = 6 m stress zone for the settlement could be of soil depth 9 m or more whereas the Plate Load Test has the data for top 1 m only, that to reinforced fill. The test is normally carried out for the working stress or limited value of settlement as test upto ultimate is difficult and time consuming. Use of SPT for shallow depths & low surcharge for cohesive soils is not advisable. It may mislead the assessment of UBC for partly saturated/desiccated clays.

5. OBSERVATION OF PARAMETERS FOR RELOOK

1. Adoption of common deep foundation data for abutments, such exploration, for shallow foundations of RE walls gives meger, inadequate data of properties forcing conservative occasionally unsafe design UBC.
2. Ignoring improvement of UBC & Settlement of foundation due to georeinforced pad.
3. Exploration in summer, execution premonsoon and 70 years of surrounding environment/WT flooding generally ignored, could cause failures during construction or in lifetime.
4. As the width of foundation pad varies with height, larger differential settlements along wall and higher settlement for wall over cohesive subsoil than normally permitted, need relook for safety of wall over years
5. The soil characteristics such as collapsible manner, practical swelling in rains/ flooding and shrinkage on drying, desiccation ignored, can occasionally lead to failure inspite of high FOS.
6. The stress extends to 1.5 (L_e - 2e) below. The mechanism to account for settlement of {1.5 (L_e - 2e} less thickness of reinforced pad need to be evolved.
7. The practice of providing drain in Fig. 4, in case of CH soil with sand pad, instead of improving provides an environment for flooding, swelling and shrinkage of the original soil.

6. CONCLUSION

Thus to conclude the present system requires through review to arrive at performance of cohesive foundation sub soil (Particularly desiccated and explore in hot weather) executed in summer with probability of rain. Probability of failure of RE block foundation designed accurately, constructed as per specification can't be ruled out.

The adoption of local fill materials meeting required properties is the need for next decade. It has an impact on the overall cost.

The observational records of performance and analysis of failures are described to evolve safe limits for total and differential settlements of foundation on deep desiccated cohesive soils of India. Structural expansion joint could be suggested in code.

The relook of treating foundation refilled reinforced pad as part of wall or foundation, reducing FOS = 3 for minimum design parameters adopted and giving some more weightage to reinforced refilled pad in UBC on basis of R&D and literature, will improve the proposed draft IS code in coming years.

Economic aspect of reinforcing elements in pad based on performance of compacted RE walls using different elements is recommended to researchers.

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REFERENCES

British standard code of practice for "*Strengthened / Reinforced Soils and Other Fills*." BS: 8006-1997.

G. Venkatappa Rao., P.K. Banerjee., J.T. Shahu & G.V. Ramana. (2005). Geosynthetics – New Horizons. M/s Asian Books Pvt. Ltd., New Delhi.

Geoff kempton et al. *Design and construction of reinforced soil walls to BS 8006 and recent advances. Geosythetics New Horizones*, Asian books Pr. Ltd, N. Delhi, 21.

J.M. Vashi. (2010). Geosythetics in pavements state of usage and economical feasibility. *PhD seminar* June, Applied Mechanics Dept, S.V. National Institute of Tech. Surat

Manfred R. Hausmann. (1990). *Standard Materials and Dimensions, Engineering Principles of Ground Modification.* McGraw-Hill international editions.

Nirav B. Umravia. (2008). *Review of Retaining earth wall With Recent Development in Reinforced Earth.* M.Tech Thesis Applied Mechanics Dept, S.V. National Institute of Tech.

Shukla S.K. (2002). *Geosythetics and their application.*

Swami Saran. (2005). *Reinforced Soil & its Engineering Application*. I.K. International Pvt. Ltd, New Delhi.