Influence of the Geotextile Force on the Stability of Embankments

Jigisha Vashi[1]; Atul Desai[2] and Chandresh Solanki[3]

[1]Assistant Professor, SVKM's NMIMS Mukesh Patel School of Technology Management & Engineering, Mumbai – 40056, vashi.jigisha@gmail.com
[2,3]Professor, Applied Mechanics Department, SVNIT Surat, Surat – 395 007

Abstract. The behavior of Geotextile reinforced force on reinforced embankment was analyzed in this study. The embankment were backfilled with flyash(80%) & clay(20%) soil and the safety factors obtained from general limit equilibrium and finite element analysis. Variable Geotextile stiffness of 50 to 2000 kN/m and varying spacing, S_v of 0.4 m and 0.5 m were taken as reinforcement and series of finite element (FEM) analyses were carried out with GEO5-FEM software. The FEM analysis results showed that the maximum geo-reinforcement force was observed in first layer of Geotextile, placed at bottom of the embankment in the range of 0.66kN/m at extreme ends to 2.34kN/m at central region of embankment. There was no force developed in geotextile from both sides of embankment boundary upto 5 m. Amongst the total number of 15th layers of geotextile (S_v = 0.5m), and 19th layers of Geotextile (S_v = 0.4m), the Geotextile forces were observed only upto the 13th layer and 16th layer of Geotextile reinforced embankment respectively. Beyond these layers, there are no forces in geotextile. Hence, there is no requirement of Geotextile reinforcements at top 1.0m to 1.2m of the embankment crest width. From this observation it can also be concluded that for further economy, the tensile strength or stiffness of each layer of Geotextile can be varied for a given reinforced embankment slope by providing geotextile of higher strength or stiffness at the bottom of the embankment and lower strength or stiffness at the top of the embankment. It results in savings in terms of cost, time, material and execution.

Keywords: deformation behavior, difficult subsoil, flyash & clay backfill, geotextile, numerical analysis, reinforced earth embankment

1 Introduction

The limited equilibrium technique has been used for the design and the analysis of reinforced structure since the reinforced earth was commercially used at the first time. In the limited equilibrium design, the force applied to the top of the wall is used to calculate the horizontal pressure, which is resisted by the reinforcement. Although these forces are easily applied to the limited equilibrium design, they cannot be simply incorporated to the prediction of deformation. The finite element technique was applied to analyze the behavior of the reinforced earth in the middle of 70's. FEM has been used for the study of numerous parameters and for the analysis of the Geotextile reinforced embankment (GRE). In the research for the GRE, FEM has been mainly applied to predict the reinforcing strains and the deformation of the embankment [1]. FEM has been also applied to analyze the parameters such as the length [2], the strength, the spacing, the stiffness, and the arrangement of the reinforcement [3], facing material and facing construction [4], compaction stress and friction at the interface between the soil and the reinforcement and the relative motion [3]. Silva and Pameria [5] and Shukla [6], suggested that by putting berm in the embankment can increase the factor of safety of reinforced structure. However the Geotextile reinforcement force calculation is still not done till date.

In this study GEO5-FEM analysis was carried out for flooded condition. The main trigger mechanism of embankment failure on soft soil is related to rainwater infiltration in monsoon season when flooding occur. The precipitation water infiltrates into the weathered clayey slope debris and seeps via stabilized clay down to the boundary to desiccated clay. Umravia et al [7] observed failure of reinforced earth wall, due to precipitation of flood water in to foundation. Therefore, FEM analysis was carried out considering worst condition so the model was analyzed for flooded condition (F.L effect at G.L) only. The typical proposed geometrical layout of GRE with berm developed by trials is shown in Fig 1. In this study, Geotextile reinforcement force for layer of Geotextile reinforced embankment on difficult subsoil condition was analyzed by GEO5-FEM software [8].

2 Geometry and Modeling

In the present investigation, typical model with 8 m high embankment, a crest width of 20 m and having slope angles of 58° at base and adopting berm at 4 m height considering slope angle of 64° was implanted. The embankment is placed over a 2 m thick embankment foundation overlying a relatively soft layer of 5 m thickness. A nominal height of 8 m is considered, based on commonly adopted industry practice of vertical clearance required for flyover openings, which is 6 m as per [9]. The embankment was reinforced by layers of Geotextile having variable length from top to bottom, covering whole width of embankment. The vertical spacing of geotextile is varied from 0.5 m and 0.4 m. The finite element fine mesh used in these analyses involved 2037 elements with 6-nodes. Fig. 1 shows the assumed boundary conditions and distinguished layers according to the representative materials. A series of finite element analyses was performed on embankments of the type shown in Fig. 1, constructed on a soft clayey desiccated foundation, for a variety of Geotextile stiffness. The analyses were performed to obtain estimates of embankment deformation for embankments reinforced with Geotextile ranging in "moduli" from 50 kN/m to 2000 kN/m (Here the market availability has been a constraint for adopting). Also it was assumed that each layer of Geotextile has same tensile strength/stiffness & placed horizontally. Soil parameters of the backfill are determined by lab test by [10], Table

1. Parameters of the foundation are determined by feedback analysis based on the measured data from the literature [11]. In this study, the analytical modeling of earth embankment with Geotextile reinforcement is performed using the GEO5-FEM software.

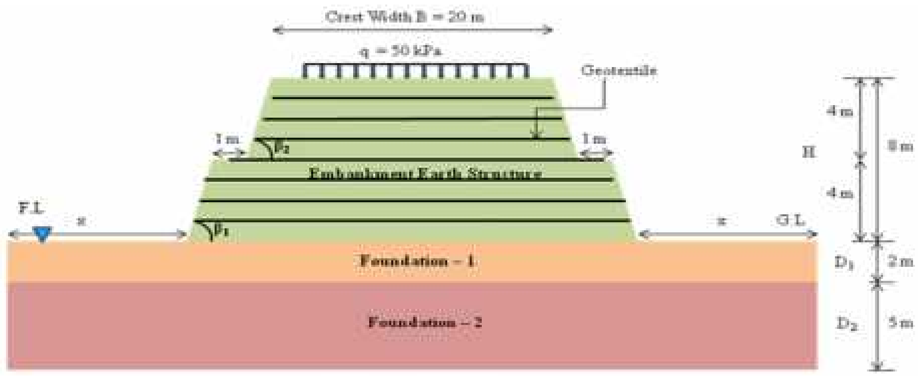

Fig. 1. A Geometry of models (Reinforced earth embankment)

Table 1. Properties of soil material of foundation and embankment structure

Properties	Type		
	Earth Structure	Foundation – 1	Foundation – 2
Unit weight, γ (kN/m^3)	14.12	14.12	20.5
Saturated unit weight, γ_{sat} (kN/m^3)	19.06	19.06	25.0
Cohesion, c_{ef} (kPa)	15	15	5
Angle of internal friction, φ_{ef} (deg)	30	30	15
Poisson's ratio, ν	0.30	0.30	0.42
Elastic modulus, E (MPa)	0.8 to 16.66*	0.8 to 16.66*	3.0
Dilation angle, Ψ (deg)	0.0	0.0	0.0
Biot Parameter, α	1.0	1.0	1.0
Material model	Mohr-Coulomb		
*Fissured clay is replaced by compacted flyash + clay fill material			

3 Results and Discussion

The analysis of FEM embankment model with distance of 12 m was selected from side boundary to embankment toe. Variation of geo-reinforcement forces (G) i.e.; forces within Geotextile reinforcement with varying stiffness's of 50 to 2000 kN/m and varying spacing of 0.4 m and 0.5 m were conducted. Among them the results of varying stiffness's of 50 and 200 kN/m and varying spacing of 0.4 m and 0.5 m are shown in Figs. 2 to 5. The maximum geo-reinforcement force was observed in first layer of Geotextile, placed at bottom of the embankment in the range of 0.66kN/m at extreme ends to 2.34kN/m at central region of embankment. There was no force developed in Geotextile from both sides of embankment boundary upto 5 m. Amongst the total number of 15th layers of Geotextile for a vertical spacing of S_v = 0.5m, the Geotextile forces are observed only upto the 13th layer of Geotextile (Figs. 2 and 3).

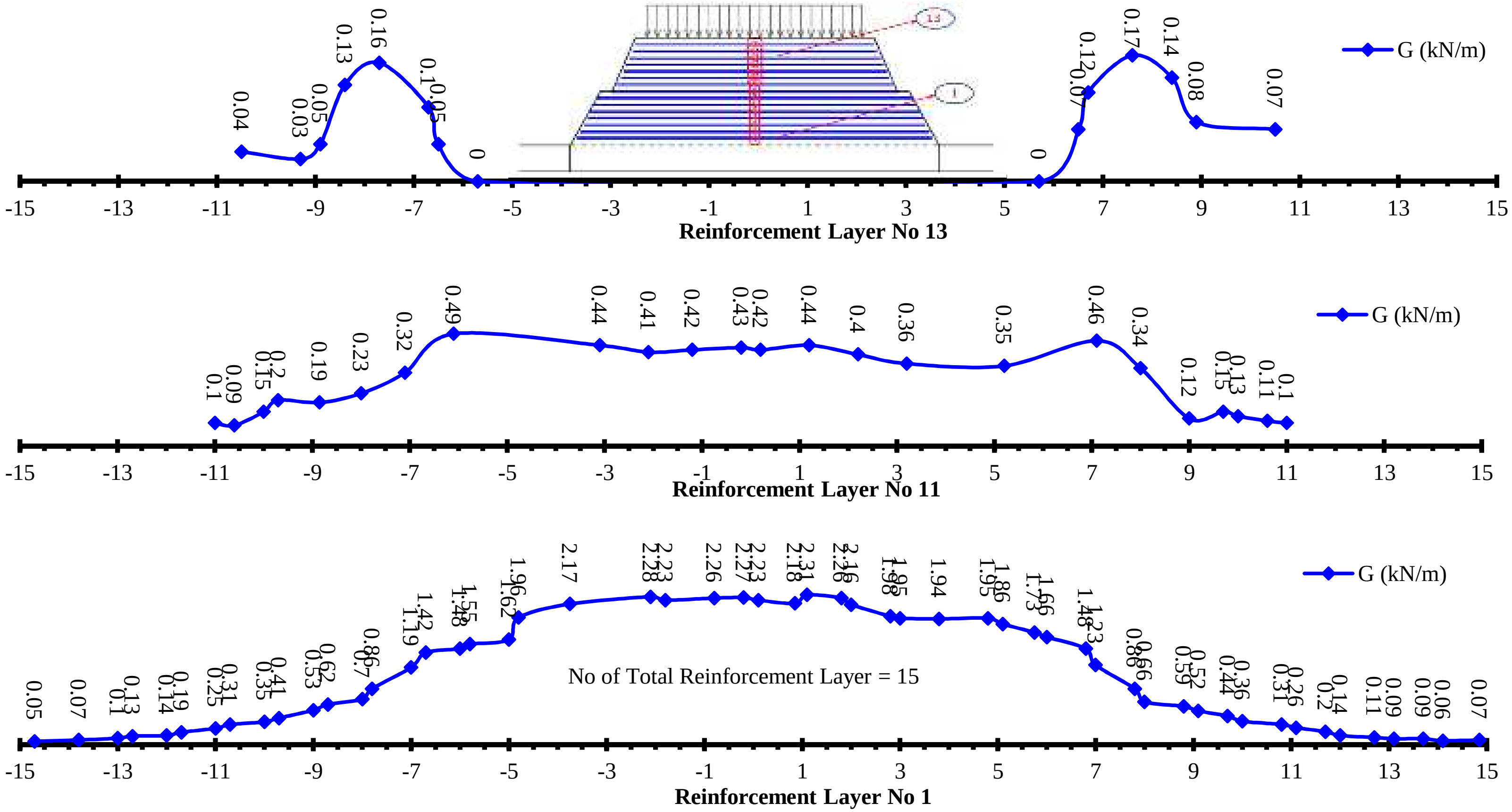

Fig. 2. Geo-reinforcements forces (G) for stiffness = 200 kN/m and S_v = 0.5 m

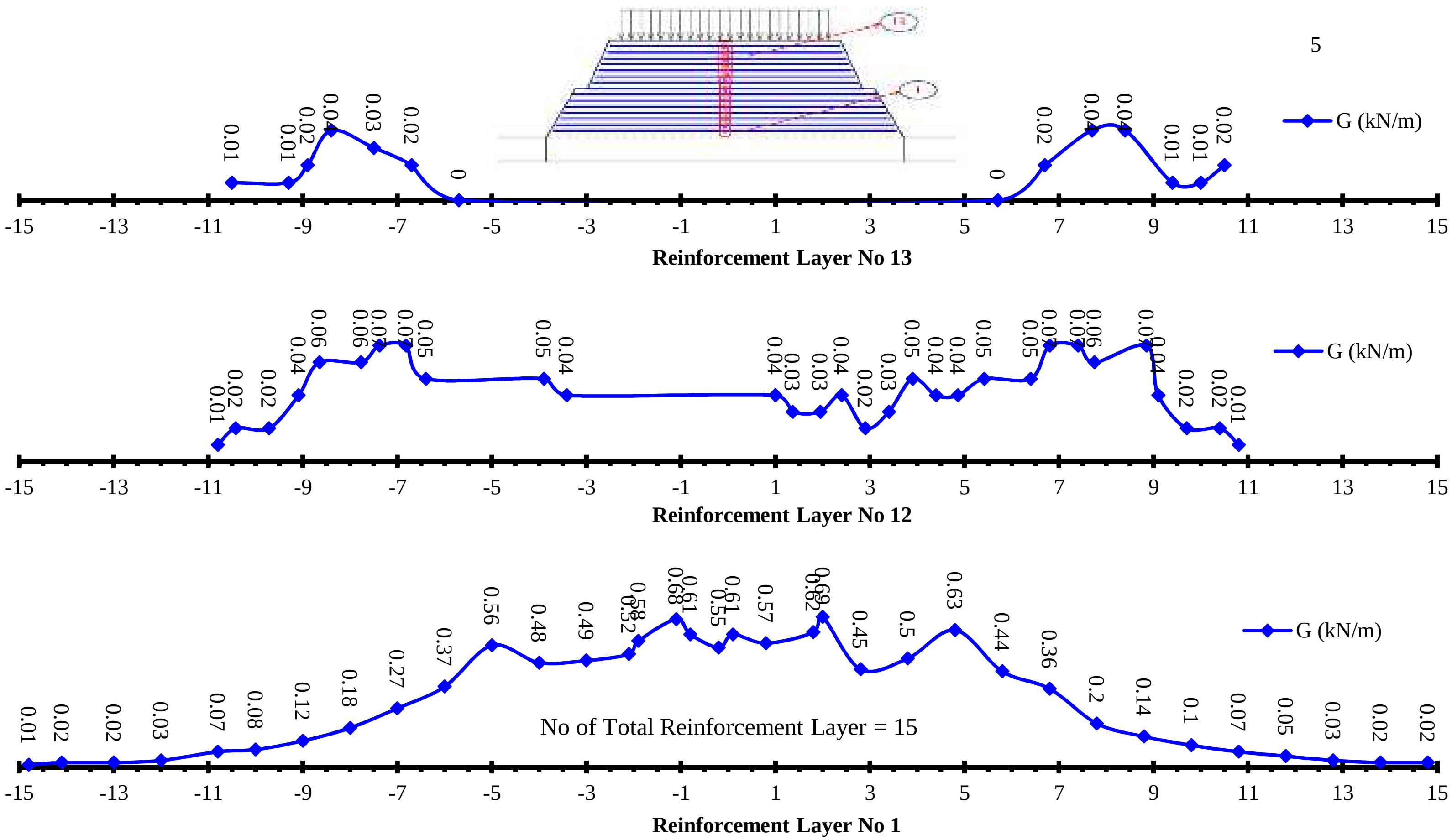

Fig. 3. Geo-reinforcements forces (G) for stiffness = 50 kN/m and S_v = 0.5 m

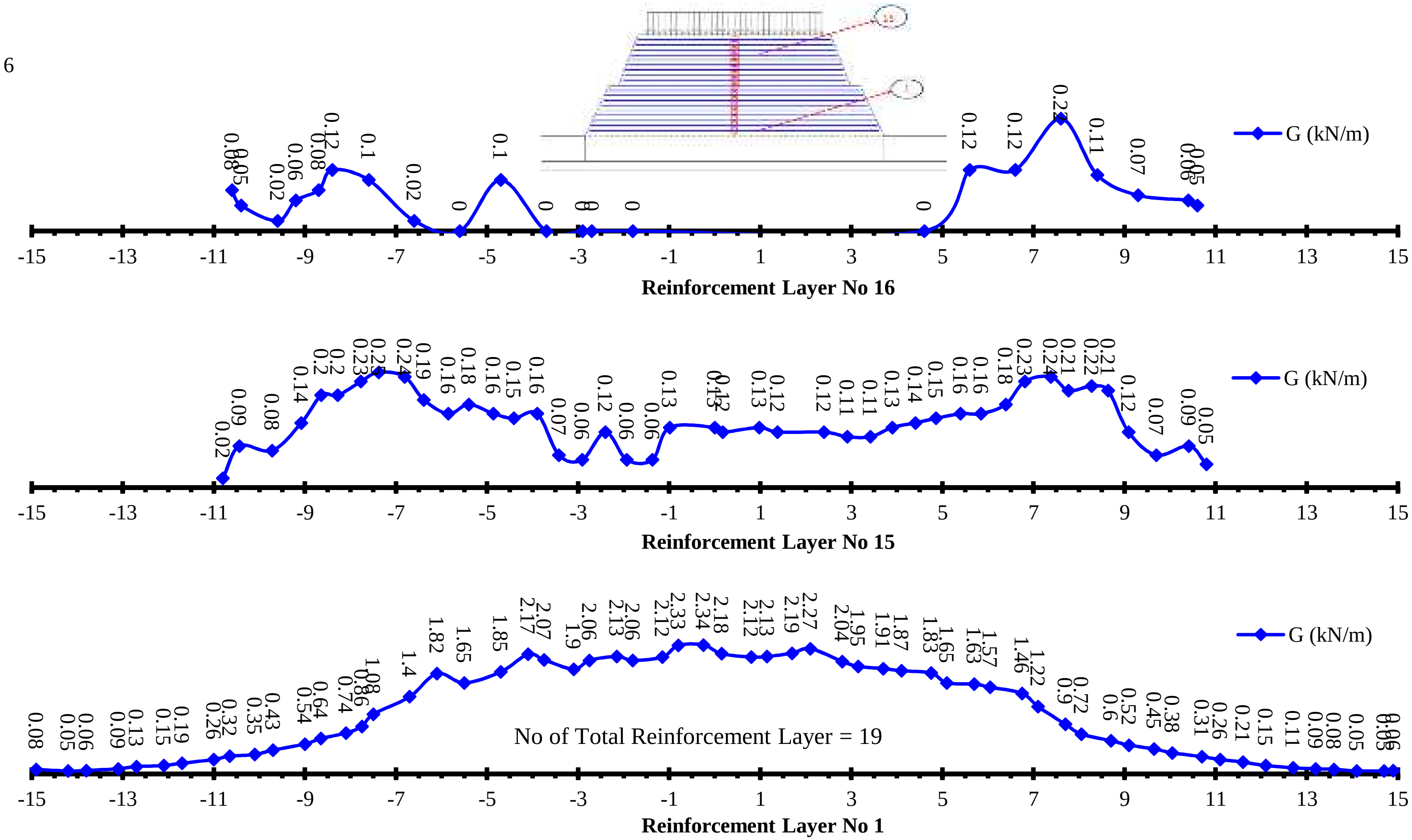

Fig. 4. Geo-reinforcements forces (G) for stiffness = 200 kN/m and S_v = 0.4 m

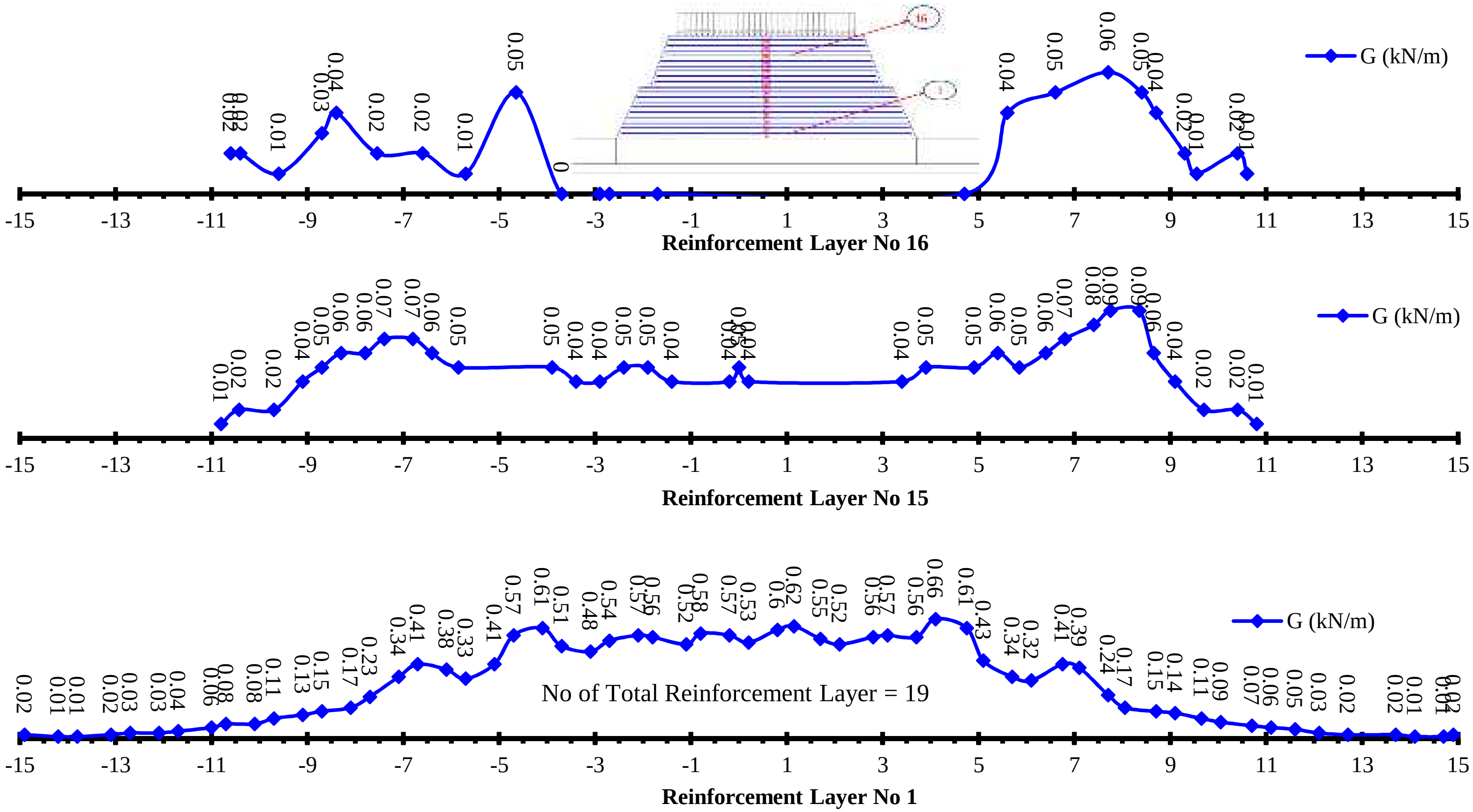

Fig. 5. Geo-reinforcements forces (G) for stiffness = 50 kN/m and S_v = 0.4

Amongst the total number of 19th layers of Geotextile for a vertical spacing S_v = 0.4m, the Geotextile forces are observed only upto the 16th layer of Geotextile (Figs 4 and 5). Beyond these layers, there are no forces in Geotextile. Hence, there is no requirement of Geotextile reinforcements at top 1.0m to 1.2m of the embankment crest width. The top 1.0m to 2.0m of embankment can be replaced by geofilter material to control the pore water pressure and seepage.

4 Concluding Remarks

From this observation it can be concluded that, there is no requirement of Geotextile reinforcement at top about 1.5 m of the embankment crest width, which can replaced by geofilter to control water seepage. For further economy, the tensile strength or stiffness of each layer of Geotextile can be varied for a given reinforced embankment slope by providing Geotextile of higher strength or stiffness at the bottom of the embankment and lower strength or stiffness at the top of the embankment. It results in savings in terms of cost, time, material and execution. Stiffness of intermediate layers can be determined by further detailed analysis for the given site conditions.

References

1. Boyle, S. R.: Deformation prediction of geosynthetic reinforced soil retaining walls. Ph.D. Dissertation, University of Washington, U.S.A. (1995).
2. Ho, S. K., Rowe, R.K.: Finite element analysis of geosynthetics-reinforced soil walls. Geosynthetics, 1, 189-201 (1993).
3. Yoo, C.S.: Seismic response of soil-reinforced segmental retaining walls by finite element analysis. Journal of the Korean Geotechnical Society, 17(4), 15-25 (2001).
4. Tatsuoka, F.: Keynote lecture: Roles of facing rigidity in soil reinforcing. Earth Reinforcement Practice, Proceedings of the International Symposium on Earth Reinforcement, Vol. 2, 831-870 (1993).
5. Silva, A. R. L., Palmeria, E. M., Stability of geosynthetic reinforced embankment on soft soil. Proceeding of 12th Brazilian Conference on Geotechnical Engineering, Brasilia, Brazil, 1213-1220 (1985).
6. Shukla S.K.: Geosynthetics and their applications, embankments, Thomas Telfords Ltd., 96-121 (2002).
7. Umravia, Nirav B., Vashi, Jigisha M., M.D. Desai.: Need for relook at the design practice for reinforced earth wall foundations. Indian Geotechnical Conference, GEOtrendz, IGS Mumbai Chapter & IIT Bombay, 73-76 (2010).
8. Geotechnical Software Suite GEO5- User's Guide Manual, Version 12 (2011).
9. IRC: 6, Standard Specification and Code of Practice for Road Bridges. Section –II (Load & Stresses), Fourth Revision (2000).
10. Vashi, J.M.: Feasibility study of geotextile reinforced embankment on difficult foundations as an alternative to reinforced earth wall in Indian environment, Ph.D. Dissertation, AMD, SVNIT, Surat, (2013).
11. Desai, M. D.: Ground Property Characterization from In-situ Testing, Published by IGS Surat Chapter. (2005).