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"THE EFFECT OF SOIL STRUCTURE INTERACTION ON GRAVITY RETAINING WALL USING VARIOUS PARAMETERS OF SOIL

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Abstract –In the proposed study, the effect of soil structure interaction on gravity retaining wall has been examined using finite element analysis software ANSYS 18.0.The gravity retaining wall is completely resting on soil media and surrounded by soil media**.** Factors such as a soil type, cohesion, friction angle, and density are studied in relation to their impact on wall stability, deformation, and overall performance. Numerical modeling techniques, such as finite element analysis, are employed to simulate soil – structure interaction and evaluate its effects on retaining walls. The implications of soil- structure on retaining wall is discussed. Design consideration such as appropriate wall geometry are examined to account for the effect of soil interaction and ensure long term stability.Overall, this study highlights the importance of considering soil-structure interaction of retaining walls.

Key Words: Gravity Retaining Wall, Soil Structure Interaction

1 INTRODUCTION

Retaining walls are relatively rigid walls used for supporting soil laterally so that it can be retained at different levels on the two sides. They are used to bound soils between two different elevations mostly in areas of undesirable slopes, hillside farming, roadway overpasses etc. A retaining wall that retains soil on the backside.Gravity retaining wall, Cantilever retaining wall, Anchored retaining wall these are some typical retaining walls.Gravity retaining walls depend on their mass to resist pressure from behind. To improve the stability it consist setback by leaning back towards the retaining soil. For short walls, they are often made from mortarless stone or segemental concrete units. Gravity walls, generally are trapezoidal in shape, but also may be built with broken backs In most of the conditions GRWs are constructed by using plain cement concrete. Sometimes Stone or brick masonry is also used for construction of GRW. The GRW is likely to fail in Any one of the following ways.

1.1 Aim of study

Analysis of gravity retaining wall along with soil structure interaction by varying the soil parameters

2.Literature Review

Retaining walls are extensively used from many years to retain mass of earth virtually in every civilization in history. contributions of researchers are presented as follows,

R.M. Ebeling[1]conducted the investigation on the accuracy of the procedures employed in the conventional equilibrium method of analysis of gravity earth retaining structures founded on rock using finite element method of analysis. The result of load analysis showed when the loss of contact along the base of a wall modeled in the finite element analysis, the calculated values of effective base contact area and maximum contact pressure are somewhat larger than those calculated using conventional equilibrium analysis. The values of the mobilized base friction angle calculated by both methods had had in precise agreement.

K. Pitilakis and A.Moutsakis[2]studied a systematic critical review of the different design methods gravity retaining walls using the case of the seismic behaviour of kalamata harbour quay wall during the large kalamata's earthquake. In there studies they applied the classical procedure of a seismic design of the gravity wall based on the limited strength criterion and the method based on the concept of the acceptance limited displacement. They compared all the results with existing measurements. They use these results for design consideration for the general review of the accuracy and limitation of each method.

MeterOner, William P. Dawkins[3]conducted a comprehensive analysis procedure to understand the soil structure interaction, mechanism involved in the behaviour of floodwall system. They used finite element method with suitable method of the soil structure interface, nonlinear soil behaviour and loading sequence. On test section they used an existed floodwall for verification analytical model.

Kenji Watanabe, YulmanMunaf, Junichi Koseki, Kenichin Kojima[4]Conducted a series of shake table tests with irregular excitation on retaining wall model consist of six different types. They studied the behaviours of several types of model retaining walls subjected to irregular excitation

S.R.K. Reddy[5]has studied Influence of the Soil-structure Interaction on response of a Multi-storied Building against Earthquake Forces- seismic waves travel through different rock or soil media and reach the response of the structure apart from the influence of other parameter such as the type of ground excitation, configuration, ductility and quality of construction. Soil is represented by introducing two additional springs, one in horizontal and other in rocking mode.

Dr.D.Neelam Sataym ,PallaviRavishankar[6]In order to carry out SSI parametric study an asymmetrical building with respect to loading of 150 m height with base dimension 40 m*20 m is analysed in Ansys-13.It has been observed that for a given ground motion the displacements increase as from soil mass to superstructure top in both X and Y direction, but this change is very minute for the vertical(z) direction displacements. Stress concentration is found to be much more in immediate soil layer below the foundation and it decreases evenly in both direction as moving away down and up from.

Gaikwad M.V., Ghogare R.B.[7]Analysis of bare frame with soil structure interaction shows more displacements than the analysis of bare frame without soil structure interaction. Also analysis of bare frame with soil structure interaction shows less shear force as compared with analysis of bare frame without soil structure interaction. Analysis of in-filled frame with soil structure interaction shows more bending moment as compared with analysis of in-filled frame without soil structure interaction.

Dr.Rajim[8]In order to find out the seismic response and soil structure interaction of a multi-storeyed building with building with varying type of foundation three different analysis have been carried out. G+12 storey structure is taken for the study with raft, pile and under reamed pile foundation systems. onanalyzing the result it is found out that the deformation is higher for raft foundation and is about 70.9mm. when the raft is changed to pile foundation the deflection reduces to 38.6mm. The soil settlement under the raft foundation is remarkably higher than that of the pile and under reamed pile footing

Dr. Alice Mathai[9] conducted a series of shake table tests with irregular excitation on retaining wall model consist of six different types. They studied the behaviors of several types of model retaining walls subjected to irregular excitation.

Wang Jiachun[10] discussed influence of several different boundary conditions on analysis of SSI. In structural response of earthquakes, the assumption in the foundation medium was stiff and the seismic motion applied at structure support points were same as free-field earthquake motion at that location means the SSI were neglected. Nevertheless, the effect was taken in to account when the structure supported on a soft soil. A comparison of reactor buildings response as predicted by CLASSI and FLUSH showed differences. In analysis of SSI the outwardly radiated energy, transmitting boundary conditions were taken into consideration.

Eduardo Kausel[11] described Early history of soil–structure interaction. The early history of Soil Structure Interaction which lies at the intersection of soil and structural mechanics, soil and structural dynamics, earthquake engineering, geophysics and geo-mechanics, material science, computational and numerical methods, and diverse other technical disciplines.

Caselunghe Aron & Eriksson Jonas[12] described Structural Element Approaches for Soil-Structure Interaction. The author compared The methods and calibrated against an elastic continuum modelled with solid elements, which was used in the study as the "correct" solution. The main interest was to simplify the method often used today, with springs representing the subgrade (Winkler model). In the study the model was modified to better capture the soil's behavior. The Winkler model were introduced. It was found that to achieve a better behavior in a structural element model, different kinds of interaction elements included, which couple the springs. The computations were performed by the soft wear ABAQUS (2010). The biggest shortcoming, identified in this thesis, for a Winkler model with uniform foundation stiffness was that no consideration was taken to the soil around the superstructure. This showed major underestimation of the foundation's stiffness towards the superstructure's edges, which normally at the edges, leads to conservative sectional forces in the ground slab and conservative ground pressure. It also leads to a convex settlement profile, when a concave would be more realistic in reality for the specific case. The Winkler model improved by introducing higher foundation stiffness towards the superstructure's edges. Tension zones between superstructure and subgrade observed, as it gave conservative sectional forces. The job time for the continuum model for KKH was 14 times the job time for the corresponding Winkler model. Including interaction elements, which couple the foundation's springs, improved the correlation to an elastic continuum compared to a Winkler model with uniform foundation stiffness. An interaction element characterized with only shear deformations was to prefer, since omitting bending deformations was shown to degrade the solution. The 2D analysis indicates that the shear layer's stiffness determined independently of the superstructure's geometry. A simple method, for practical use, to determine the shear layer model's foundation properties was developed.

Dr. S. A. Halkude, Mr. M. G. Kalyanshetti,Mr. S. H. Kalyani[13]described,Soil Structure Interaction Effect on Seismic Response of R.C. Frames with Isolated Footing. The author investigated the effect of soil flexibility on the performance of building frame. Two SSI modes was considered for the analysis; one replaced soil by spring of equivalent stiffness (Discrete Support) and second by considered the whole soil mass (Elastic Continuum). Symmetric space frames rested on isolated footing of configurations 2 bay 2 storey (2X2X2), 2 bay 5 storey (2X2X5) and 2 bay 8 storey (2X2X8) was considered with fixed base and flexible base. The spring model was developed by using stiffness equation along all 6 DOF and elastic continuum model was developed by Finite Element Method using SAP-2000. For SSI study three types of soil was considered i.e. Hard, Medium Hard and Soft Soil. The dynamic analysis was carried out using Response Spectrum, given in IS1893-2002. The influence of soil structure interaction on various structural parameters i.e. natural time period, base shear, roof displacement, beam moment and column moment was presented. The study reveals that the SSI significantly affects on the response of the structure. Finite Element Method has proved to be the effective method for consideration of elastic continuum below foundation.

Dr. P. P. Tapkire[14] described Optimization of gravity retaining wall profile by introducing cavity. In which the main aim of this paper is to develop a cost effective and structurally efficient profile of gravity retaining wall by introducing cavity in the section. For this, various section sizes of gravity retaining wall are analyzed and accordingly profile is selected and then after selection of an appropriate profile of gravity retaining wall stability calculations are carried out for various heights using 'C' programming by strength of material approach.

Ms.Patil Swapnali.[15] described, Effect of Soil Structure Interaction on Gravity Dam. The effect on gravity dam had been examined using finite element analysis software ANSYS 14. The gravity dam completely resting on soil media and surrounded by soil media. The relevant amount of soil around and bottom of the gravity dam had been modeled to simulate the in-situ conditions. The gravity dam was analyzed using dynamic loading in transient analysis using Imperial Valley (1940) earthquake record was included. Analysis of the gravity dam carried out and the influence of soil properties studied at the region of transverse sections, which exhibited the response in terms of stress and deformation with significant difference.

Snehal R. Lahande[16] described, Analytical Study of Cantilever Retaining Wall Including Effect of Soil Structure Interaction. The influence of the different types of soil on the different heights of the wall was addressed. A cantilever retaining wall was considered and modeled for the soil-structure interaction using finite element package SAP2000 Version 14.0.0. Dynamic distress and response of a cantilever retaining wall was studied considering six degrees of freedom system. For the validation purpose of the retaining wall, support conditions were considered to be fixed. For the analysis, the inputs are density of concrete, modulus of elasticity of concrete, density and SBC of soil, modulus of elasticity of soil, angle of internal friction and loading (active and passive earth pressure). The targeted output was maximum lateral displacement. The response spectrum inputs were given to the retaining wall for all the three types of soils (soft, medium, soft rock and hard rock) and three types of seismic zones (III, IV and V).

3 Problem Formulation

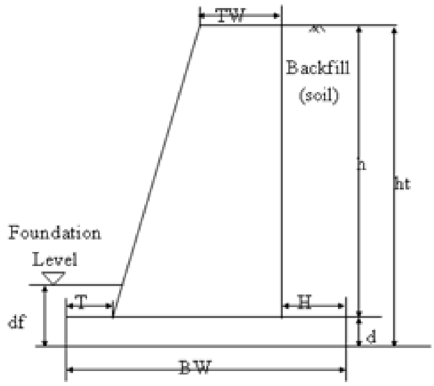
Numerous studies have been made on the effect of soil structure interaction. These studies have considered the effect in a very simplified manner and demonstrated that the quantities are revised due to such interaction. A limited Number of studies have been conducted on soil structure interaction with gravity retaining wall, and this is taken as problem definition of current dissertation work. In this work GRW is analyze with the effect of soil structure interaction along with varying geotechnical parameters like density & friction for different heights with horizontal backfill as loading condition.

3.1 Geometrical Parameters for the GRW

In the properties of Gravity retaining wall,geometry variables of retaining wall and material properties are mentioned. The geometry variables is shown in fig no.1

GRW	TopWidth	0.7m
	BottomWidth	1.55m
	StemHeight	3.15m
Foundation	SlabDepth	0.35m
	SlabWidth	2.6m

Table1:GeometryparametersofGRW



3.2 Geotechnical parameters.

The various geotechnical parameters are considered to study the effect of soil structure interaction, the soil parameters such as friction of soil and density of soil. In this project we analyze the change in maximum deformation, maximum stress and minimum stress by varying densities for same friction of soil & from that results and graphs are workout. The following are the geotechnical parameters of GRW and soil is taken for consideration.

GRW	Density	25kN/m³
	Modulusofelasticity	25000MPa
	Poisson'sratio	0.2
soil	Density	18kN/m³
	Modulusofelasticity	2.62Mpa
	Poisson'sratio	0.4

Table2:The material properties of GRW and Soil

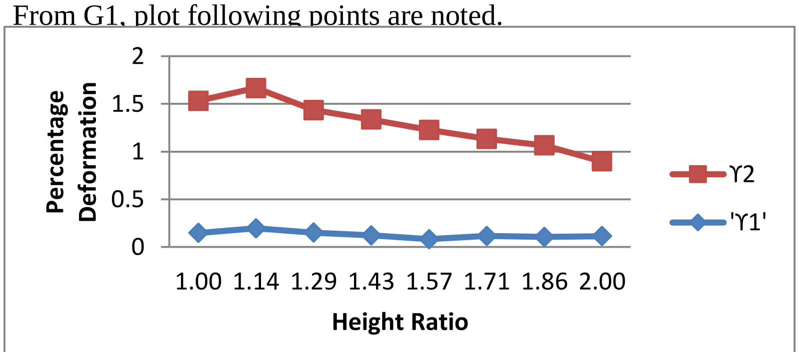
4 Result

The current research paper is focused on the effect of SSI on Gravity retaining wall as per mentioned in the previous section. Geometry of gravity retaining wall and parameter considered for the finite element analysis of gravity retaining wall exercised as discussed. Gravity retaining wall with different geometry and heights are designed which are governed by stability criteria, dimensions of gravity retaining wall for various heights are calculated using worksheet which separately developed for design of gravity retaining wall with considering horizontal backfill as a loading case. The various Heights with and without consideration of soil structure interaction are solved using finite element package. Maximum and minimum of deformation and maximum and minimum stresses are obtained for each case, the non-dimensional variations are plotted which are mentioned in sub-sequent section

4.1 Variation of Deformation percentage of GRW with Height ratio

The variation of the Deformation percentage of gravity retaining wall with and without soil structure interaction are considered & plotted against Hr.The deformation percentage are obtained by considering only retaining wall, retaining wall with soil as a whole mass (soil+ retaining wall as whole structure), only retaining wall with soil mass (considering soil structure interaction). To understand the effect of SSI deformation percentage with reference to GRW without SSI is consider as reference as discussed above.

From G1, plot following points are noted.

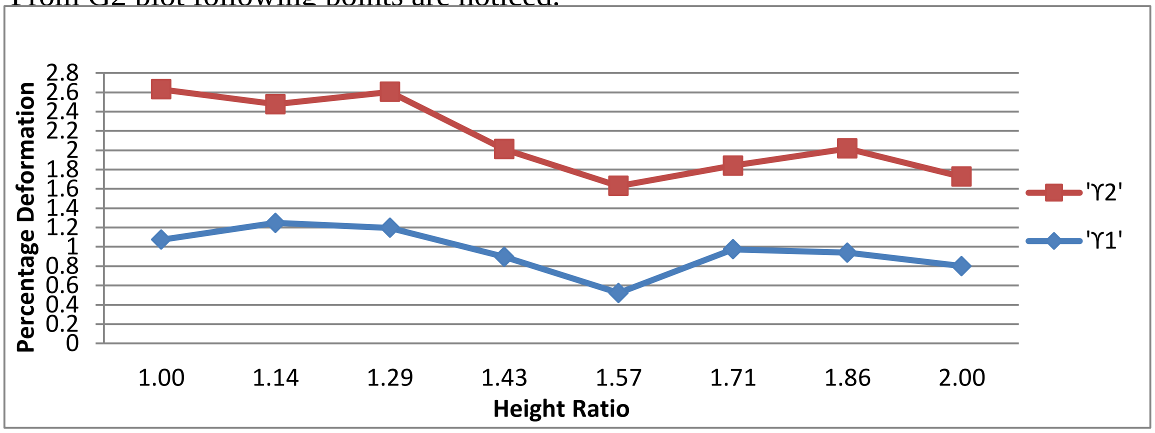


Graph G1 : Variation of deformation percentage against height ratio forϕ1 only for GRW Without SSI

Observations

- For higher density deformation is remains practically same as height ratio (Hr) increases
- The deformation of GRW with SSI lies between 1% to 2% considering wall along with soil mass.

From G2 plot following points are noticed.



Graph G2 : Variation of deformation percentage against height ratio for ϕ2 only for GRW Without SSI.

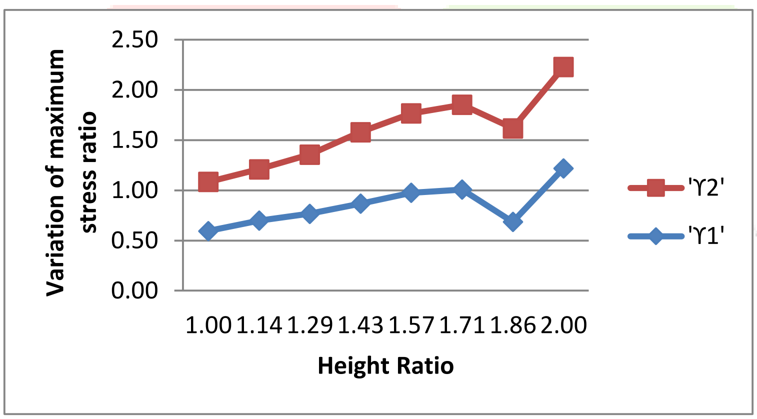
Observations

- For considered friction, the variation of deformation decreases for increases in height ratio
- The variation of deformation for both densities is minimum at height ratio 1.57.
- As height ratio increases for density, deformation decreases for considered friction angle and profile of GRW

4.2Variation of Maximum Stresses percentage of GRW with Height ratio

The variation of the Deformation percentage of gravity retaining wall with and without soil structure interaction are considered & plotted against height ratio (Hr)The deformation percentage are obtained by considering only retaining wall, retaining wall with soil as a whole mass (soil+ retaining wall as whole structure), only retaining wall with soil mass (considering soil structure interaction). To understand the effect of SSI deformation percentage with reference to GRW without SSI is consider as reference as discussed above.

From G3,plot following points are noticed.

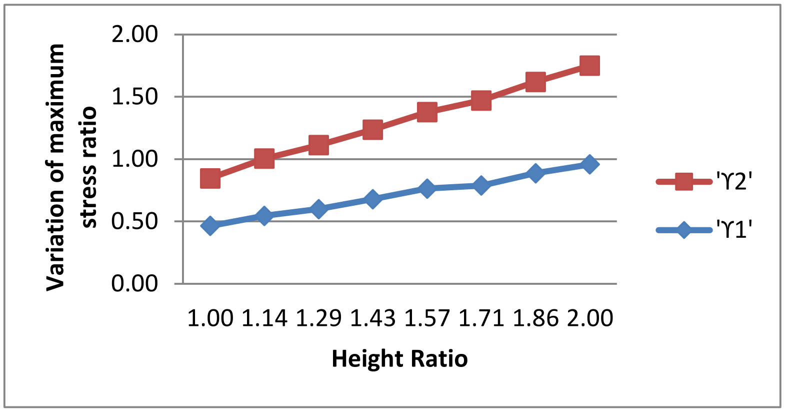


Graph G3 : Variation of maximum stress against height ratio forϕ1 only for GRW without SSI.

Observations

- The variation of maximum stress is observed having same flow for both densities, maximum stress are increases as height ratio increases.
- The variation of maximum stress without SSI is minimum for lower wall height ratio and higher for high wall height ratio for both densities.

From G4 plot, following points are noticed

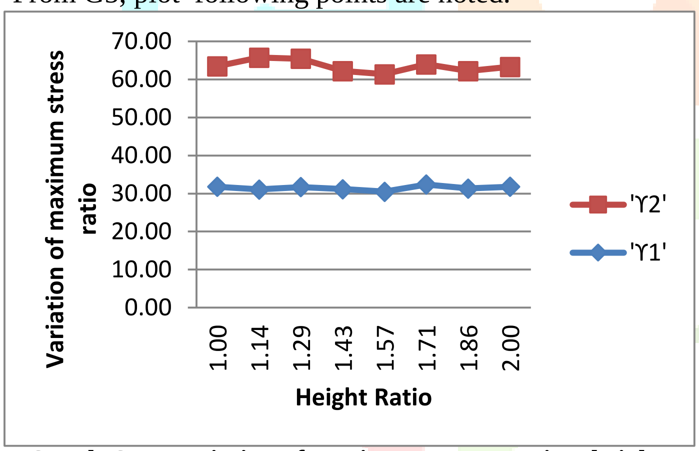


Graph G4 : Variation of maximum stress against height ratio for ϕ2 for only GRW without SSI.

Observations

- The variation of maximum stress is parallel to each other for both the densities for considered friction angle and profile of GRW.
- For both considered densities, friction angle and profile 1 shows increase in stress for increasing in height ratio (Hr).

From G5, plot following points are noted.

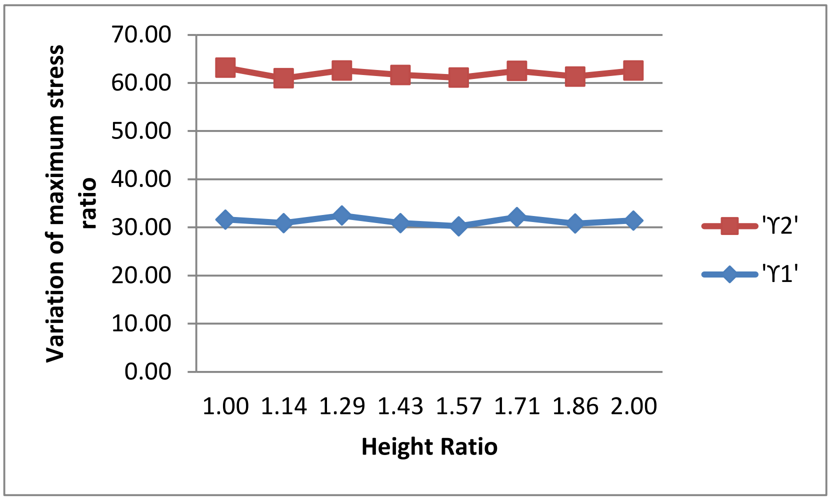


Graph G5 : Variation of maximum stress against height ratio for ϕ1 for only GRW& Soil mass with SSI.

Observations

- The variation in maximum stress is constant upto a certain height ratio after that as height ratio increases variation is also increases for both densities
- For higher density, the variation of maximum stresses is practically same for Φ1 and profile 1

From G6, plot following point are noticed



Graph G6 : Variation of maximum stress against height ratio for ϕ2 for only GRW Soil mass with SSI.

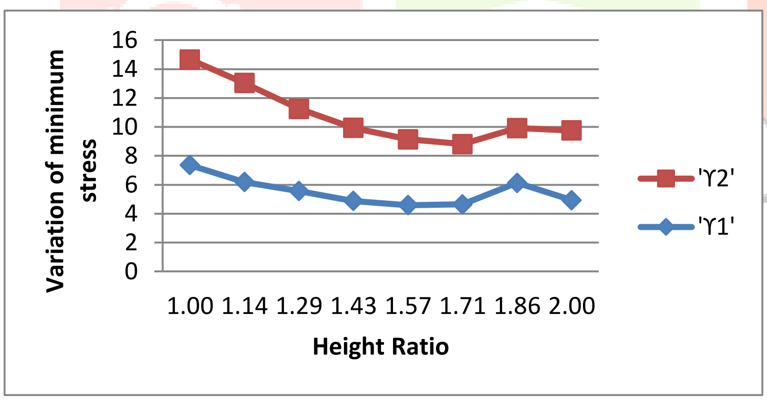
Observations

- The increasing variation of maximum stress is same for both densities to increasing in height ratio for considered friction angle and profile of GRW.
- The value of maximum stress for both densities is approximately same for height ratio of 1.43 & 1.57
- For both the densities it is observed that the variation in maximum stress are practically same.

4.3 Variation of Minimum Stresses percentage of GRW with Height ratio

The variation of the Deformation percentage of gravity retaining wall with and without soil structure interaction are considered & plotted against Hr.The deformation percentage are obtained by considering only retaining wall, retaining wall with soil as a whole mass (soil+ retaining wall as whole structure), only retaining wall with soil mass (considering soil structure interaction). To understand the effect of SSI deformation percentage with reference to GRW without SSI is consider as reference as discussed above.

From G7, plot following points are noticed.

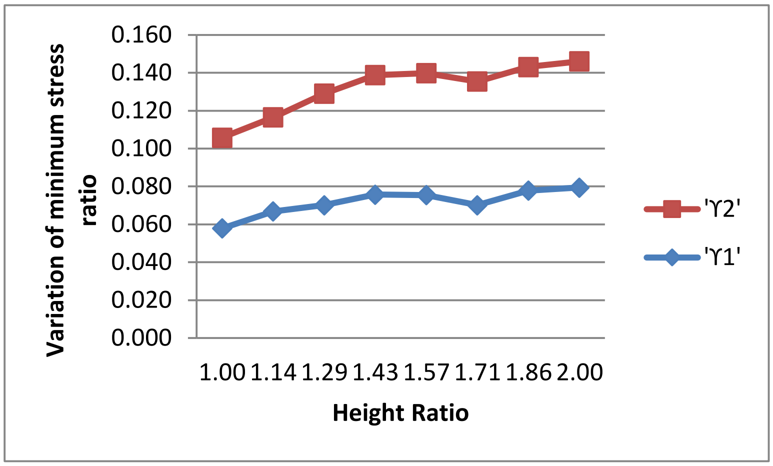


Graph G7: Variation of minimum stress against height ratio forϕ1 for only GRW without SSI.

Observations

- The variation of minimum stress is decreasing as height ratio (Hr) increases for both densities of considered friction angle and profile of GRW.
- The variation of minimum stress is lower at maximum height ratio for considered both densities.

From G8, plot following points are noticed.

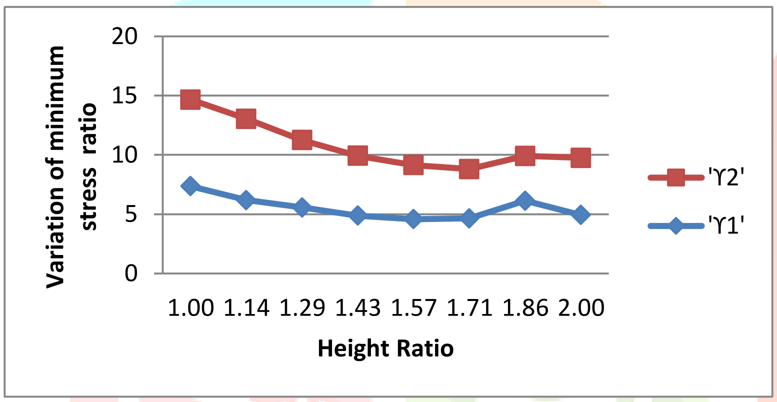


Graph G8: Variation of minimum stress against height ratio for ϕ2 for only GRW without SSI.

Observations

- The flow of variation in minimum stress is same for both densities for considered angle of friction and profile of GRW.
- For given friction angle, profile 1 shows increase in minimum stress for increase in height ratio (Hr). and both densities.

From G9, plot following points are noticed

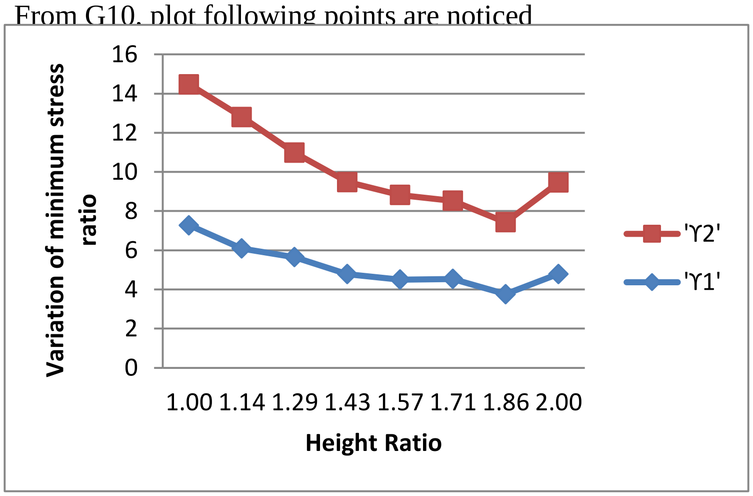


Graph G9: Variation of minimum stress against height ratio for ϕ1 for only GRW& Soil mass with SSI.

Observations

- As height ratio increases, the variation in minimum stress decreses for considered angle of friction and increase in the profile 1.
- The variation of minimum stress is higher for lower density.

From G10, plot following points are noticed



Graph G10 :Variation of minimum stress against height ratio for ϕ2 for only GRW & Soil mass with SSI.

Observations

- For considered friction, the minimum stress is decreasing for increase in height ratio. The decreasing stress is higher at lower wall height ratio.
- The variation of minimum stress decreases as the density decreases.
- The variation for both density are practically parallel for considered range of heights , the values does not exceed

4.4 Summary of Results

GRW with SSI & without SSI are analysed using FEM Package. Various parameters are studied and. Comparison of results carried out .The Graphs of variations of these parameters are plotted and observation are carried out.Based on results obtained, conclusions are drawn .

5 .Conclusion

5.1 Variation of Deformation Percentage of GRW

1) From plots it is concluded that due to consideration of SSI the deformation of GRW for horizontal backfill is significantly reduces for all height ratio.

2) The deformation percentage varies with height ratio for considered profile

3) For considered friction angles profile shows higher percentage deformation compared wall without SSI. While deformation for profile , for 'ϕ1 is quite similar to all height ratio for higher density.

4) Considering profiles maximum variation of percentage deformation not exceed 2.60 Percentage with SSI for both densities and friction angles.

6) The above conclusion indicates that the soil mass active along with GRW significantly affect the deformation.

5.2 Variation of Maximum Stresses Percentage of GRW with Height ratio

1) From plots it is concluded that due to consideration of SSI the Maximum Stresses of GRW for horizontal backfill is significantly reduces for all height ratio.

2) Profile show 0.0235 Percentage of Maximum Stresses as compared to without SSI for higher height ratio and for higher height ratio it is reaches to the condition, where the Maximum Stresses are negligible as compared to without SSI

3) Profile for 'ϕ1, the variation of maximum stress is practically same till height ratio 1.71 and after that maximum stress is increases as height ratio increases.

6) The maximum stress is observed 3.46 %, and it is observed in without SSI case.

7) The variation of maximum stress inr Profile for 'ϕ1 for higher density is not vary to much while for lower density is shows small variation.

9) The variation of maximum stress with SSI is higher than without SSI.

10)The above conclusion indicates that the soil mass active along with GRW significantly affect the Maximum Stresses.

5.3 Variation of Minimum Stresses Percentage of GRW with Height ratio

1) From plots it is concluded that due to consideration of SSI the Minimum Stresses of GRW for horizontal backfill is significantly reduces.

.2) Profile I show 0.060 % of Minimum Stresses as compared to without SSI for lower height ratio, for higher height ratio it is reaches to the condition, where the Minimum Stresses are negligible as compared to without SSI.

3) Considering all I profiles maximum 0.249%, Minimum Stresses % of with SSI is observed and for without SSI 0.323%.

4) The variation of minimum stress with SSI is noticed well as compared to without SSI.

5) The above conclusion indicates that the soil mass active along with GRW significantly affect the Minimum Stresses.

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