"EFFECT OF SOIL STRUCTURE INTERACTION ON GRAVITY RETAINING WALL"

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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. The relevant amount of soil around and bottom of the gravity retaining wall has been modeled to simulate the in-situ conditions. The gravity retaining wall has been analyzed using static loading. While analysing the gravity retaining wall, height and profile variation of gravity retaining wall has been carried out, which exhibited the response in terms of stress and deformation with significant difference.*

Key Words: Gravity Retaining Wall, Soil Structure Interaction

1. INTRODUCTION

Many problems in civil engineering involve some type of structural element in direct contact with the ground. Examples include building and bridge foundations; pavements and railway track systems, earth retaining structures; and underground conduits and tunnels. When forces are applied externally to the structural element and/or forces developed internally within the ground, both problem components (structural element and ground) must deform and move in a compatible manner. This is because neither the structural-element displacements nor the ground displacements are independent of each other as a result of their intimate physical contact. Therefore, these types of problems are broadly referred to as soil-structure interaction. Gravity Retaining Wall commonly used in various civil engineering construction, bridges, roads, infra project etc. The case of design and construction practicing engineer prefers gravity retaining wall. Normally, it is constructed with PCC for masonry. The Gravity Retaining Wall design is hail and process which is driven by stability criteria. The backfill soil defines the earth pressure acting on it. Along this parameter, it has coupled effect with retaining wall. In this proposed study Gravity Retaining Wall is analysed using Finite Element Method along the effect of Soil Structure Interaction When forces are applied externally to the structural element and/or forces developed internally within the ground, both problem components (structural element and ground) must deform and move in a compatible manner. This is because neither the structural-element displacements nor the ground displacements are independent of each other as a result of their intimate physical contact. Therefore, these types of problems are broadly referred to as soil-structure interaction.

1.1 Aim of Study

The present research is aimed to study the effect of Soil Structure Interaction on Gravity Retaining Wall for economical feasible cross-section.

An attempt is made to optimize the cross section of Gravity Retaining Wall by introducing Soil Structure Interaction to the structure. Height variation is considered for GRW. The maximum stresses induced due to SSI and without SSI are analyzed and by those results economical cross section area is obtained.

2. Literature Review

A retaining wall is any geotechnical structure which is used to retain a mass of soil that would otherwise tend to move down slope due to gravity and stresses acting within the soil.

The contribution has been done by the researchers to optimize the design of earth retaining structures and also in the direction to develop an earth retaining system using different innovative concepts. The researchers applied different optimization techniques and adopted a non-conventional system for different types of retaining walls like reinforced concrete structure wall, a gravity wall, etc. The researcher used soil structure interaction with various structures, with various parameters, some of researchers contributed in cavity retaining wall & in soil structure interaction along with gravity retaining wall presented as follows,

Sunil Gupta, Tsung-Wu Lin, Joseph Penzien, Chan-Shioung Yeh [1] described a hybrid model for the analysis of soil-structure interaction proposed which promises to be superior to the 19th time methods of analysis. The modelling achieved by partitioning the total soil-structure system into a near field and a far field with hemispherical interface. The near field consists of the structure, which analyzed and a finite region of soil around it was modelled by the finite element method. For the semi-infinite far field, impedance matrix corresponding to the interface degrees of freedom developed which accounts for the loss of energy due to waves travelling away from the foundation.

R. M. Ebeling [2] 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 results of load analyses 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 analyses. The values of the mobilized base friction angle calculated by both methods had in precise agreement.

K. Pitilakis and A. Moutsakis [3] studied a systematic critical review of the different design methods gravity retaining walls using the case of the seismic behavior of Kalamata harbor quay wall during the large Kalamata's earthquake (Ms =6.2, 13.9.86). In their studies they applied the classical procedures of a seismic design of the Gravity Retaining Walls based on the "limited strength" criterion (Mononoke Okabe method), and the method based on the concept of "acceptance limited displacement" (Richards and Elms). They compared all the result with the existing measurements. They use this result for design consideration for the general review of the accuracy and limitation of each method.

Robert M. Ebeling [4] presented a review of previous work in which the finite element method was used to analyze the soil- structure interaction of earth retaining structures such as U-frame locks, Gravity Retaining Walls, and basement walls. This method of analysis resulted in the computation of stresses and displacements for both the structure and the soil backfill. Applications of the procedure showed the importance of modeling the actual construction process as closely as possible and the use of a nonlinear stress-strain soil model. Additional requirements included modeling the interface between the soil backfill and the wall, which used interface elements. He also included two recent applications of the finite element method for the analysis of earth retaining structures, which was loaded so heavily that a gap developed along the interface between the base of the structure and its foundation

Timothy D. Stark, Steven M. Fitzwilliam, Joseiph J. Vettel, Robert M. Ebeling [5] described Soil-Structure Interaction Parameters for Silts. They tried to characterize the drained and undrained stress-strain behavior of normally consolidated silts and clayey-silts. They used the result of their research to develop a database of hyperbolic stress-strain and Mohr-Coulomb strength parameters for silts and clayey-silts. They carried out extensive drained and undrained triaxle tests on silt specimens with varying clay contents. They used percentages of clay in the silt mixtures were 0, 10, 30, and 50%. "The effect of density was investigated by compacting the triaxle test specimens at Standard Proctor relative compactions of 85, 90, 95, and 100%. They summarize the test results and the resulted hyperbolic stress-strain and Mohr-Coulomb strength parameters for the various silt mixtures considered.

T. Kupsmy, Mark A. Zarco [6] described the finite element computer program SOILSTRUCT used in the evaluation of soil structure interaction of earth retaining structure.

Mete Oner, William P. Dawkins [7] conducted a comprehensive analysis procedure to understand the soil structure interaction, mechanism involved in behavior of floodwall systems. They used finite element method with suitable model of the soil structure interface, nonlinear soil behavior, and loading sequence. On test section, they used an existed floodwall for verification of analytical model.

Ernesto Cascone, Agatino Simone Lo Grasso, Michele Maugeri [8] conducted some shaking table tests performed on a small prototype of Gravity Retaining Wall retaining dry sand was described. Shaking table studies carried out in order to study the dynamic behavior of gravity retaining walls resting on rigid foundation soil. Two different system had taken into consideration namely a wall retaining a horizontal backfill on which uniform surcharge were placed and a wall on which the uniform surcharge was placed to a distance to the head of the wall.

Kenji Watanabe, Yulman Munaf, Junichi Koseki, Masaru Tateyama, Kenichi Kojima [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 models 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.

Dr. P. P. Tapkire [11] 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 Swapnal V. [12] 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.

3. Problem formulation

In a gravity retaining wall the force of the retained soil is held back by the self-weight of the wall, with some assistance from shearing resistance and bond. Analysis of structure with soil structure interaction effect is done by Finite Element Method (FEM).

A gravity retaining wall with a vertical face retaining horizontal backfill is considered in this research work. Backfill soil having a density of 18kN/m^3 is considered along with M25 grade of concrete for gravity retaining wall for analysis. The cross-section of GRW under consideration is shown in Fig No. 1. Variation of dimensions with respect to their heights are analysed. In this research work, the response for modeling of GRW soil is formulated by discretizing the system into two substructures which are GRW section without and with SSI. Here ANSYS 18.0 is used for the analysis of the gravity retaining wall section.

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 of retaining wall are given in Table 1. Shape of retaining wall with geometry variables is shown in Fig. no. 1. Material properties of retaining wall [12], soil is mentioned in Table 2.

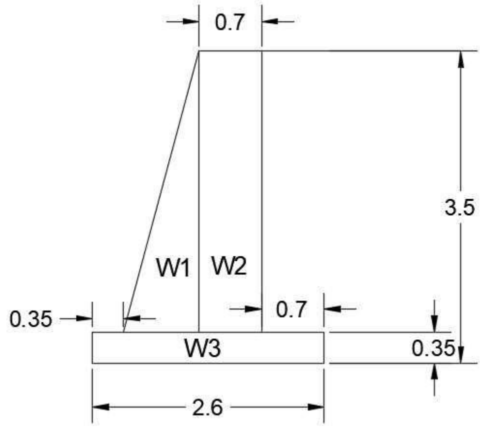


Fig. No. 1: Geometry variables of GRW

Table 1: Geometry parameters of GRW

GRW	Top Width	0.7m
	Bottom Width	1.55m
	Stem Height	3.15m
Foundation	Slab Depth	0.35m
	Slab Width	2.6m

Table 2: The material properties of GRW and Soil

GRW	Density	25 kN/m^3
	Modulus of elasticity	31027 MPa
	Poisson's ratio	0.2
soil	Density	18 kN/m^3
	Modulus of elasticity	2.62Mpa
	Poisson's ratio	0.4

4. Research Methodology

Considered GRW c/s is obtained by trial-error process using stability condition for profile and heights. For that excel spread sheets are prepared and cross-section of GRW is finalized. Finalized cross-section of Gravity Retaining Wall are analysed using Finite Element package considered for profile and different height using SSI.

4.1 Validation of problem solution by software

In this problem of GRW with and without soil structure interaction system is analyzed using simplified analysis of fundamental response is validated with ANSYS results.

The stresses obtained by SOM approach calculation at different load of GRW are compared with results obtained by Anasys18.0

After comparing the results, it is observed that SOM approach and Ansys 18.0 results are practically similar.

Hence, the formulation which is adopted for the farther study to solve GRW-soil interaction and effect for calculating deformation, maximum stress and minimum stresses.

5. Results

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.

5.1 Variation of Weight and Height Ratio

As mentioned, worksheets are developed for design of gravity retaining wall using stability criteria. It is observed that stability against sliding is governing stability criteria for design of gravity retaining wall.

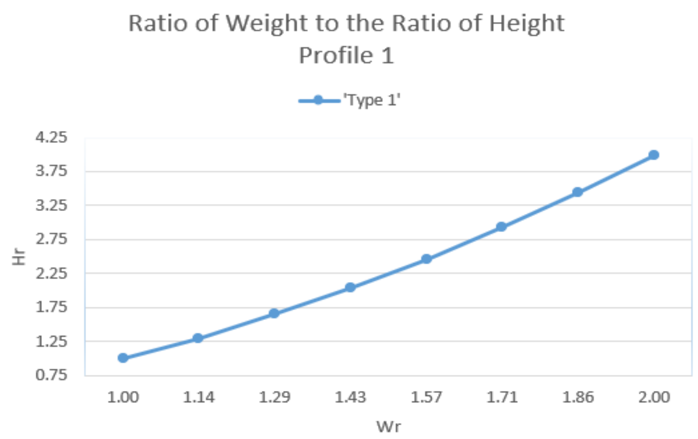
Variation of weight of gravity retaining wall as per various Heights can be observed from the graph number one and two different terms are defined for the generalizing the results are as follows.

Gravity Training wall with 3.5 m height is considered as a reference case and the term are defined with reference of case considered. Various ratios are considered to explain the results. The height ratio Hr is defined as the ratio of height of gravity retaining wall to the ratio of height of gravity retaining wall considered as a reference case.

Weight ratio Wr is defined as weight of gravity retaining wall to the weight of gravity retaining wall of reference case

Table 3: Height and Weight Ratio of GRW

Height Ratio	1	1.14	1.29	1.43	1.57	1.71	1.86	2
Mass Ratio	1	1.3	1.66	2.03	2.47	2.93	3.44	3.99



Graph G1: Height and Weight Ratio of GRW

Plot G1 shows that, height ratio and wight ratio increases simultaneously. They are directly proportional to each other.

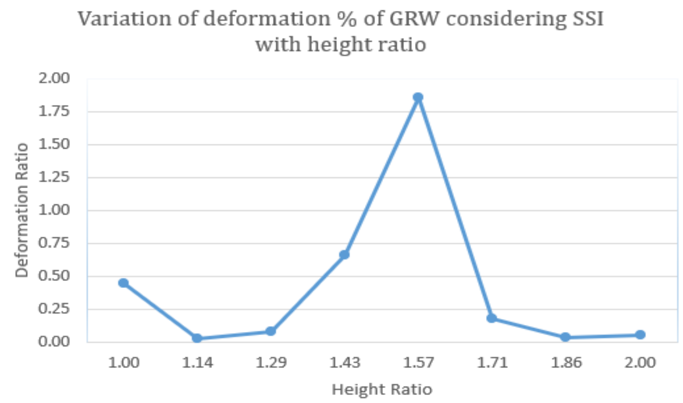
5.2 Variation of Deformation of GRW

The variation of the Deformation of gravity retaining wall with and without soil structure interaction are plotted against height ratio referring to table no. 5.2

The deformations are obtained by considering only retaining wall, retaining wall with soil as a whole mass (soil and retaining wall as whole structure), only retaining wall with soil mass (considering soil structure interaction)

Table 4: Height Ratio & Deformation values of GRW with and without SSI

Height Ratio	1	1.14	1.29	1.43	1.57	1.71	1.86	2
Deformation %	0.44	0.03	0.08	0.65	1.86	0.18	0.03	0.05



Graph G2: Height and Deformation Ratio of GRW

The deformation ratio is defined for the comparing results of various Heights and profile which are plotted in the graph.

1. For plot G2 shows that, variations in deformation compare to standard case without soil structure interaction.

2. In this case, if soil-structure interaction considered, variation of deformation is observed for lower heights, the variation of gravity retaining wall with SSI are very close to without SSI.

5.3 Variation of Maximum Stresses in GRW

The variation of maximum stresses in gravity retaining wall with and without soil structure interaction are plotted against height ratio referring to table 5.

The maximum stresses 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)

The maximum stress ratio is defined for the comparing results of various Heights of profile which are plotted in the graph.
From graph G3 shows that, variations in maximum stresses compared to standard case of without soil structure interaction.

Table 5: Height Ratio & Deformation values of GRW with and without SSI

Height Ratio	1	1.14	1.29	1.43	1.57	1.71	1.86	2
Maximum Stresses %	0.48	0.45	0.43	0.42	0.42	0.46	0.44	0.41

Graph G3: Height and Maximum Stresses Ratio of GRW

In this case soil structure interaction is considered the difference between results of stresses in which soil structure interaction and without soil structure interaction of gravity retaining wall are varying tremendously. The stresses developed in gravity retaining wall with soil structure interaction are very less as compared to without soil structure interaction. Stress ratio of with soil structure interaction ranges between 0.40 to 0.476

5.4 Variation of Minimum Stresses in GRW

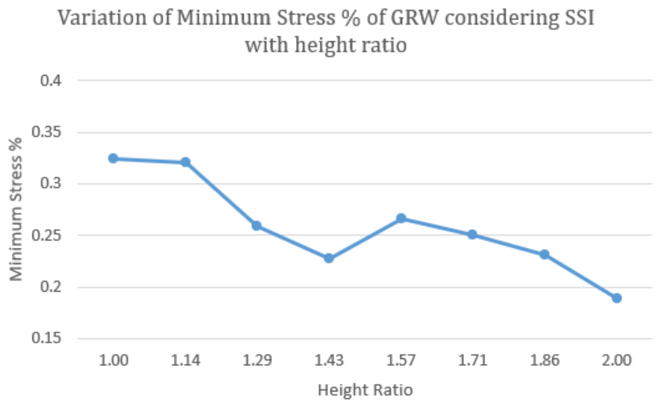
The variation of minimum stresses in gravity retaining wall with and without soil structure interaction are plotted against height ratio referring to table no. 6.

The minimum stresses 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)

The minimum stress ratio is defined for the comparing results of various Heights of profile which are plotted in the graph. From graph G4 shows that, variations in minimum stresses compared to standard case of without soil structure interaction.

Table 6: Height Ratio & Minimum Stresses values of GRW with and without SSI

Height Ratio	1	1.14	1.29	1.43	1.57	1.71	1.86	2
Minimum Stresses %	0.32	0.32	0.26	0.23	0.27	0.25	0.23	0.19



Graph G4: Height and Maximum Stresses Ratio of GRW

In this case variations of percentages of minimum stresses ratio Are not much significant. The line of the graph of this case decreases very silently as the ratio of height increases.

6. CONCLUSIONS

From the result discuss in previous section conclusion for drone as follows,

As height ratio increases, deformation varies for1.3 height ratio and below height ratio the variation is negligible.

But, for height ratio more than 1.3 to 1.57 percentage deformation with respect to standard case is observed to be increase up to 2 %. After 1.57 ratio the deformation percentage are decreased and remain practically constant for height ratio 1.6

The percentage of stresses with reference to considered case varies along with height ratio. The stresses are decreasing from 0.48% to 0.42% up to height ratio 1.43. Slightly increased in the variation she is observed for height ratio in between 1.32 to 1.71. For higher height ratio that is above 1.71 the stresses are decreases

So, from the above conclusion, if GRW with SSI is considered only 2% stresses are induced in the cross section.

If proper care is taken against sliding factor of safety section reduction is possible with consideration of SSI

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