"DYNAMIC ANALYSIS OF GRAVITY RETAINING WALL WITH SOIL STRUCTURE INTERACTION"

Dr. Pradeep P. Tapkire[1], Somnath M. Patil[2], Atul S. Chandanshive[3]

[1]H.O.D. Civil Dept., N.B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India-413255
[2]Research Scholar at N.B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India-413255
[3]Lecturer at Solapur Education Society's Polytechnic, Solapur, Maharashtra, India -413002

Abstract - ***Gravity retaining walls play a crucial role in civil engineering by providing essential support to control soil erosion and maintain the stability of slopes and embankments. The interaction between these retaining walls and the surrounding soil is a complex phenomenon that becomes even more intricate when subjected to dynamic loads, such as seismic events or sudden impact loads. This study presents a comprehensive investigation into the dynamic behavior of gravity retaining walls, considering the intricate interplay between the wall and the surrounding soil.***

The analysis involves a detailed examination of soil-structure interaction (SSI) effects on the dynamic response of gravity retaining walls. A numerical framework based on finite element methods is developed to simulate the coupled behavior of the retaining wall and the underlying soil. The soil is modeled using appropriate constitutive models in software ANSYS 18.0 that capture its nonlinear and dynamic characteristics, while the retaining wall is represented as a rigid or flexible structure, depending on the specific scenario.

Key Words: Gravity Retaining Wall[1], Soil Structure Interaction[2], Dynamic Loading[3]

1. INTRODUCTION

A wall designed to maintain the difference in elevations of the ground surfaces on each side of the wall is called a retaining wall. The material that is retained on one side of wall is commonly called as back-fill and the wall is constructed to retain this backfill. Retaining walls are extensively used in connection with railways, highways, bridges, canals and many other engineering works whenever material is to be retained on one side of the wall.

Gravity retaining wall, semi gravity retaining wall, cantilever retaining wall or T – wall and counterfort retaining wall etc. are common types of retaining walls. Besides these, few more types of retaining walls are also used like buttress retaining wall, braced wall, etc. Due to ease of the construction gravity retaining wall (GRW) is commonly used.

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. Failure due to sliding
2. Failure due to overturning
3. Failure due to excessive settlement
4. Failure due to excessive scour of the earth under the base

First three types of failure are most common and hence while designing a GRW, the trail geometry of the cross-section is checked against first three stability criteria viz. sliding, overturning and bearing capacity given in the list. The cross-section of GRW is also checked for strength of material provided.

Amongst the three criteria, stability criteria against sliding is critical, as the area required to satisfy the criteria is more. This governing factor generally leads to a cross-section which is under stressed.

A number of retaining wall failures have been reported during the post-earthquake reconnaissance. The structural response of retaining wall is a complex topic due to the soil structure interaction and uncertainties in the determination of actual earthquake data and soil properties. The frequent earthquake events, followed by the failure have increased the demand on the seismic design of retaining walls. The classic earth pressure theory of Coulomb (1776) and Rankine (1857) is widely used to determine the lateral earth pressure on the retaining wall.

1.1 Aim of Study

To find out the feasible and economical cross section area of Gravity retaining wall for Dynamic loading considering soil structure interaction.

2. Literature Review

Retaining walls are not a new concept. Walls used to retain masses of soil have been around for thousands of years and were used in virtually every civilization in history. Geotechnical engineering is a branch of civil engineering that deals with soils as engineering materials; 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 (Terzaghi et al, 1996).

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 obtained according to Richard and Elms (1979) analytical model, Some of these research contributions of researchers are presented as follows,

S. Al-Homoud Jordan And lrbid, Jordan [1] studied The behavior of earth retaining structures during earthquakes is considered an important design problem in seismic regions, One such structure is the gravity retaining wall, which uses its mass for stability against failure. Field observations indicate that, where there has been significant movements of gravity retaining walls during earthquakes, rotational displacement (or tilting) of these walls has been important.

Vijay K. Puri[2]observed that design of retaining walls in seismic areas poses a complex problem, For safe design of retaining walls in seismic areas, the calculation of static and dynamic earth pressure behind the retaining walls is the first requirement. Realistic calculation of displacement of the retaining wall is an equally important aspect. The paper presents a simple method for calculation of static and dynamic active force on the rigid retaining wall. The method follows the pseudo-static approach of analysis and includes the effects of cohesion of the backfill and the friction between the backfill and the wall face.

Aram M. Raheem and Mohammed Y. Fattah[3] used a numerical method through finite element(FEM) with two models: Elastic &Equivalent Linear was used to investigate the seismic behavior of retaining wall supporting saturated, liquefiable, cohesionless backfill soil. It was shown that the Equivalent model gives more reasonable results and the liquefaction zones concentrated in the passive side more than the active side. Max. horizontal displacement at the top of the wall reaches 0.67m while vertical displacement increased in the range (66-116)% with the wall increasing in dimensions. Both pore water pressure/horizontal total stress increased with time/dimensions in the range (37%),(200%) respectively.

Md. Abu Taiyab ; Md. Jahangir Alam ; and Md. Zoynul Abedin[4]observed that the lateral spreading of backfill soil caused by displacement of gravity-type quay walls is a major concern for geotechnical engineers. This paper evaluates the efficiency of a technique for mitigation of damage to quay walls, which involves densification of loose sand around the toe. The beneficial and unfavorable effects of densification of sand of different locations of the gravity-type quay walls are also answered. For these purposes, numerical simulations (using a finite-element code) and shake table tests were conducted. From numerical simulations and model tests, it was observed that the displacement of a gravity-type quay wall occurred mainly because of shear strain in the foundation.

KAVEH AND M. KHAYATAZAD[5] In the previous studies, the optimization of the retaining walls has been accomplished by quasi-static methods; however, in this paper a pseudo dynamic approach is utilized. Here, by optimizing a cantilever retaining wall via a recently developed method, so-called Ray Optimization, the design controlling parameters are investigated. Ray Optimization method is a multi-agent optimization method which is inspired from the concept of light refraction. In this method by moving the agents to new positions, the optimal solution is found.

Abhay Tripathi And Tarik Salman[6] This paper presents a comparison of the various methods of analysis of retaining wallsunder seismic loads, which is considered to be very complex. As the soil-structure interaction during the earthquake is very complex, the most commonly used methods for the seismic design of retaining walls are the Pseudo static method, Seed and Whitman method and Mononobe and Okabe method.

Kamal Mohamed Hafez Ismail Ibrahim[7] In this study plain strain numerical analysis is performed using Plaxis dynamic program where prescribed displacement is applied at the bottom boundary of the soil to simulate the applied seismic load. It is also found that seismic wall displacement is directly proportional with the positive angle of inclination of the back surface of the wall, soil flexibility and with the earthquake maximum ground acceleration. Seismic wall sliding is dominant and rotation is negligible for rigid walls when the ratio between the wall height and the foundation width is less than 1.4, while for greater ratios the wall becomes more flexible and rotation (rocking) increases till the ratio reaches 1.8 where overturning is susceptible to take place.

Ms. Patil Swapnal[8] In the proposed study, the effect on gravity dam has been examined using finite element analysis software ANSYS 14. The gravity dam is completely resting on soil media and surrounded by soil media. The relevant amount of soil around and bottom of the gravity dam has been modeled to simulate the in-situ conditions. The gravity dam has been analyzed using dynamic loading in transient analysis using Imperial Valley (1940) earthquake record are included. Analysis of the gravity dam has been carried out and the influence of soil

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properties has been studied at the region of transverse sections, which exhibited the response in terms of stress and deformation with significant difference.

3. Problem formulation

The researchers have been analyzing various structures using soil structure interaction the various researcher have focused on soil structure interaction along with retaining wall. But the soil structure interaction along with Gravity Retaining Wall is untouched / rarely touched. Considering this as gap in researcher the problem is formulate to study Gravity Retaining Wall using Soil Structure Interaction.

In this research, a gravity retaining wall with a vertical face retaining horizontal backfill is taken into account. For analysis, backfill soil with a density of 18 KN/m3 and M25 grade concrete are both taken into account. Fig. No. 1 depicts the cross-section of the GRW under study. Analysis is done on the variation in dimensions relative to their heights. In this study, the system is discretized into two substructures, the GRW section without and with SSI, in order to establish the response for modeling GRW soil. The gravity retaining wall portion in this instance is analyzed using ANSYS 18.0.

3.1 Profile and Material considerations for the GRW

In the properties of Gravity retaining wall, two considered profile of retaining wall and material properties are mentioned. The both profiles of retaining wall are shown in Fig No.1&2 Material properties of retaining wall [12], soil is mentioned in Table 2.

1)Profile I-

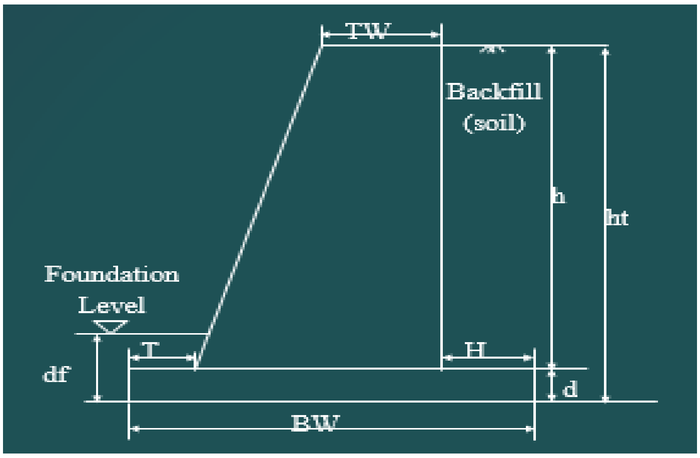


Fig.1- Gravity retaining wall With toe side slope

2)Profile II-

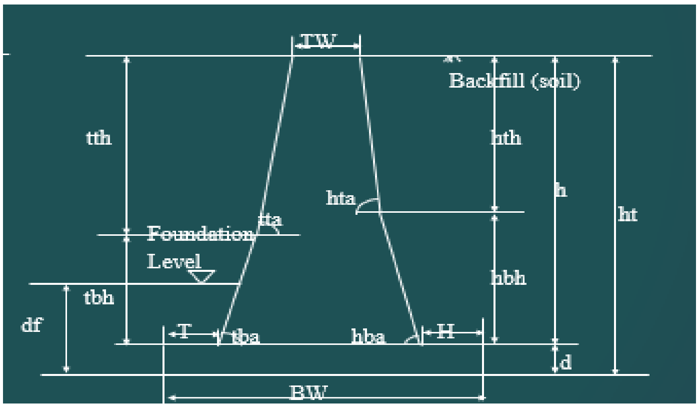


Fig.2- Gravity retaining wall With Both side Two different slope

Table 1: Geometry parameters of GRW

GRW	Top Width	0.70m
	BottomWidth	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

As per researcher methodology various parameters are considered for analysis of GRW with & without SSI. As mentioned in fig. no. 4.4. Two different profiles with 8 different heights are considered for Dynamic Analysis with & without SSI.

Deformation & Stresses are obtained from the analysis from each case considered

The obtained results are tabulated as per given in Appendix B. Variation of parameters are plotted and discussed in next chapter.

4.1 Validation of problem solution by software

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

Deformation is obtained by SOM approach calculation at different load of GRW are compared with results obtained by Anasys18.0 Software.

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.

5. Results

The current project work is to study the effect of Dynamic analysis on Gravity retaining wall with SSI as per flow of project mentioned in the previous chapter. Profiles of gravity retaining wall and parameters considered for the Dynamic analysis of gravity retaining wall with SSI as discussed in previous chapter.

Gravity retaining wall with different geometry and heights are designed governed by stability criteria dimensions of gravity retaining wall for various Heights are calculated using worksheet. which are separately developed for design of gravity retaining wall with considering horizontal backfill as a loading case (details given as per appendix A). As per flow of proposed study two earthquake sample cases are considered. The various Heights with different geometry with and without consideration of soil structure interaction along with different earthquake cases are solved using finite element package of ANSYS. Maximum and minimum of the deformation and stresses obtained for each case, the non-dimensional variations are plotted and discussed in the current chapter.

5.1 Parameter Considered for Research Work

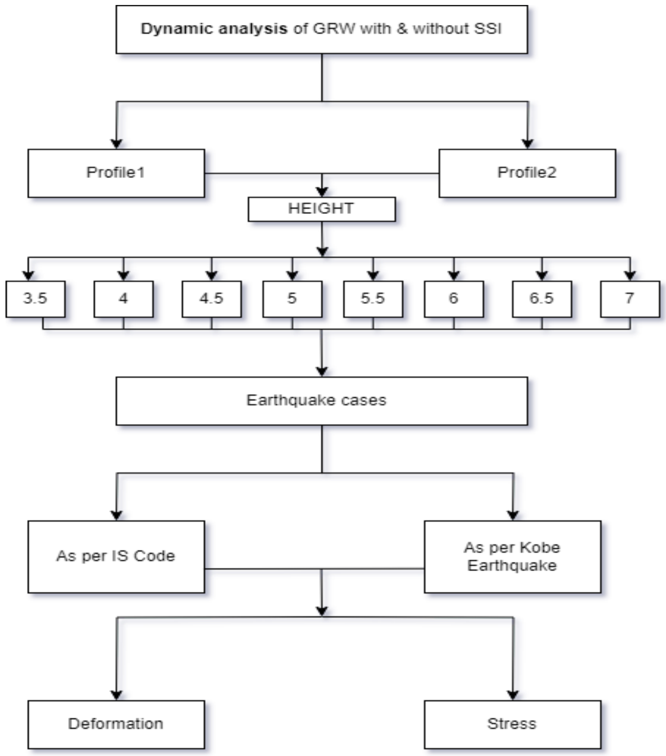


Fig.5.3 Flow Chart of the research

5.2 Variation of Weight and Height Ratio

As previously indicated, stability criteria are used to build spreadsheets for gravity retaining walls. It has been noted that the stability against sliding criterion (appendix A) directs the stability criteria for the design of gravity retaining walls.

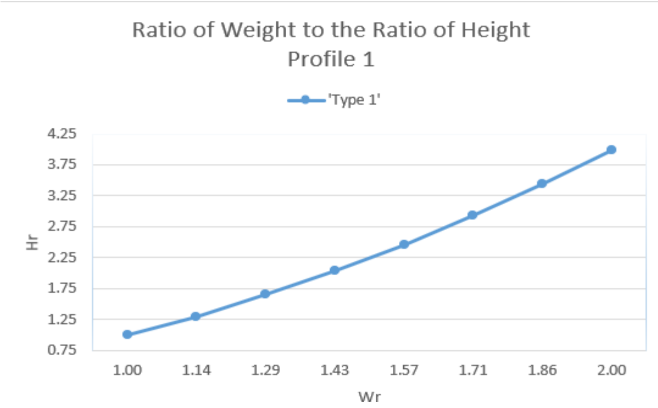
Plot G1 shows how the cross-section area of the GRW varies with varied Heights. Two alternative terms are created for each profile to allow for generalization, and the results are as follows. The phrase is defined with reference to the situation analyzed, which is a gravity training wall with a height of 3.5 meters. The height ratio (Hr) is the comparison of the height of the gravity retaining wall to the height of the gravity retaining wall taken as the reference case.

Ratio of cross-sectional area The definition of Ar is the area in cross-section between a gravity retaining wall and its cross-section in the reference scenario.

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.

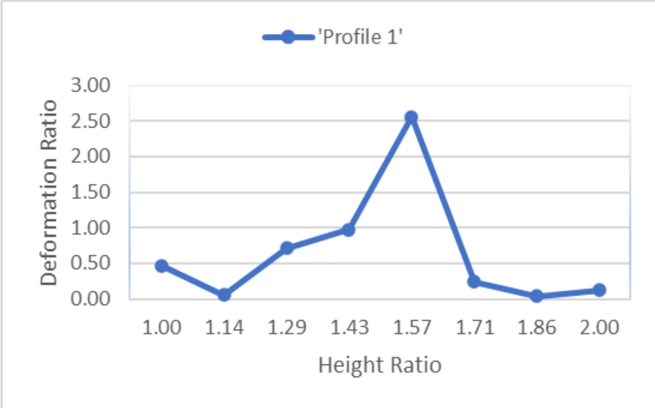
5.3.1 Variation of deformation percentage of GRW as per dynamic loading (Kobe)considering SSI with height ratio for different types

The variation of the Deformation percentage of gravity retaining walls as per dynamic loading (Kobe) with and without soil structure interaction are considered & plotted against Hr (As mentioned above) referring to Table no.4

The Deformations are obtained as per considered dynamic loading case, only retaining wall and retaining wall with soil mass (considering soil structure interaction). Are analyzed using FEM package as per cases mentioned in the fig.5.1. To understand the effect of dynamic loading and SSI deformation percentage is obtained with reference to GRW without SSI and results are tabulated and given in Table no.4

Table No 4 - Variation to Deformation percentage of GRW with SSI considering against Height ratio (Hr) for various profiles dynamic loading (Kobe)

Height Ratio	1	1.14	1.29	1.43	1.57	1.71	1.86	2
Deformation %	0.47	0.05	0.72	0.97	2.56	0.24	0.04	0.12



Graph G2: Variation to Deformation percentage of GRW with SSI considering against Height ratio (Hr) for various profiles dynamic loading (Kobe)

Following observations are noted,

From above plot profile, showing variation of deformation percentage which is substantially reduced as compared to without SSI.

The deformation percentage including all profile is only 2.56 percentage as compared to without SSI (that is 97.44 percentage reduction is observed.)

For Profile I shows variation of deformation percentage increases up to maximum value that is 2.56 percentage. There after deformation percentage increases up to Hr 1.57. Afterwards the variation in Deformation percentage is abruptly decreases.

For Profile I show Maximum deformation percentage at Hr 1.57 .

5.3.2 Variation of deformation percentage of GRW with soil mass as per dynamic loading (Kobe) with height ratio for different types

The variation of the Deformation percentage of gravity retaining walls as per dynamic loading (Kobe) with and without soil structure interaction are considered & plotted against Hr (as mentioned above) referring to Table no.5

The Deformation are obtained as per considered dynamic loading case, only retaining wall and retaining wall with soil as a whole mass (soil+ retaining wall as whole structure). Are analyzed using FEM package as per cases mentioned in the fig.5.1. To understand the effect of dynamic loading and SSI deformation percentage is obtained with reference to GRW without SSI & results are tabulated and given in Table no.5.

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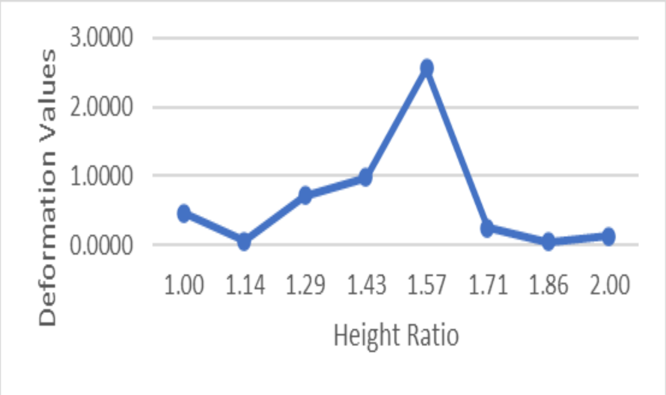
Table No.5 Variation of Deformation percentage of GRW with SSI with whole soil mass considering against Height ratio (Hr)for various profiles dynamic loading (Kobe)

Height Ratio	1	1.14	1.29	1.43	1.57	1.71	1.86	2
Deformation %	0.17	0.36	0.26	0.95	0.75	0.45	0.68	0.13



Graph G3: Variation of Deformation percentage of GRW with SSI with whole soil mass considering against Height ratio (Hr)for various profiles dynamic loading (Kobe)

Following observations are noted,

From above plot profile, showing variation of Deformation percentage which is substantially reduced as compared to without SSI.

The Deformation percentage including all profile is only 2.55 percentage as compared to without SSI (that is 97.45 percentage reduction is observed.)

1. For Profile I show variation of Deformation percentage increases up to maximum value that is 2.55 percentage. There after Deformation percentage increases up to Hr 1.57. Afterwards the variation in Deformation percentage is abruptly decreases.

2. For Profile I show Maximum Deformation percentage at Hr 1.57 .

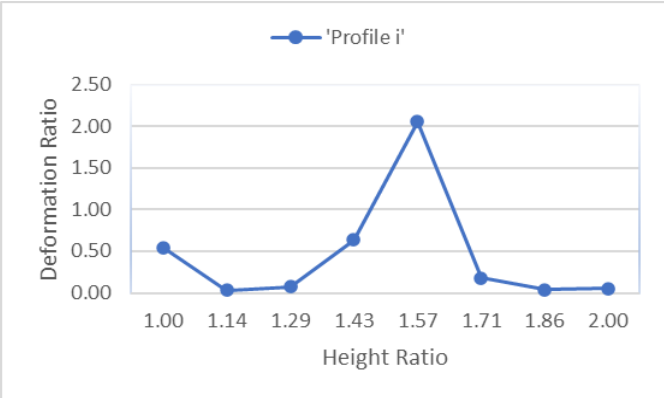
5.3.3 Variation of deformation percentage of GRW as per dynamic loading (IS Code) considering SSI with height ratio for different types

The variation of the Deformation percentage of gravity retaining wall as per dynamic loading (IS Code) with and without soil structure interaction are considered & plotted against Hr referring to table no. 6

The Deformation are obtained as per considered dynamic loading case, only retaining wall and retaining wall with soil mass (considering soil structure interaction). Are analyzed using FEM package as per cases mentioned in the fig.5.1. To understand the effect of dynamic loading and SSI deformation percentage is obtained with reference to GRW without SSI & results are tabulated and given in Table No6.

Table No-6 Variation to Deformation percentage of GRW with SSI considering against Height ratio (Hr) for various profiles dynamic loading (IS Code)

Height Ratio	1	1.14	1.29	1.43	1.57	1.71	1.86	2
Deformation %	0.28	0.17	0.18	0.11	0.18	0.07	0.08	0.04



Graph G4: Variation to Deformation percentage of GRW with SSI considering against Height ratio (Hr) for various profiles dynamic loading (IS Code)

Following observations are noted,

From above plot profile, showing variation of Deformation percentage which are substantially reduced as compared to without SSI.

The Deformation percentage including all profile is only 2.06 percentage as compared to without SSI (that is 97.94 percentage reduction is observed.)

1. For Profile I show variation of Deformation percentage increases up to maximum value that is 2.06 percentage. There after Deformation percentage increases up to Hr 1.57. Afterwards the variation in Deformation percentage is suddenly decreases.

2. For Profile I show Maximum Deformation percentage at Hr 1.57.

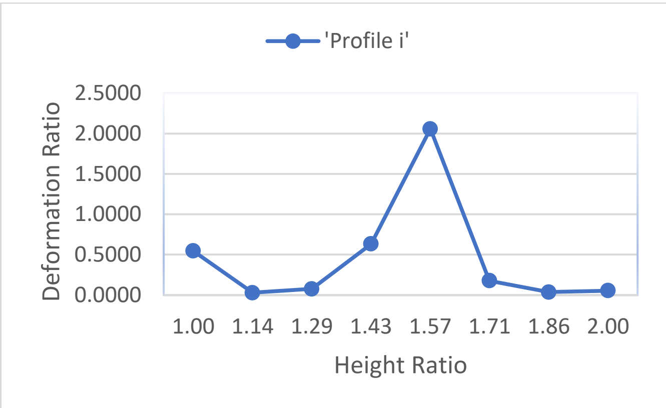
5.3.4 Variation of deformation percentage of GRW with Soil mass as per dynamic loading (IS Code) considering SSI with height ratio for different types

The variation of the Deformation percentage of gravity retaining wall as per dynamic loading (IS Code) with and without soil structure interaction are considered & plotted against Hr (As mentioned above) referring to table no. 7

The Deformation are obtained as per considered dynamic loading case, only retaining wall and retaining wall with soil as a whole mass (soil+ retaining wall as whole structure). Are analyzed using FEM package as per cases mentioned in the fig.5.1. To understand the effect of dynamic loading and SSI Deformation percentage is obtained with reference to GRW without SSI & results are tabulated and given in Table No.7.

Table No.7 Variation of Deformation percentage of GRW with SSI with whole soil mass considering against Height ratio (Hr) for various profiles dynamic loading (IS Code)

Height Ratio	1	1.14	1.29	1.43	1.57	1.71	1.86	2
Deformation %	0.54	0.03	0.08	0.63	2.06	0.18	0.04	0.06



Graph G5: Variation of Deformation percentage of GRW with SSI with whole soil mass considering against Height ratio (Hr) for various profiles dynamic loading (IS Code)

Following observations are noted,

From above plot profile, showing variation of Deformation percentage which is substantially reduced as compared to without SSI.

The Deformation percentage including all profile is only 2.05 percentage as compared to without SSI (that is 97.95 percentage reduction is observed.)

1. For Profile I show variation of Deformation percentage increases up to maximum value that is 2.05 percentage. There after Deformation percentage increases up to Hr 1.57. Afterwards the variation in Deformation percentage is suddenly decreases.

2. For Profile I show Maximum Deformation percentage at Hr 1.57.

6. CONCLUSIONS

6.1 Variation of cross-section area of GRW with Heights

1) From the variation of height ratio against area ratio it is concluded that the area of cross-section of GRW increases with increase in height up to 4 times for HR=2

2) Profile I shows higher cross-section area for HR >1.57

6.2 Variation of Deformation Percentage of GRW with Height ratio

1) From the tabulated result and plots it is concluded that due to consideration of SSI the deformation of GRW for horizontal backfill is significantly reduces.

2) the deformation percentage varies with height ratio for profile I higher than other profile

3) Profile I show 2 % of deformation as compared to without SSI for lower height ratio, for higher height ratio it is reaches to undeformed condition as compared to without SSI

6) Considering profile I maximum 1.85 %, deformation % of with SSI is observed

7) the above conclusion indicates that the soil mass active along with GRW significantly affect the deformation. All together maximum 1.85% deformation is observed for considered profile including all heights.

REFERENCES

[1] AZM S. AL-HOMOUD (1994) "INSTABILITY AND STABILIZATION OF AN EMBANKMENT ON THE IRBID-AMMAN HIGHWAY IN JORDAN " Civil Etzgineerit~g Department, Jordan University of Science and Technology, P.O. Box 3030, Irbid, Jordan.

[2] Vijay K. Puri. (2011) " DYNAMIC EARTH PRESSURE AGAINST RETAINING WALLS.", Professor, Civil and Environmental Engineering, SIU Carbondale, IL, USA , puri@engr.siu.edu Proceedings of Indian Geotechnical Conference December 15-17,2011, Kochi (Invited Talk - 5.).

[3] Aram M. Raheem and Mohammed Y. Fattah (2008) "ANALYSIS OF RETAINING WALL SUBJECTED TO EARTHQUAKE LOADING." Journal of Kirkuk University – Scientific Studies, vol.3, No.1, 2008.

[4] Md. Abu Taiyab ; Md. Jahangir Alam ; and Md. Zoynul Abedin (2010) "SEISMIC ROTATIONAL STABILITY OF WATERFRONT RETAINING WALL USING PSEUDODYNAMIC METHOD", International Journal of Geomechanics 10(1)DOI:10.1061/(ASCE)1532-3641(2010)10:1(45)

[5] A. KAVEH AND M. KHAYATAZAD (2014) "OPTIMAL DESIGN OF CANTILEVER RETAINING WALLS USING RAY OPTIMIZATION METHOD." IJST, Transactions of Civil Engineering, Vol. 38, No. C1+, pp 261-274.

[6] Abhay Tripathi and Tarik Salman (2014) "REVIEW OF ANALYSIS OF RETAINING WALL UNDER STATIC AND SEISMIC LOADING." IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 07, 2014 | ISSN (online): 2321-0613.

[7] Kamal Mohamed Hafez Ismail Ibrahim (2011) "SEISMIC DISPLACEMENT OF GRAVITY RETAINING WALLS." HBRC Journal.

[8] Ms. Patil Swapnal V. (2015), "EFFECT OF SOIL STRUCTURE INTERACTION ON GRAVITY DAM", Assistant Professor, Dept. of Civil Engg., JSPM's Imperial College of Engineering & Research, Pune.