Seismic Stability of Retaining Wall With and Without Geogrid Inclusions in the Back Fill

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Abstract. Retaining Structures are not inherently stable against seismic loads unless they designed to withstand strong earthquakes. Earthquake have unfavorable effects on lateral soil pressures acting on retaining wall. Behavior of retaining structures are also depends on properties of backfill and sub grade soil. During earthquake the reinforced soil-wall system may either move together with the ground or move relatively respect to the ground. These two conditions are referred to as absolute motion and relative motion, respectively. This paper presents an analytical method of non-linear dynamic behavior retaining wall using Finite element method, when subjected to seismic loads. The primary objective of the study is to develop a model to determine the response of retaining wall under seismic load. The drucker-prager material approach is used for elasto-plastic soil behavior. Sub-grade soil is modeled as 3-D element by Drucker-Prager Method. In this study dynamic behavior of retaining wall for different backfill soil material with Geogrid at different levels are studied. The Geogrid layer inclusions in backfill is expected to reduce the active earth pressure subsequently enhancing the stability. Finite element model of retaining wall of height 7m and 15m length modeled in ANSYS software and dynamic response spectrum analysis is carried out. The properties of the materials, dynamic seismic loads, site effects, water pressure are prime factors considered to evaluate response. The results with and without geogrid are compared.

Keywords: Earth pressure; Retaining Wall; Geogrid; Dynamic Analysis; ANSYS.

1. Introduction

Retaining walls have been experiencing severe damages due to earthquake. It essential to study the dynamic behavior of retaining wall with resting backfill material. And various reasons have been identified for failure of Retaining walls when subjected to seismic forces, predominantly soil structure interaction between backfill and retaining wall. Usually the analyses don't take into account the retained soil's interaction. This consideration makes the wall-soil system more flexible than the wall alone. Reinforcement of backfill earth material considerably dominates the dynamic behavior of retaining wall. The paper presents a study on the behavior of the retaining wall seismic conditions considering all above aspects.

In this study dynamic 3-D model of retaining wall with backfill material has been modeled by Finite element method. Prominent soil reinforcement material Geogrid is selected and considered at various depths of backfill material. Stress and displacement values for cases are evaluated using finite element analysis and presented for dynamic conditions. The problem has been analyzed using ANSYS.

Aditya Parihar et al. 2010 studied dynamic characteristics of retaining wall by considering separation of wall and concluded displacement response of retaining wall significantly changes with the introduction of interface. When interface movement is allowed the retaining wall move in outward direction which is the realistic situation.

Ashok K. Chugh et al. 2016 concludes Soil-structure interaction can significantly affect the response of soil and the soil-supported or soil-supporting structure to an external load. Continuum based analysis procedures provide rational means to model construction sequence and to allow for relative movements between distinctly different materials or surfaces.

The first known investigation into the behavior of reinforced earth walls under dynamic load was carried out by Richardson and Lee [1975] using a shaking table, providing preliminary data for the development of a semi-empirical design method. Subsequent shaking table studies were conducted by various researchers [Wolfe, et al., 1978; Rea and Wolfe, 1980; Sommers and Wolfe, 1984]. Fairless [1989] tested six one-meter tall reinforced earth wall models under normal gravity on a shaking table. He concluded that seismic shaking and permanent displacement of reinforced walls cause quite dramatic increases of the forces in the reinforcing strip; theorizing that the reinforced wall would not collapse if the reinforcing strip did not break. The outward displacement at failure was about 4% of the wall height. Full scale tests were conducted refining the results of model studies [Richardson, et al., 1975; Reid, 1995]. Recently, a few finite element model studies have been reported [Bachus, et al., 1993; Cai and Bathurst, 1995].

Objectives of the Study

- To study the dynamic behavior of Retaining wall with and without Geogrid reinforced backfill.
- To study the influence and effect of Geogrid layers placed at various depths of backfill.
- To study the stresses developed, strains and Displacement in different types of backfill soils with and without geogrid.

Model Description

In present study Cantilever retaining wall of total height 6.25 is considered. Base width of retaining wall is 3.5m with slab thickness of 0.6m. Models with different backfill soil properties in combination with geogrid at different depths are considered.

In reinforced models 3 layers of geogrids are provided. The model of the reinforced retaining wall is shown in Fig.1.

Model 1: Un reinforced Retaining wall with well graded backfill soil (URWG).
Model 2: Un reinforced Retaining wall with poorly graded backfill soil (URPG).
Model 3: Un reinforced Retaining wall with clay soil backfill (URC).
Model 4: Retaining wall with Geogrid reinforced well graded backfill soil (RWG).
Model 5: Retaining wall with Geogrid reinforced poorly graded backfill soil (RPG).
Model 6: Retaining wall with Geogrid reinforced clay soil backfill (RC).

Properties of the Backfill Material

In the present study, three different types of backfill materials are considered, well graded soil, poorly graded gravel and clay soil. The properties of the soils are given in Table 1, Table 2 and Table 3. The material properties of retaining wall are given in Table 4.

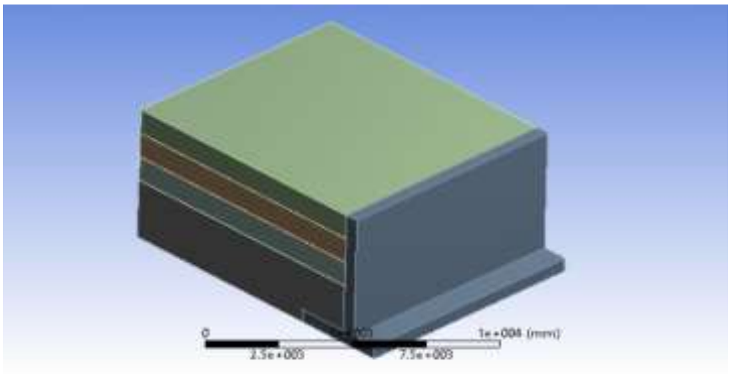

Fig. 1. Retaining Wall With Reinforced Backfill

Table 1. Well Graded Soil Properties

Density (kN/m^3)	20.4
Modulus of Elasticity (N/m^2)	8×10^7
Poisons ratio	0.3
Angle of Internal friction	35^0

Table 2. Poorly Graded Soil Properties

Density (kN/m^3)	19.4
Modulus of Elasticity (N/m^2)	8×10^6
Poisons ratio	0.3
Angle of Internal friction	23^0

Table 3. Clay Soil Properties

Density (kN/m^3)	18.4
Modulus of Elasticity (N/m^2)	7×10^6
Poisons ratio	0.3
Angle of Internal friction	18^0

Table 4. Material Properties of Retaining Wall

Density (kN/m^3)	24
Modulus of Elasticity (N/m^2)	27386
Poisons ratio	0.2

2. Methodology

A typical Geogrid reinforced soil retaining wall is modeled and analyzed for seismic response. 3D elements are considered to model retaining wall with backfill in ANSYS. The soil is characterized employing the Drucker-Prager model. Dynamic behavior of the models is studied for Savannah River earthquake acceleration history and time history data is given in Table 5. Retaining wall is designed as per IS 456-2000.

Table 5. Savannah Earthquake Data

Frequency (Hz)	**Acceleration (m/s^2)**
0.1	0.002
0.11	0.003
0.13	0.003
0.14	0.005
0.17	0.006
0.2	0.006
0.25	0.01
0.33	0.021
0.5	0.032
0.67	0.047
1	0.07
1.11	0.088
1.25	0.105
1.43	0.11
1.67	0.13
2	0.15
2.5	0.2
3.33	0.255
4	0.265
5	0.255
6.67	0.2
10	0.165
11.11	0.153
12.5	0.14

14.29	0.131
16.67	0.121
20	0.111
25	0.1
50	0.1

3. Results and Analysis

Dynamic Analysis results have been studied for all 6 models. Comparative study on the stresses, strains & deformations is done. Stress & deformation of model 1 is presented in fig 2 & fig 3.

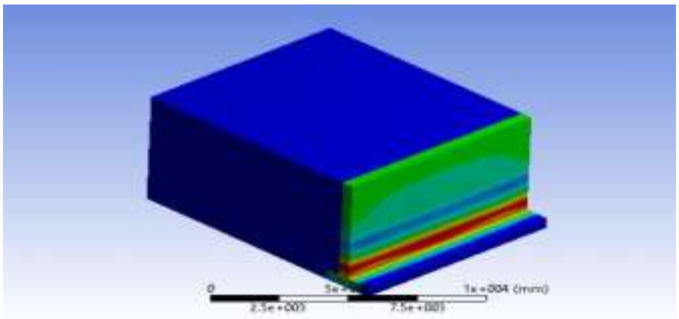

Fig.2. Equivalent Stresses in Model 1

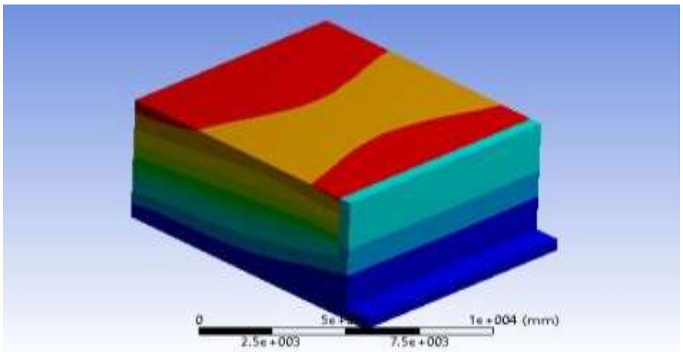

Fig.3. Deformation in Model 1

Stress & deformation of model 2 is presented in fig 4 & fig 5.

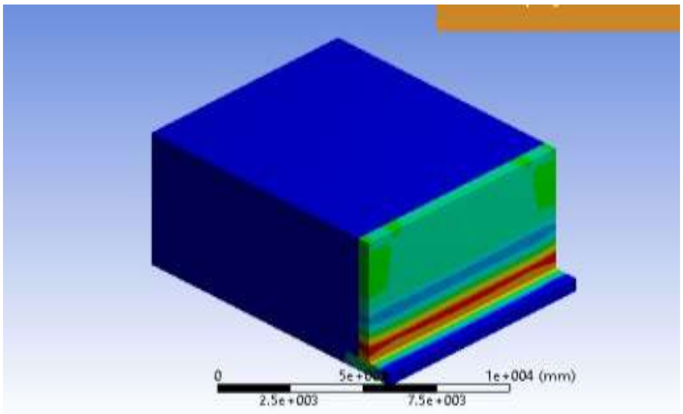

Fig.4. Equivalent Stresses in Model 2

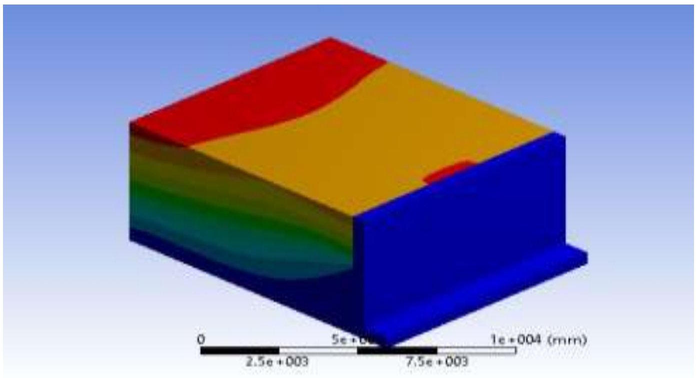

Fig.5. Deformation in Model 2

Stress & deformation of model 3 is presented in fig 6 & fig 7.

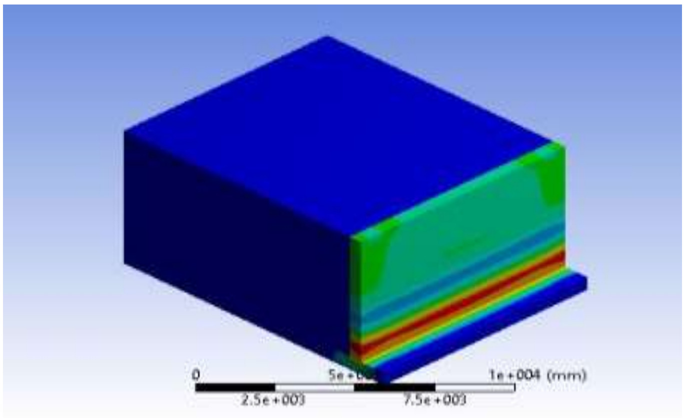

Fig.6. Equivalent Stresses in Model 3

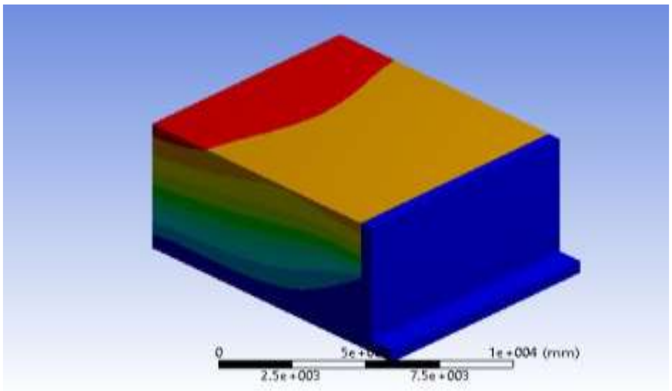

Fig.7. Deformation in Model

Stress & deformation of model 4 is presented in fig 8 & fig 9.

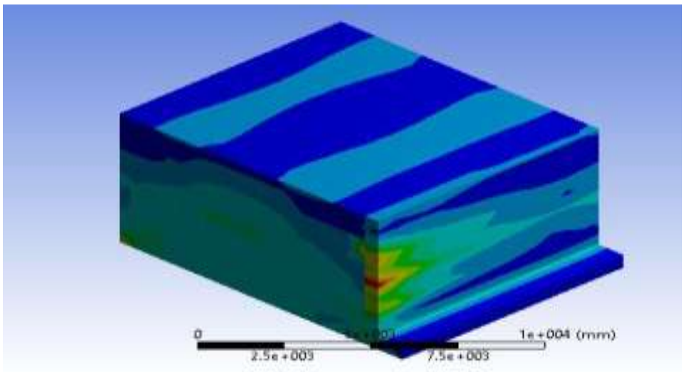

Fig.8. Equivalent Stresses in Model 4

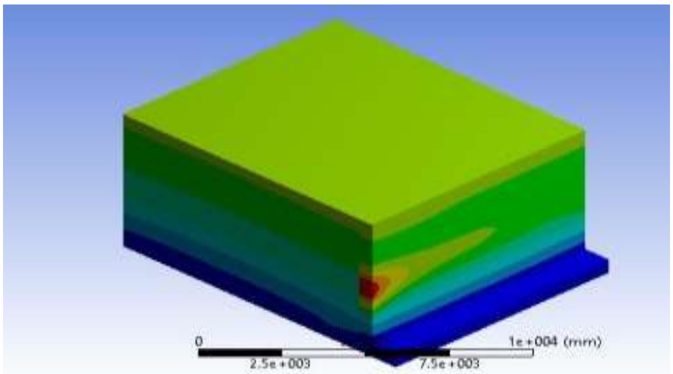

Fig.9. Deformation in Model 4

Stress & deformation of model 5 is presented in fig 10 & fig 11.

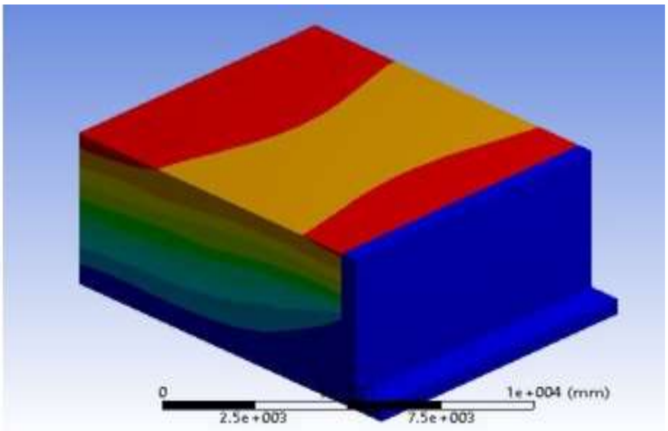

Fig.10. Equivalent Stresses in Model 5

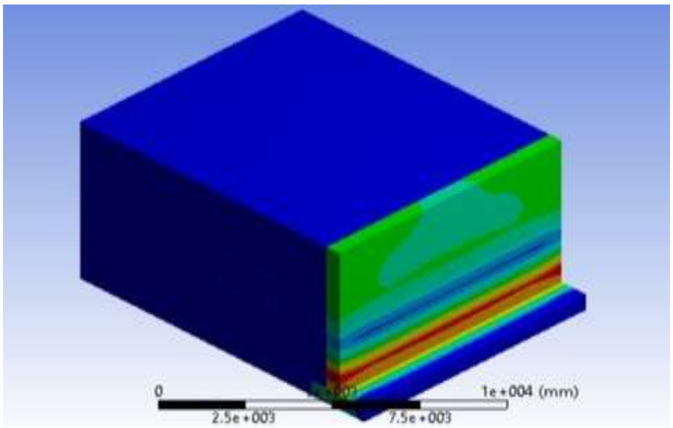

Fig.11. Deformation in Model 5

Stress & deformation of model 6 is presented in fig 12 & fig 13.

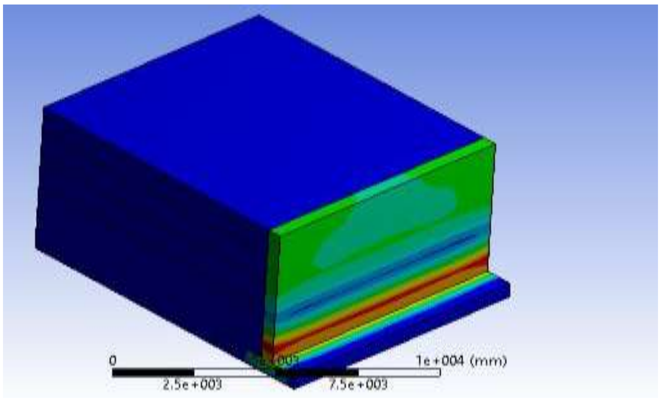

Fig.12 . Equivalent Stresses in Model 6

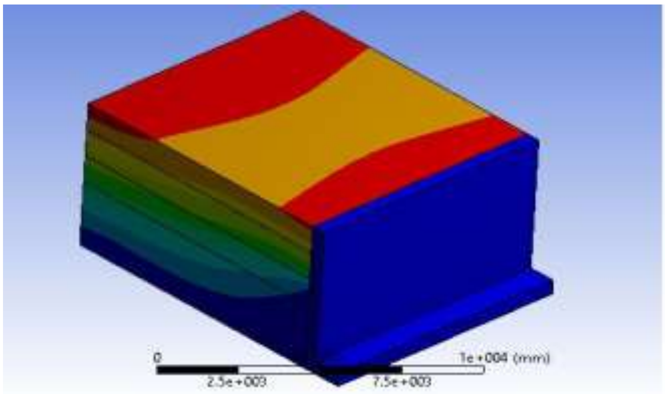

Fig.13. Deformation in Model 6

Table 6. Deformation in Different Backfill Soils

	Deformation in m
Unreinforced well graded Soil Backfill	0.0046169
Unreinforced poorly graded Soil Backfill	0.018204
Unreinforced clay Soil Backfill	0.018888
Reinforced well graded Soil Back-fill	0.0021893
Reinforced poorly graded Soil Backfill	0.012048
Reinforced clay Soil Backfill	0.012334

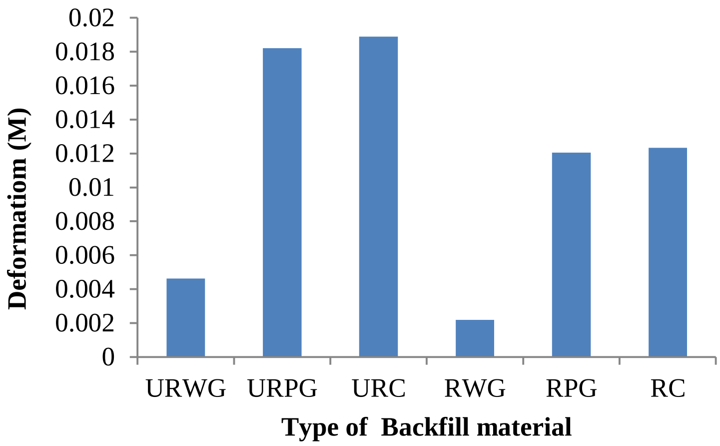

Fig.14. Deformation in Different Backfill Material

Table 7. Equivalent Stress in Different Backfill Material

	Equivalent stress in MPa
Unreinforced well graded Soil Backfill	0.001754
Unreinforced poorly graded Soil Back-fill	0.000973
Unreinforced clay Soil Backfill	0.000879
Reinforced well graded Soil Backfill	0.00209
Reinforced poorly graded Soil Backfill	0.001069
Reinforced clay Soil Backfill	0.000983

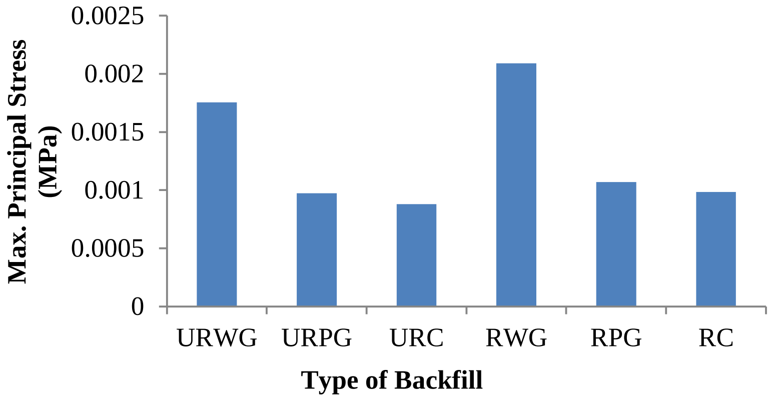

Fig.15. Deformation in Different Backfill Material

3. Conclusions

- The ANSYS was used to analyse the behavior of reinforced soil and unreinforced retaining wall with three different types of backfill material. The displacement of retaining walls were measured and the comparisons were made between unreinforced and reinforced soil retaining wall. The following conclusions could be derived based on this research.
- Displacement of the retaining wall decreases with the increase in friction angle of backfill soil.
- The deformation is observed to be very high in the case of unreinforced poorly graded soil and clay soil backfill. The inclusion of reinforcement shown significant decrease in deformation of poorly graded soil as well as clay soil. The reduction was observed to be 33.8% in the case of reinforced poorly graded soil when compared with unreinforced poorly graded soil and the reduction was observed to be 34.7% in the case of reinforced clay soil when compared with unreinforced clay soil.

- The reinforced soil retaining wall performs well in reducing the earth pressure and lateral displacement of the retaining wall and decreasing the potential of failure under static and dynamic loading.

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