RESEARCH ARTICLE

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Dynamic Analysis of Cantilever Retaining Wall

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Abstract

Retaining walls are relatively stiff walls used for supporting soil laterally. Study of seismic behavior of retaining wall is important for safe design and to know the behaviour of how the response of soil influences the motion of the structure. This paper presents static and dynamic analysis of cantilever retaining wall by 3D finite element analysis using ANSYS software. Aim of this study is to investigate seismic behaviour of wall. For that purpose, soil modeling is done by direct method of analysis carried out by bonding of wall and soil together. Study contains three-parts, modal analysis is carried out after static analysis, mode shapes and natural frequencies of the wall is calculated and then nonlinear time history analysis is done by using three different earthquake ground motions. The influences of parameter are discussed such as dynamic characteristics of wall and soil, shear stresses, equivalent stresses. From this analysis it is observed that maximum displacement occurs at top of the wall and wall does not fail under given loading condition. The significant effect on seismic behaviour of retaining wall has been found in the soil. Also, the Equivalent (Von Mises) stress distribution for retaining wall supporting clayey soil, the lowest Von Mises stress values are detected near the ground level and increases at bottommost of retaining wall and higher stress detected amongst the base slab and the stem of the retaining wall in the soil cover zone.

Keywords : retaining wall, static and dynamic analysis, ANSYS.

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Introduction

Retaining walls are relatively stiff walls used for supporting soil laterally so that it can be retained at altered levels on the 2 sides. Study of seismic behavior is vital for design of cantilever retaining wall. The objective in seismic design of structure is to make sure the structure has adequate performance when it is subjected to ground motion.

The accessible literature review demonstrates that Mohammad Saeed Ramezani et al. (2016) proposed analytical model for estimating natural frequencies of retaining wall considering effect of backfill soil interaction. Author considered retaining wall with variable and equivalent cross-section with different wall height. The results are acquired from the suggested formulas and are compared with numerical analysis using the ANSYS software and a decent arrangement was noticed. Susumu Nakajima et al. (2020) study the effects of backfill cohesion on the seismic behaviour of retaining wall on the basis of a series of 1 g shaking table model tests. Author has performed a detailed analysis by measuring seismic active earth pressure acting on retaining wall. Backfill consist cohesive (Clay) and cohesionless (Sand) soil in unsaturated condition. The model test results express that a retaining wall having cohesive backfill soil is more constant than a wall without it. Tufan Cakir (2013) study the three dimensional backfill-structure interaction

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using FEM to analyse dynamic behaviour of cantilever retaining wall subjected to different ground motions. Author considered 5 different seismic motions and 6 different soil types and investigated effect of earthquake frequency considering soil interaction and nonlinear time history analysis are done. It is resulted that the dynamic response of the cantilever wall is very sensitive to frequency features of the earthquake record and soil-structural interaction. Prajakta R. Jadhav et al. (2019) study a displacement based design methodology for cantilever retaining wall with shear key to improve its performance under seismic loading. 2-D finite element analysis with various location of shear key accomplished in opensees. Author considered four different earthquakes and varying height of the wall with different Sandy soil types. They concluded that cantilever retaining wall with shear key located at heel has appropriate configuration. Sanket Pramod dongare et al. (2019) study on comparative design of retaining wall and analysis it in ANSYS APDL software. Author was developing an approach which can be used in reduction of cross section area and material cost. The aim of this project is to develop a structurally effective profile of retaining wall vis-a-vis cantilever retaining wall. Swapnil Bhaskar zaware et al. (2021) study the nonlinear analysis of retaining wall including soil structure interaction for T-retaining wall & counterfort retaining wall for silty soil, clay soil and sandy soil using ANSYS. And find out Shear stress, Normal stress, total deformation, Equivalent Stress, Shear Strain, Normal Strain & It is observed that counter fort retaining wall has more capacity than T- shape retaining walls from the results. Majid Beygi et al. (2018) assesses the effect of variation in the rotational stiffness and wall height on the behaviour of a retaining wall using finite-element method. In order to reach the purpose of this study, the software PLAXIS 2D is used. The results of the numerical study are available in the form of displacement, normal & shear stresses as well as the factor of safety taken for the rigid and rotational retaining walls and the case of rotational wall, the plastic points are intense in proximity to the connection point amid the wall stem and the foundation. This concentration fades as the value of rotational stiffness increases. The factor of safety of retaining wall decreases as the value of wall height increases. Shweta Shrestha et al. (2018) static and dynamic behaviours of a retaining wall backfilled with tire aggregate are examined. Analyses were performed using an advanced finite element software called PLAXIS. Geotechnical projects and the computer-based simulations present a significant reduction in the structural demand in relation of maximum shear force and bending moment, construction rate in terms of excavation behind the wall, material essential for constructing a retaining wall, and the volume of backfill material when tyre aggregate is used as the backfill. The consequence of a parametric observe show that the financial benefit is full size regardless of the maximum and the minimum values of the important thing properties and the parameters of enter movement. Hachemi Djadouni et al (2019) studied the performance and balance of a cantilever retaining wall with special sand tire chips aggregate as light weight backfill materials, had been evaluated and analyzed numerically the usage of the finite detail RS2 software program. The elastic parameters of the sand tire chips mixtures have been computed. The outcomes exhibit that the whole & vertical displacement, lateral pressures & displacements, most shear forces & maximum bending moments are decreased drastically. The global stability of the retaining wall is advanced whilst sand tire chips combinations are used as a substitute of sand by myself. He Wang el at (2020) studied the harm of roadbed retaining wall because of mountain torrent primarily based on the central factor method. The overall performance capabilities of the anti-sliding and anti-overturning balance have been derived. Analyse the sensitivity of stability reliability by changing the values of 5 variables: the angle of mountain torrent load, internal friction angle, included angle between the retaining wall and the straight surface, and friction angle, friction coefficient. The anti-sliding reliability, friction coefficient, angle of mountain torrent and internal friction angle take the best results on the retaining wall's strength. The anti-sliding strength improves when the other two variables are increased. For the anti-overturning strength, the index coefficient increases with the increases of straight surface and angle of mountain torrent, and decreases with the increase of internal friction angle until strength.

Considering previous studies, confined studies has been performed at the direct method of evaluation for soil structure interaction. Aim of this study is to investigate seismic behaviour of wall by modal and nonlinear time history analysis. For that purpose, three different earthquake ground motion are considered.

In this paper 1st results of static analysis are validated, Section 1 describes introduction of retaining wall followed by literature review, section 2 describes methodology used for analysis, and section 3 contains results obtained after analysis.

METHODOLOGY

For time history and modal analysis software ANSYS 2020 R2 version is used. Ansys Workbench is a wide ranging purpose Finite Element Analysis (FEA) software that is commonly used in the industry to resolve numerous diverse engineering problems through a computer generated simulation of the Engineering Designs under consideration.

The problem under investigation consists of T-shape cantilever retaining wall, the dimension of wall is calculated by conventional design method. For backfill and subsoil well graded clayey soil is considered. Modal analysis is done using ANSYS 2020 R2 version and ten modes of retaining wall are considered and frequency was given from 0 to 1000 Hz. For dynamic analysis of retaining wall three different types of earthquakes are considered, which are taken from COSMOS Virtual Data center. Earthquake records, station numbers and names are described in table 1.

Table-1: Properties of ground motion

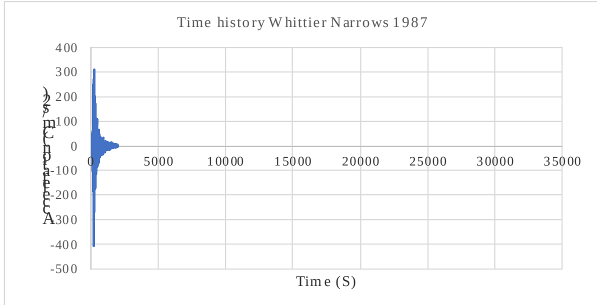
Earthquake records	Station
Loma prieta - 1989	47524: Hollister-south & pine
Northridge - 1994	24278: Castaic old ridge route
Whittier Narrows-1987	24400: Obregon Park

CASE STUDY

The model consists of a T shape cantilever concrete retaining wall supporting horizontal backfill. Density of soil is 18 kN/m^3 for backfill and subsoil length, width and height of strata is 15000 mm, 6000 mm, 14700 mm are considered respectively.

Table-2: Details of Retaining Wall

	Components of retaining wall	Sizes
1	Depth of foundation	1200 mm
2	Base width	4000 mm
3	Width of toe slab	1200 mm
4	Heel width	2350 mm
5	Thickness of base width	500 mm
6	Bottom thickness of stem	450 mm



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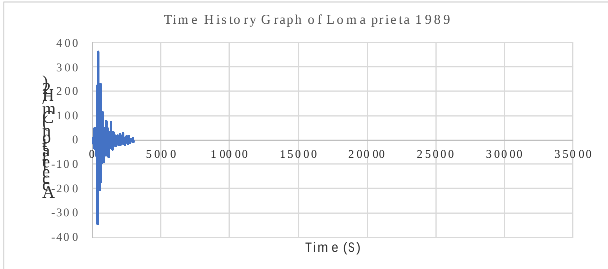

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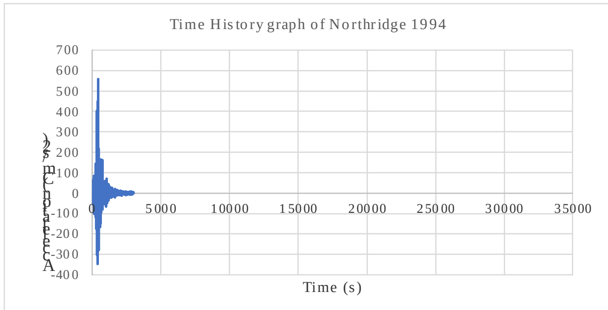

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Figure 1: Acceleration time history for (a) Whittier Narrows 1987 earthquake (b) Loma prieta 1989 earthquake (c) Northridge 1994 earthquake

MODELLING IN ANSYS

Modeling in ANSYS 2020 R2:

For modelling the structure in ANSYS following steps are performed.

Engineering Data < Geometry < Model < setup < solution < Result.

Figure 2 shows, meshing of retaining wall in brown color and soil in grey color. Which is consist of 500 mm in size of linear type of mesh. The soil was modeled by means of SOLID185 elements with linear behavior which obeys all properties of soil that are inputted in engineering data were material properties are assigned. For soil structure interaction direct method of analysis is used in that soil and wall modelled together creating contact between them.

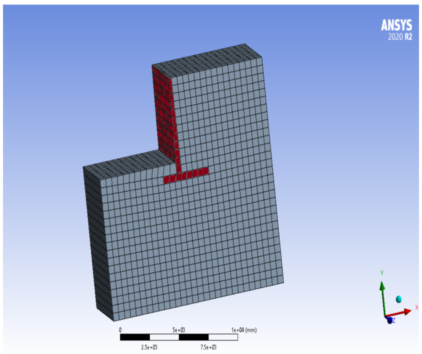


Figure 2: Meshing

Result And Discussion

Result acquired by using the suggested methodology, are offered in terms of the natural frequencies, mode shapes, lateral displacements, shear stress and equivalent stress on seismic behavior of cantilever retaining wall.

Table-3: Natural Frequencies of Wall

Mode	Frequency (Hz)
1	0.82145
2	1.4447
3	1.8325
4	3.0664
5	3.0779
6	3.6583
7	3.7935
8	5.3543
9	5.4381
10	6.1758

Table-3 shows, the results obtained by the FEM simulation for the modal analysis ten mode shapes of the wall are considered. 6.1758 Hz is maximum value of frequency for 10th mode shape and the Minimum Frequency obtained as 0.82145 Hz for 1st mode shape.

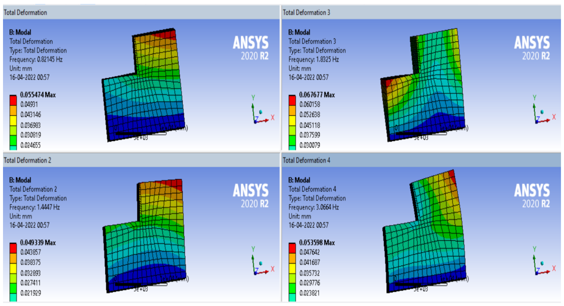


Figure 4: Mode Shapes of The Wall

Figure 4 shows four mode shape of wall, it deflects 0.055 mm, 0.049 mm, 0.067 mm, 0.053 mm respectively of 0.82145 Hz, 1.4447 Hz, 1.8325 Hz, 3.0664 Hz frequency.

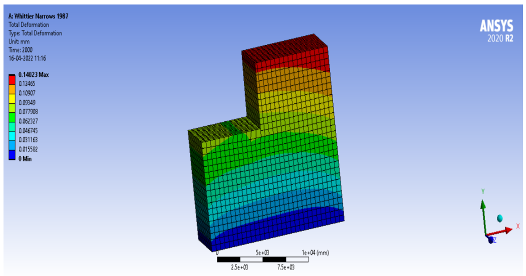


Figure 3: Total Deformation of retaining wall For Whittier Narrows 1987 Earthquake

Figure 3 shows total deformation of retaining wall For Whittier Narrows 1987 Earthquake. Maximum Displacement occurs at top of the wall is 2.5866 mm and minimum displacement occurred at bottom of subsoil strata is 0.14023 mm.

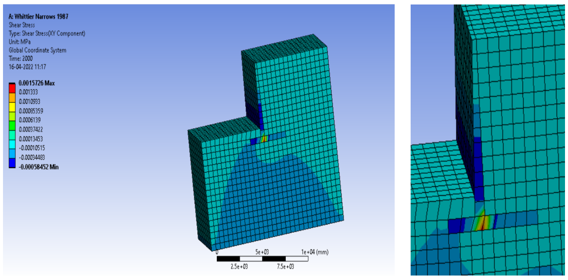


Figure 4: Shear stress for Whittier Narrows 1987 Earthquake

From figure 4, Shear stresses of wall is calculated for XY component. Maximum shear stress of 0.34985 MPa occurred at center of base slab in red color and minimum stresses occur at middle portion of stem in dark blue color. Same observation seen under Northridge earthquake.

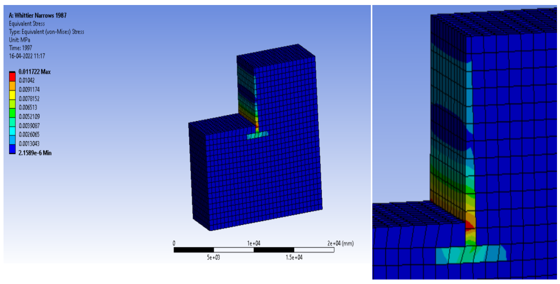


Figure 5: Equivalent stress (von – mises) for Whittier Narrows 1987 Earthquake

For the Loma Prieta earthquake shear stresses behave differently maximum shear stress occurred at the middle portion of the stem and minimum stresses occurred at the bottom portion of the stem.

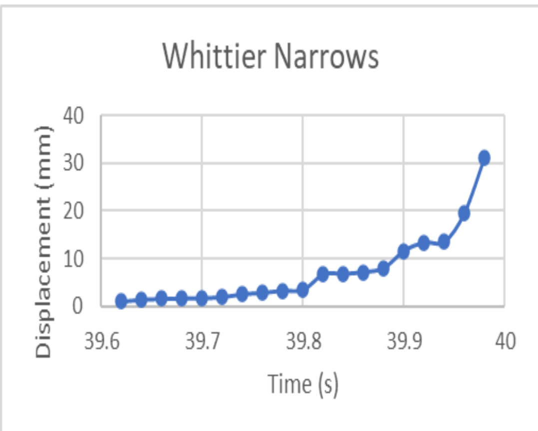
The Von Mises stress sharing for retaining wall supporting clayey soil under dynamic loading condition 1.0027 x10^{-6}- 1.6886 MPa. (Figure 5). The lowest Von Mises stress values are detected near the ground level in dark blue color. Von Mises stress increases at bottom of wall. The higher Von Mises stress (1.6886 MPa) is detected between the base slab and the stem of the retaining wall in red color in the soil cover zone.

For Northridge 1994 The Von Mises stress distribution for retaining wall supporting clay under dynamic loading condition 7.0163

10^{-7}- 2.6076 MPa. The lowest Von Mises stress values are detected near the ground level. Von Mises stress increases at bottom of wall. The higher Von Mises stress (2.6076 MPa) is detected between the base slab and the stem of the retaining wall in the soil cover zone.

For Loma prieta 1989 The Von Mises stress distribution for retaining wall supporting clay below dynamic loading condition 1.1022 10^{-6}- 3.4918 MPa. The lowest Von Mises stress values are observed near the ground level. Von Mises stress increases at bottom of wall. The higher Von Mises stress (3.4918 MPa) is detected amongst the base slab and the stem of the retaining wall in the soil cover zone.

Form above description it is concluded that equivalent stresses is maximum at bottom of wall and minimum at bottom of subsoil strata.



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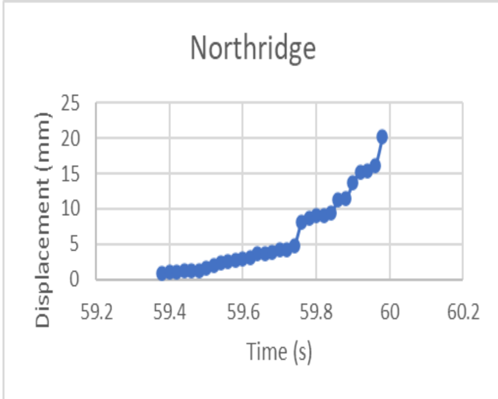

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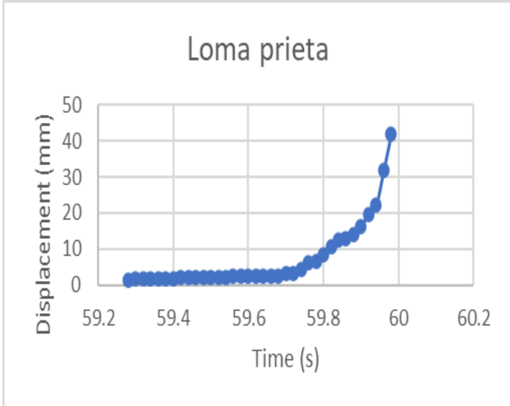

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Figure 6: Displacement versus time graph for (a) Whittier Narrows 1987 Earthquake, (b) Northridge 1994 Earthquake, (c) prieta 1989Erthquake

Figure 4 (a) shows time history analysis at given acceleration at interval of 0.02s. Till time 39.58 s. displacement was observed almost zero and maximum displacement was observed 31.197 mm at 39.98 s. Similarly, figure 4 (b) shows that wall displaced more at time 59.98 s is 20.202 mm. Figure 4 (c) shows that wall displaced more at 59.98 s is 41.774 mm.

Form Figure 4, it is observed that maximum value of displacement occurs at top of the wall and minimum displacement occur at bottom of the wall. Among these three earthquakes, it was observed that wall deflected more by 41.774 mm in Loma prieta ground motion. Overall stable condition of retaining wall observed in all earthquakes and wall does not occurred failure under earthquake loading condition.

Conclusion

A seismic analysis is carried out for the calculation of dynamic behavior of cantilever retaining wall under horizontal excitation. The study investigates different factors such as displacement, shear stress, equivalent (von-mises) stresses. The soil interface behavior is taken into account by using direct method of analysis for that wall and soil modelling together and creating contact between them.

1. Three different ground motion are applied to examine the effect of seismic behavior of cantilever wall and from this analysis it is observed that maximum displacement occurs at top of the wall.
2. Among these three earthquakes, it was observed that wall deflected more by 41.774 mm in Loma prieta ground motion.
3. At Loma prieta earthquake shear stresses and equivalent stresses are also observed maximum.
4. It is observed that wall defected by excitation given in x direction but failure of retaining wall does not occur.
5. For present study dynamic analysis of retaining wall with soil gives stable condition.
6. The significant effect on seismic behaviour of retaining wall has been found in the soil.

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