JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Comparative Analysis of the Retaining Wall with Soil Structure Interaction with different Heights and Soil conditions

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Abstract : ***The primary goal of this paper is to contribute to a quantification of the impact of soil structure on the seismic response of the various types of retaining walls, taking into account four different subsoil conditions and varying stem heights such as 4m, 5m, 6m, 7m, 8m using the finite element program SAP 2000, a seismic analysis of the backfill cantilever wall soil/foundation interaction system was constructed, taking into consideration loads such as dead load, and live load, along with the soil pressure and surcharge load. Result shows the comparative study on stability, overturning and sliding.***

Based on the comparative study the size optimization is done by observing the parameters such as bending moment and deflection in the stem wall and base of the footing slab. The maximal lateral displacement is the desired result. Finally, the retaining wall is provided with the response spectrum inputs for the three different types of soil (soft, medium, soft rock, and hard rock).

Index terms - **Soil Structure interaction, Retaining wall, Dynamic Analysis, SAP 2000 V24**

I. INTRODUCTION

I. A retaining wall is a structure designed to retain soil or other materials and prevent them from eroding or collapsing. It is typically used in conditions where there is a significant difference in ground elevation, such as sloping terrain, to create level areas or to prevent soil from sliding down slopes or hilly regions. They are built to resist the lateral earth pressure exerted by the soil or other materials behind them. The pressures might be active or passive earth pressure. The Active earth pressure occurs when the soil is exerting pressure away from the wall It is trying to push forward, The passive earth pressure occurs when the soil is prevented from moving away from the wall instead of resisting the applied pressure. It is Important to Design and Construct retaining walls properly, taking into account factors such as soil properties, water drainage, wall height, and potential lateral forces. Consulting with a qualified engineer or professional is recommended to ensure the wall is safe, effective, and compliant with local regulations and IS 456: 2000 codal provisions. The retaining wall with different shapes are considered for the analysis along with 4 different subsoil conditions and varying stem wall height 3m, 4m, 5m, 6m, 7m. The change in the Deflection, Bending moment, and Base shear is observed among the different types of retaining wall with varying height, the increase of the Bending moment is observed when the stem wall height increases considerably.

Figure 1: Collapsed Retaining wall Beverly Hills Tanjung Bungah, Penang

Figure 2: Retaining wall failure Malaysia

II. Methodology

- Study the parameters required for the modeling of retaining wall
- Modeling of the same model by the help of the SAP 2000 Software
- Analysis of the different models with different soil conditions
- Post process mode after the Analysis process, check for shell stresses for maximum Deflection/displacement and Bending moment.

Obtained results are compared with other models with varying heights and soil conditions.
In the present study of retaining wall with varying height 4m, 5m, 6m, 7m 8m numerical analysis is performed using SAP 2000 software as per IS 1893(Part 2: 2014). Various parameters get related with analysis while considering the dynamic method. Pressure distribution on the retaining wall due to Dead load, Live load, Earth pressure and Surcharge load are some of these factors. This work is mostly focused on the Soil structure analysis effect during the earthquake.
Traditional structural design techniques ignore the impacts of SSI. For light structures on relatively stiff soil, such as low-rise buildings and straightforward rigid retaining walls, neglecting SSI is feasible. However, the influence of SSI becomes more pronounced for massive structures resting on relatively soft soil, such as nuclear power stations, high-rise structures, and elevated roadways.

3.1 Properties of the Soil

All tables should be numbered with Arabic numerals. Every table should have a caption. Headings should be placed above tables, left justified. Only horizontal lines should be used within a table, to distinguish the column headings from the body of the table, and immediately above and below the table. Tables must be embedded into the text and not supplied separately. Below is an example which the authors may find useful.

Table 1. Properties of the soil various types

Soil type	Young's modulus E(KN/m^2)	Shear modulus G (KN/m^2)	Voids ratio v	Density ϒ(KN/m3)
Alluvial soil S1	35000	12500	0.40	18
Medium clay soil S2	75000	26786	0.40	18
Hard clay Soil S3	500000	185185	0.35	19
Weathered basal rock S4	2000000	769231	0.30	20

3.2. Dynamic analysis method

Dynamic analysis is done by using SAP 2000 software with stem heights 4m, 5m, 6m, 7m, and 8m considering earthquake zone 5 to simulate the worst case.

The retaining wall is modeled in SAP 2000 Software for Dynamic analysis for stem heights, for the chosen grid spacing then selected number of grid lines in X and Y direction.

Following this, ETABS defines attributes like material, section, spring, function, different load scenarios, and load combinations. Concrete of the M30 grade and Fe415 steel are used in the materials. Slab section (bottom slab) and wall section (stem) are determined in section attributes. Because soil does not require tension to stimulate the load, applied area springs solely in compression at the base. This takes into account the subgrade modulus of 25000 KN/m/m2 according to IS code 2911 (shown in table no. 3). The worst case function characteristics according to IS 1893:2002 were then stimulated using seismic zone 5, which was chosen after that. Then, all load situations were developed, including Earthquake load (response spectrum), Earth pressure (linear static), and Dead load (linear static). Lastly, three load combinations were applied: 0.9D.L.+1.5EQ, 1.5(D.L.+SOIL), and 1.5(D.L.+SOIL+EQ).

3.3 Retaining wall with Different shapes

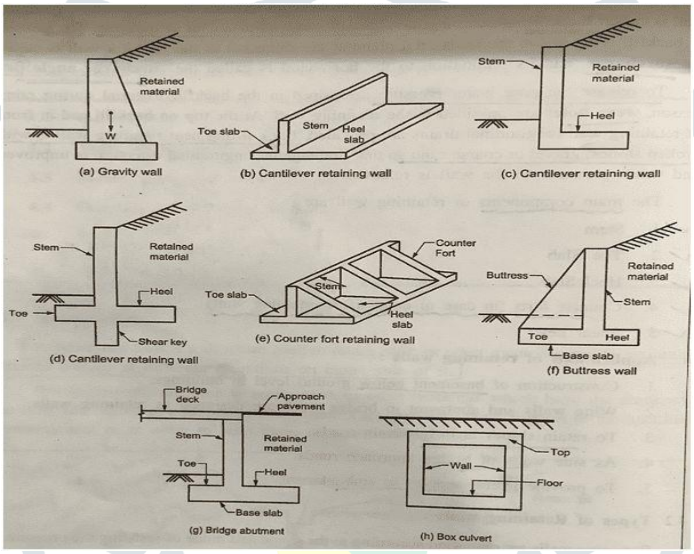


Figure 3: Retaining wall with different shapes

4.1 Analysis Procedure

4.1.2 Define the Grid line spacing
4.1.2 Define the material properties
4.1.3 Define the soil Profile
4.1.4 Define the load patterns & load combinations
4.1.5.Define the section properties
4.1.6 Define the section properties
4.1.7 Assignment of area spring properties
4.1.8 Assignment of the loads & load combinations to the sections
4.1.9 Finding out the resultant shell stresses, displacement, Bending moment & Shear force

4.2. Dimensional view of the Model from SAP 2000

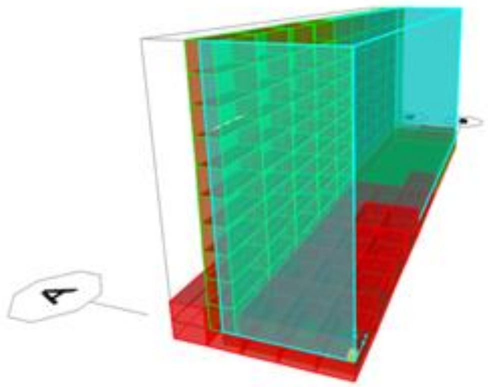


Figure 4: 3D Model of the Retaining wall

4.3 Stress patterns observed from the retaining wall models with different height

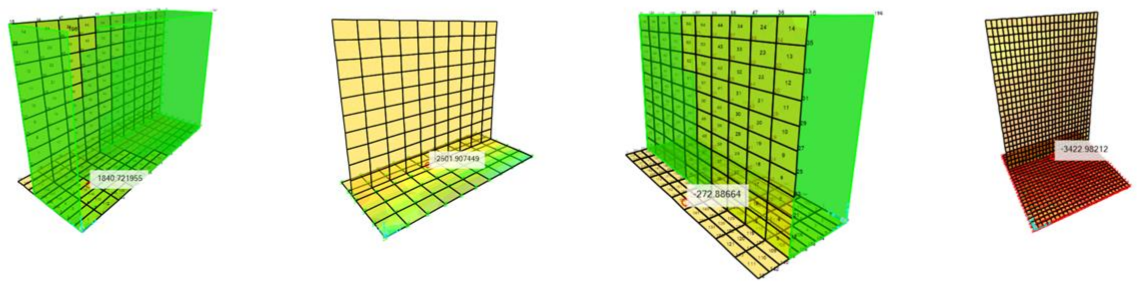


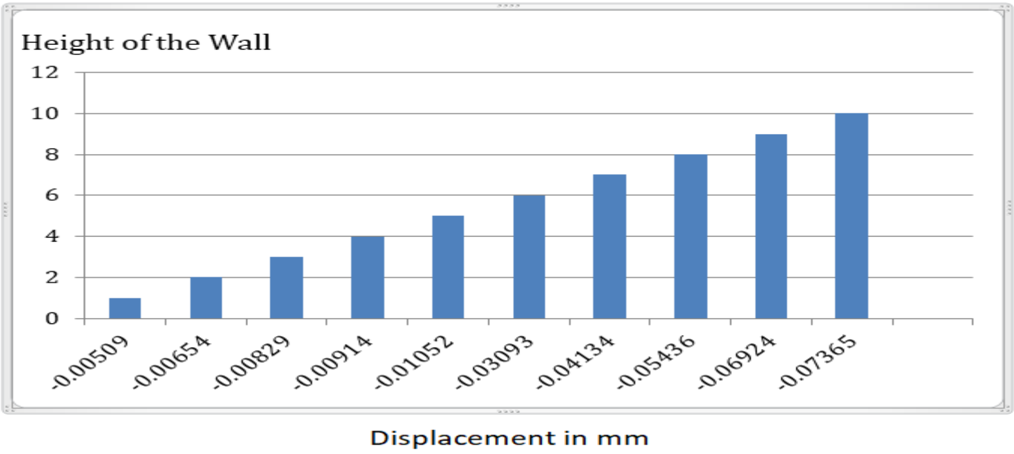
Figure 5: Retaining wall models with varying heights from 3m,4m,5m,6m

4.4 Height vs Displacement

Table 2: Comparison between wall height and Displacement pattern

Height of the Wall	Displacement in mm
1	-0.00509
2	-0.00654
3	-0.00829
4	-0.00914
5	-0.01052
6	-0.03093
7	-0.04134
8	-0.05436
9	-0.06924
10	-0.07365

Table 3: Height vs Displacement graph



4.5 Joint reaction of the retaining wall model with 3m height

Table 4: Joint reactions in KN with respect to joint number

Joint number	Load combination	Joint reaction in KN
1	DL+EQ	105.410
1	0.9DL+1.5EQ	65.626
1	1.5DL+1.5EQ	130.240
2	DL+EQ	102.456
2	0.9DL+1.5EQ	67.412
2	1.5DL+1.5EQ	135.265
3	DL+EQ	103.256
3	0.9DL+1.5EQ	85.245
3	1.5DL+1.5EQ	140.253

Table 5: Base reactions of the retaining wall model with 3m height

Joint number	Global FX in KN	Global FY in KN	Global FZ in KN	Global MX in KN
1	-279.634	428.223	862.56	1022.200
2	-414.952	365.444	765.45	1045.25
3	-414.851	532.445	677.75	1075.30

4.6 Joint reaction of the retaining wall model with 4m height

Table 6: Joint reactions in KN with respect to joint number

Joint number	Load combination	Joint reaction in KN
1	DL+EQ	107.240
1	0.9DL+1.5EQ	68.450
1	1.5DL+1.5EQ	135.245
2	DL+EQ	108.452
2	0.9DL+1.5EQ	70.412
2	1.5DL+1.5EQ	155.265
3	DL+EQ	123.256
3	0.9DL+1.5EQ	89.245
3	1.5DL+1.5EQ	145.253

Table 7: Base reactions of the retaining wall model with 4m height

Joint number	Global FX in KN	Global FY in KN	Global FZ in KN	Global MX in KN
1	-280.634	432.223	869.56	1042.200
2	-420.952	367.344	775.42	1041.25
3	-442.851	535.425	674.72	1072.30

4.7 Joint reaction of the retaining wall model with 5m height

Table 8: Joint reactions in KN with respect to joint number

Joint number	Load combination	Joint reaction in KN
1	DL+EQ	108.240
1	0.9DL+1.5EQ	67.450
1	1.5DL+1.5EQ	145.225
2	DL+EQ	162.552
2	0.9DL+1.5EQ	73.412
2	1.5DL+1.5EQ	154.265
3	DL+EQ	160.256
3	0.9DL+1.5EQ	89.245
3	1.5DL+1.5EQ	168.253

Table 9: Base reactions of the retaining wall model with 5m height

Joint number	Global FX in KN	Global FY in KN	Global FZ in KN	Global MX in KN
1	-285.634	452.223	869.568	1052.201
2	-428.952	357.344	775.425	1061.25
3	-444.851	525.425	674.722	1085.263

4.8 Joint reaction of the retaining wall model with 6m height

Table 10: Joint reactions in KN with respect to joint number

Joint number	Load combination	Joint reaction in KN
1	DL+EQ	120.240
1	0.9DL+1.5EQ	87.440
1	1.5DL+1.5EQ	165.325
2	DL+EQ	192.552
2	0.9DL+1.5EQ	93.512
2	1.5DL+1.5EQ	174.365
3	DL+EQ	190.356
3	0.9DL+1.5EQ	101.345
3	1.5DL+1.5EQ	188.253

Table 11: Base reactions of the retaining wall model with 6m height

Joint number	Global FX in KN	Global FY in KN	Global FZ in KN	Global MX in KN
1	-486.634	457.223	929.568	1152.201
2	-526.952	457.345	875.425	1161.252
3	-456.851	530.475	774.722	1185.280

5. Results and Discussion

1. By the end of the comparative analysis of the retaining wall, can be able to find out the stress patterns, Bending moment, and Displacements observed in the model.
2. Dimension optimization based on the maximum Stresses and maximum Bending moment of the retaining wall.
3. Economical Design of the retaining wall with less Stem wall thickness in case of Highway embakment in an elevated/ Hilly regions.
4. Suggestion of the type of the retaining wall which is best suitable for the particular soil condition.
5. To construct the modular type of the retaining wall by observing Stress results from the model analysis.
6. The magnitudes of the wall movements and pressures brought on by horizontal ground shaking are very sensitive to the response of the soil supporting the wall, and the seismic response of cantilever retaining structures is a complex soil-structure interaction problem.

7. Excluding precise soil parameters could result in an under or overestimation of the reaction, which could result in a dangerous seismic design for cantilever retaining walls.

6. Acknowledgement

The satisfaction and fulfilment that accompany the successful completion of any task would be incomplete without mention of the people who made it possible. Whose constant guidelines and encouragement crowned my efforts with success.
First and foremost, I would like to express our sincere thanks to ***Dr. Nayana N. Patil***, *HOD Department of Civil Engineering, Ramaiah University of Applied Sciences.*
I earnestly thank ***Dr.J V Desai***, *Dean of FET, Ramaiah University of Applied Sciences,* for facilitating academic excellence in the college that helped in completing this project. We are extremely grateful to ***Dr. Govind R. Kadambi***, *Pro- Vice Chancellor, MSRUAS* and ***Prof. Kuldeep Kumar Raina***, *Chancellor, MSRUAS* whose emphasis for excellence and quality kept us focused on this project and helped to complete it on time.

Mere words cannot express our sentiments and affectionate feelings towards our parents and friends who have been the source of inspiration in my life. Last but not the least we would also like to thank all the teaching and non-teaching staff of our Civil Engineering department who helped directly or indirectly during our project work.

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