Study of 'T' Shape Cantilever Retaining Wall Subjected to Static and Dynamic Loading

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Abstract: *This paper deals with Static and Dynamic analysis of a retaining wall. The construction behavior of wall is first analyzed by static method. It consists of analysis of 'T' shaped cantilever retaining wall for height of 3.5m, 4m, 4.5m and 5m. Safe bearing capacity of soil is assumed to be 150 KN/m². Static analysis is done using Excel Sheet. Dynamic Analysis is done using ASDIP Retaining wall Software as per ACI Code. For comparative study Dynamic analysis is also done using ETABS Software by applying earth pressure on heel and stem. At bottom, thickness wise three-dimensional area springs are adopted to simulate the earth. Earth pressure, surcharge and earthquake forces are also applied on the retaining wall. It shows the comparative study such as bending moment, Stability against overturning & sliding. The conclusion is drawn based on the discussion and results obtained analytically (Excel Sheet), ASDIP Retaining wall Software and using ETABS model study. The results of analysis for both static and dynamic methods compared reasonably.*

Key Words: Static and Dynamic analysis, 'T' Shape cantilever Retaining wall, ETABS Software, Stability, Overturning-moment, Bending moment, Comparative study.

1. INTRODUCTION

In earlier days land was not in that scarcity and the cost of land was also less, therefore natural slopes on approaches of structures were preferred. But this idea fails in cities and towns due to non-availability of land for natural slopes on embankments and approaches of structures fewer lands available for grade separation. To fulfill these requirements, developed an idea to construct a masonry wall. Then in further development stages came in mind to restrain the approach with Reinforced Cement Concrete (RCC) Retaining Wall.

Retaining walls are the structures which retain the earth material or any other material where there is change in levels of ground surface. The predominant force is lateral force which is acting between structure and retained earth mass and in the analysis of retaining wall it is known as lateral earth pressure. Retaining structures are constructed in various fields of engineering such as dams, subways, roads, tunnels, mines, harbors, railroads, and military protections. Retaining structures shall be designed to withstand self-weight of the wall, lateral earth pressure and water pressure, effects of surcharge loads and earthquake loads also.

A cantilever retaining wall is a freestanding structure without lateral support at its top. These are cantilevered from a footing and rise above the grade on one side to retain a high-level grade on the opposite side. The walls must resist the lateral pressures generated by loose soils or, in some cases, water pressure. It is constructed from reinforced concrete, precast concrete or prestress concrete. The wall consists of stem and base slab. The base is also divided into two parts, the heel and the toe. The heel is part of base under the backfill. The toe is the other part of base. This type of retaining wall requires much less concrete than monolithic gravity walls, but it requires more design and careful construction. It's similar to gravity walls, sliding, overturning and bearing pressure shall be taken into consideration during its design. Generally, it is economical up to 8m to 9m in height. It can be precast in a factory or formed on site.

Methods used for determining earth pressure of cantilever retaining wall in the present study are static & dynamic method. Static load or forces are loads that do not change size, position or direction. On other hand, dynamic loads or forces are those that change size, position or direction of structure. The dynamic load causes a structure to vibrate. Dynamic analysis is based on acceleration, velocity and force acting on it individually. Dynamic response of even simplest type of retaining wall is quite complex. Wall movement and pressure depends on the response of the soil underlaying the wall, the response of the backfill, the inertial and flexural response of the wall itself and the nature of input motions. Magnitude and distribution of dynamic wall pressure are influenced by the mode of wall movements (e.g. translation, rotation about base, or rotation about top). Wall can move by translation and or by rotation. One or the other may be predominant for some wall, and both may occur for others. In this paper an attempt is made to focus on analysis of cantilever retaining wall and compare bending moments due to static and dynamic forces

2. METHODOLOGY

In the present study static and dynamic analysis of cantilever retaining wall is done using MS Excel, ASDIP Software and ETABS software for various height of RW (3.5m, 4.0m, 4.5m and 5.0m) height of wall, SBC of soil, angle of repose and all other parameters kept same for both the analysis for various parts like stem, toe slab and heel slab. The cantilever wall is statically analyzed using MS excel program that estimates the earth pressure satisfying the stability criteria. Dynamic Analysis is done using ASDIP Retaining wall software as per ACI Code. For comparative study, Dynamic analysis is also done by using ETABS Software by applying earth pressure on heel & stem. At bottom, thickness wise three-dimensional area springs at base are applied. Forces like earth pressure, surcharge etc. are applied on model in ETAB's and Various parts of cantilever retaining wall are analyzed. Also, for the purpose of dynamic analysis earthquake forces are applied on the retaining wall and dynamic analysis is done in ETABS software. Finally change in the bending moments due to static and dynamic forces is noted.

3. ANALYSIS PARAMETERS

- Angle of Internal friction (ϕ) = 30º
- Backfill Slope Angle = 0º
- Wind Height from Top = 1.52 m
- Vertical load eccentricity = 15.2 cm
- Coefficient of active earth pressure (ka) = 0.33
- Coefficient of passive earth pressure (kP) = 3.00
- Unit weight of Concrete = 25 kN/m3
- Unit weight of soil, g = 18.00 kN/m3
- Saturated Unit weight of soil = 20kN/m3
- Uniform Surcharge, q = 1.20 kN/m2
- Soil bearing capacity, SBC = 150 kN/m3
- Modulus of Elasticity of Concrete (E) = 5000√fck = 27386.12 N/mm2
- Modulus of Rigidity (G) = 11410.89 N/mm2
- Earthquake zone = V
- Grade of concrete = M30
- Grade of steel = Fe415

4. MODELING AND ANALYSIS

Static analysis- Static analysis is done by preparing Excel Sheet for Stem heights of 3.5m, 4.0m, 4.5m and 5.0m. Also, model is done in ETABS Software for same Stem heights.

Then the results of Excel Sheet and results of ETABS Software are as shown below in Table 4.1 When done the Static analysis these results are obtained.

Table 4.1: Results of Max. Factored BM (kN-m) for Static Analysis

RESULTS of Max. Factored BM (kN-m)			
Height of Wall	Component Parts of RW	Using Excel (Static)	Using ETABS (Static)
		Mu	

3.5m	**Heel**	35.04	34.04
	Toe	24.62	26.21
	Stem	56.20	58.40
4.0m	**Heel**	61.77	62.41
	Toe	42.31	41.40
	Stem	91.40	90.44
4.5m	**Heel**	82.85	81.55
	Toe	49.33	47.54
	Stem	131.4	133.41
5.0m	**Heel**	112.50	113.52
	Toe	53.21	54.41
	Stem	182	181.22

ii) Dynamic analysis - Dynamic analysis is done by using ASDIP Software for Stem heights of 3.5m, 4.0m, 4.5m and 5.0m considering Earthquake zone V to simulate the worst case.

1. The Retaining wall is also modelled in ETABS Software for Dynamic analysis for same Stem heights, for the same uniform grid spacing of 0.5x0.5m and then selected number of grid lines in X and Y direction, number of stories in Z direction depending on height of RW.

2. After this, properties like material, section, spring, function, various load cases and load combinations are defined in ETABS. In materials M30 grade of concrete and Fe415 steel are adopted. In section properties defined slab section (bottom slab) and wall section(stem). In spring properties, applied area springs at base in compression only because soil does not take any tension to stimulate the load. For this, subgrade modulus of 25000 KN/m/m^2 as per IS code 2911 (Given in table no-3) is considered. After this, selected earthquake zone 5 to stimulate the worst case in function properties as per IS 1893:2002. Then defined all load cases like Dead load (linear static), Earthpress (linear static) & Earthquake load (response spectrum). And finally applied three load combinations (0.9D.L.+1.5EQ), 1.5 (D.L.+SOIL) & 1.5(D.L.+SOIL+EQ).

3. For the purpose of applying shell load on heel slab, translation restricted in X & Y direction, then selected total area of heel and applied the load in downward direction i.e. gravity.

4. After this, applied uniform shell load on stem in local-3 direction.

5. And got maximum bending moment in toe slab, heel slab & stem for both static and dynamic behavior of retaining wall. Also, found the amount of deflection occurs in retaining wall.

6. Finally, these results compared with the results of Excel and ASDIP software due to Static and Dynamic forces.

Table 4.2: Results of Max. Factored BM (kN-M) in Dynamic Analysis

RESULTS of Max. Factored BM (kN-m)			
Height of Wall	**Component Parts of RW**	**Using ASDIP (Dynamic)**	**Using ETABS (Dynamic)**
3.5m	**Heel**	69.71	65.13
	Toe	54.50	34.72
	Stem	112.8	123.33

4.0m	**Heel**	87.1	83.12
	Toe	72.7	76.29
	Stem	180.2	190.96
4.5m	**Heel**	121.9	115.83
	Toe	91.7	92.03
	Stem	253.5	268.83
5.0m	**Heel**	173.9	161.87
	Toe	103.5	105.71
	Stem	357.8	367.13

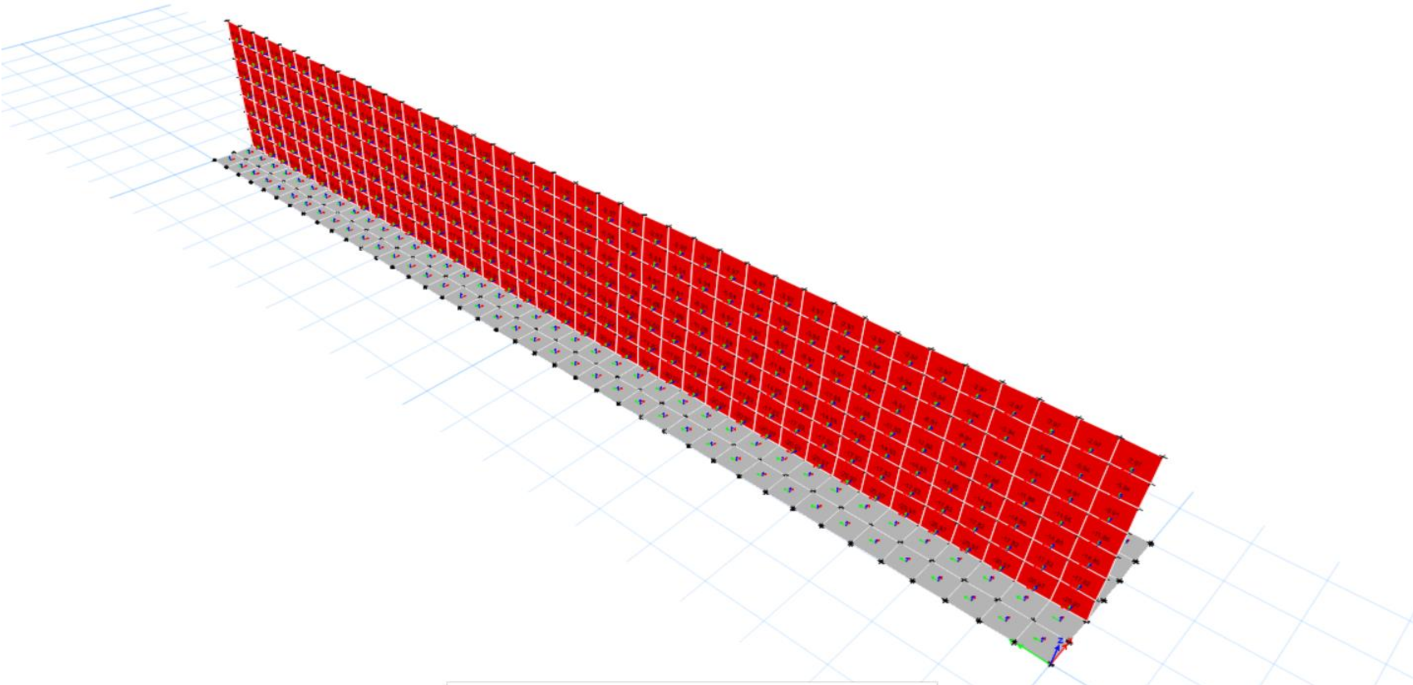

Figure 1: Modeling of 3.5m ht. of retaining wall in ETABS

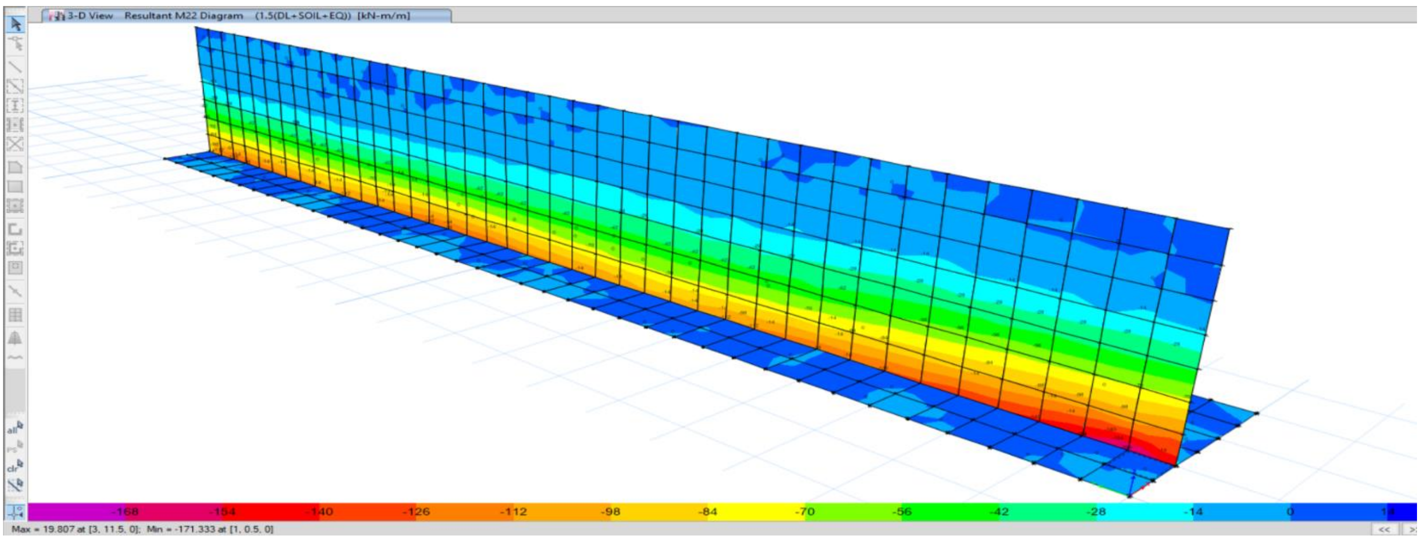

Figure 2: Resultant Bending Moment Diagram of 3.5m ht. of retaining wall in ETABS

5. RESULTS AND DISCUSSION

Table 5.1: Results of Max. Factored BM (kN-m) using ETABS Software

RESULTS of Max. Factored BM (kN-m)						
Height of Wall	Component Parts of RW	Using Excel (Static)	Using ASDIP	Using ETABS		% Change in BM between Static and Dynamic Analysis Considering Zone V
		Mu	(Dynamic)	Static	Dynamic	
3.5m	Heel	35.04	69.71	34.04	65.13	85.87
	Toe	24.62	54.50	26.21	34.72	41.02
	Stem	56.2	112.8	58.40	123.33	119.45
4.0m	Heel	61.77	87.1	62.41	83.12	34.56
	Toe	42.31	72.7	41.40	76.29	80.31
	Stem	91.4	180.2	90.44	190.96	108.93
4.5m	Heel	82.85	121.9	81.55	115.83	39.81
	Toe	49.33	91.7	47.54	92.03	86.56
	Stem	131.4	253.5	133.41	268.83	104.59
5.0m	Heel	112.57	173.9	113.52	161.87	43.79
	Toe	53.21	103.5	54.41	105.71	98.67
	Stem	182	357.8	181.22	367.13	101.72

6. CONCLUSIONS

As observed from the Results Table following conclusions can be drawn

1. Dynamic Analysis of Retaining walls is not to be neglected because dynamic loads change either size, position or direction of structure and it also causes a structure to vibrate.
2. The Maximum Factored BM in Stem increases by about nearly 100% due to Inertia of soil because earthquake gives acceleration and then mass comes in contact with acceleration and hence inertia force is setup, due to this deflection of retaining wall is occurred.
3. The same is observed when ASDIP software as per ACI code is used.
4. As the height of Retaining wall increases the BM increases obviously in stem, Toe and heel as observed from the Results, therefore requirement of steel quantity also increases.
5. Percentage change in BM between Static and Dynamic Analysis Considering Zone V increases in Heel Slab but decreases in Toe Slab and Stem as the height of Retaining wall increases.

7. REFERENCES

(1) Trandafir AC, Kamai T, Sidle RC. Earthquake-induced displacements of gravity retaining walls and anchor-reinforced slopes. Soil Dynamics and Earthquake Engineering 200929:428–37

(2) Bathurst, R. J., Walters, D. L. Hatami, K., and Allen, T. M. ~2001‘‘Full-scale performance testing and numerical modeling of reinforced soil retaining walls.'' IS Kyushu preprint, 3–28

(3) Cai, Z., and Bathurst, R. J. ~1995"Seismic response analysis of geosynthetic reinforced soil segmental retaining walls by finite element method. Comput. Geotech., 17, 523–546

(4) Whitman, R. V. 1990. "Seismic design and behavior of gravity retaining walls." Proc. Design and Performance of Earth Retaining Structures, Vol. 25, ASCE GSP, Ithaca, N.Y., 817–842.

(5) Richards, R., Jr., and Elms, D. G. 1992. "Seismic passive resistance of tied-back walls." J. Geotech. Engrg., 1187, 996–1011.

(6) Basavanna, B.M. (1970), "Dynamic Earth Pressure Distribution behind Retaining Walls", Proc., 4th Symposium on Earthquake Engineering, University of Roorkee, Roorkee.

(7) Nandakurnaran, P. (1973), "Behaviour of Retaining Walls Under Dynamic Loads", Ph.D. Thesis, Roorkee University, Roorkee, India.