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Seismic Behavior of Tall Structure with Underground Storeys Resting on Flat Ground

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Abstract – *Increase in the population has caused rapid urbanization. Due to scarcity of land, the construction of high rise buildings vertically above and below the ground surface has increased many folds. This paper focus on the evaluation of seismic response of tall structure with underground storeys where the retaining wall for underground storeys are placed in different geometric position. The behavior of G+9 with 4 basement structure having retaining wall attached to column, retaining wall 1m away from column and cantilever slab resting on 1m away retaining wall are evaluated. Equivalent static method, response spectrum method and time history method has been used for analysis of these structures. The seismic loads used are seismic zone V, SMRF structure and Medium soil according to IS1893:2016. 2001Bhuj earthquake data is used for time history analysis. Design forces in terms of storey shear is calculated for all storey of buildings and results are compared with buildings with different geometric placement of retaining wall. This study reveals that retaining wall attached to column performs better in terms of deflection and time period compared to retaining wall 1m away and cantilever slab structure.*

***Key Words*: displacement, retaining wall, base shear, time period, basement storeys .**

1. INTRODUCTION

In current scenario, buildings with underground storeys are an important component of new efficient building construction technique. During the design, the basement storeys are neglected as it is considered as more stable that the above storeys. But the placements of retaining wall also play an important role in the design of economical and stabilized structure. Building code also lacks the recommendation concerning the design of building with underground storeys.

In most of structural design practices the structures are designed to carry vertical loads due to which the structures have less capacity to resist the lateral loads. When structures are designed for lateral loads, the cost of construction also increases with increase in number of storeys. The geometric orientations of the structural elements play an important role in increase the stability and reduce the cost of construction.

2. SCOPE AND OBJECTIVES

a) The proposed study involves the evaluation of seismic behavior of tall structures with underground storeys on flat ground.
b) To evaluate the performance of building with retaining wall placed in different geometric positions in underground storeys under seismic loads.
c) Study the seismic behavior of building with underground stories for different methods of seismic analysis.

3. DESIGN SPECIFICATION OF BUILDING

A high rise building with underground storeys resting on flat ground has been modeled and analysed using FEM based software ETABS 2017. Geometric details of building are given in Table 1.

Table 1: Structural and geometric details of building

Description	Data
Number of stories	14
Storey height	3.2m
Number of bays in X-direction	3
Number of bays in Y-direction	3
Bay width	6m C/C
Dimension of the beam	0.25m x 0.45m
Thickness of the slab	0.2m
Dimension of column	0.6m x 0.6m
Thickness of retaining wall	0.4 m
Thickness of Stair case	0.2m
Thickness shear wall	0.25m

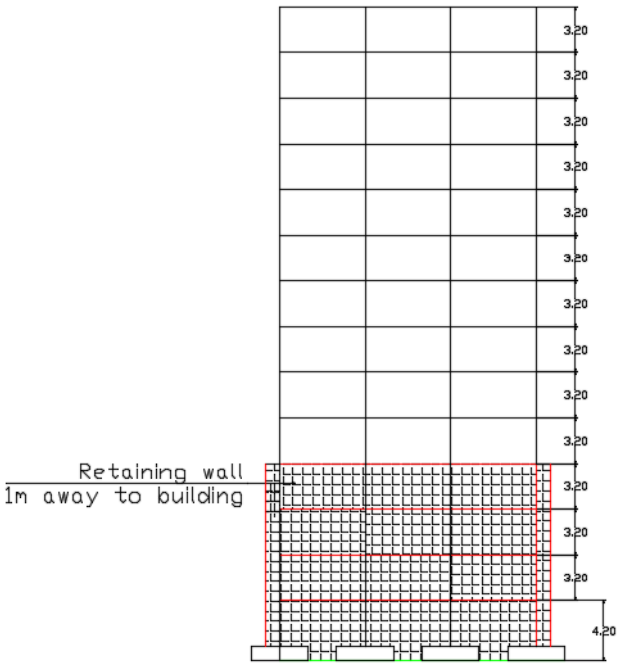

Fig. 1: Geometric Elevation of building

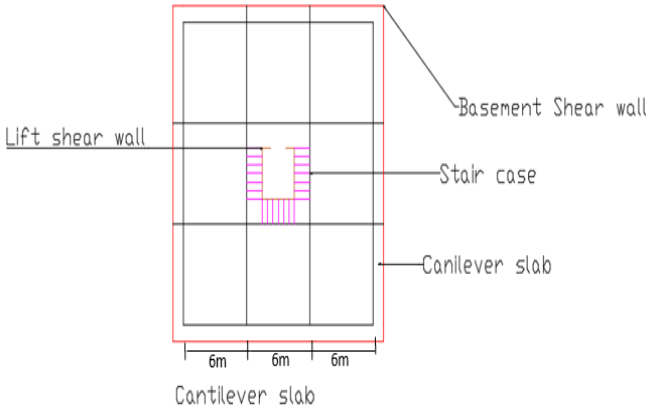

Fig. 2: Geometric plan of the building.

1.1. Loading on structures

Dead load : Self weight of structure

Weight of exterior frame: 6kN/m

Live load : 3kN/m^2

Seismic load : Seismic zone v, Type II soil

Importance factor (I) -1.2

Response reduction factor (R) – 5 (SMRF)

Time history: Bhuj earthquake data

1.2. Model created are as follows

1. **Building with retaining wall attached**

In this structure the retaining wall is attached to the columns of the basement storeys (see Fig.3)

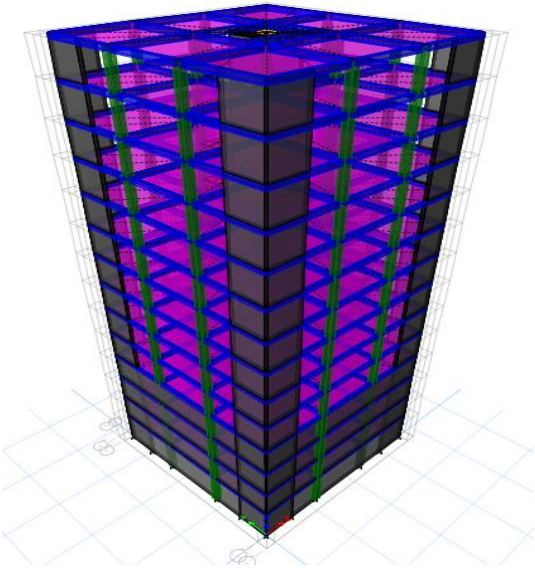

Fig. 3: Building with retaining wall attached to column

2. **Building with retaining wall with cantilever slab**

In this type of structure the retaining wall is 1m away with cantilever slab resting on the retaining wall in basement storeys as shown in Fig 4.

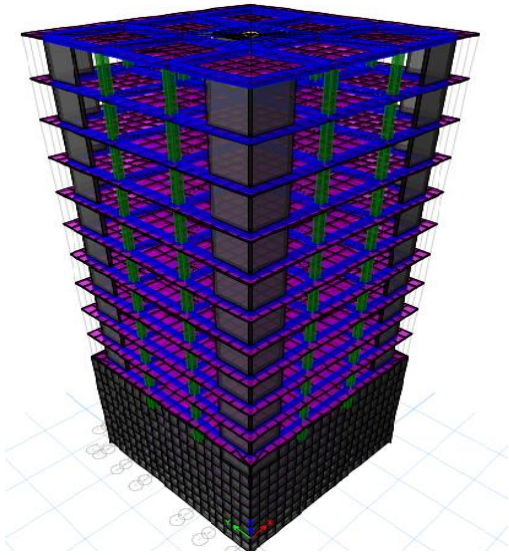

Fig. 4: Building with cantilever slab resting on retaining wall

3. **Building with Retaining wall 1m away** In this type of structure, the retaining wall is attached to the columns in the basement storeys (see Fig.5).

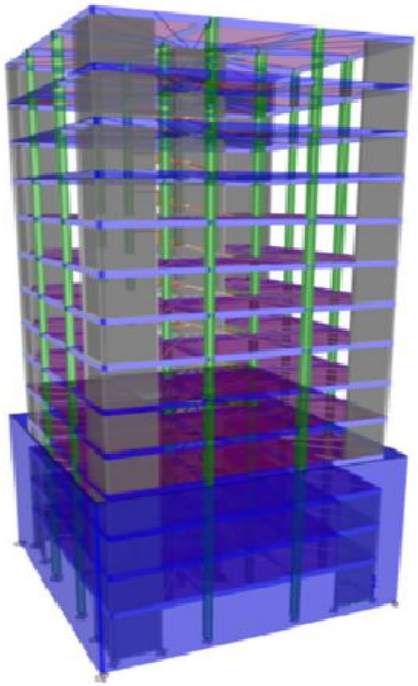

Fig. 5: Building with Shear wall 1m away from column

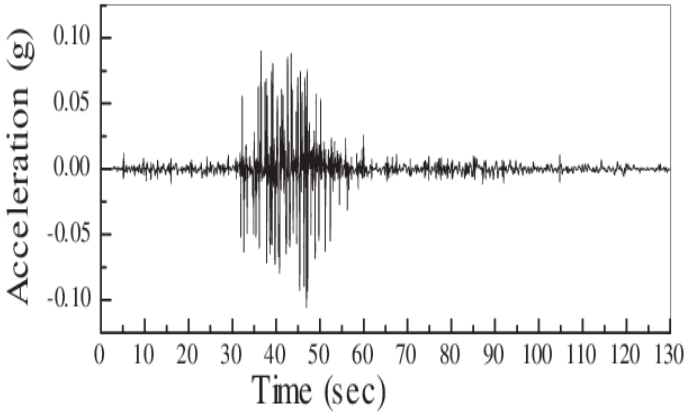

Fig. 6: Ground motion record of Bhuj earthquake

4. RESULTS AND DISSCUSSION

The present study is to evaluate the performance of building with underground storyes having retaining wall placed at different positions and different methods of analysis.

Table-2 Comparison of maximum displacement and base shear by equivalent static method of analysis .

Title	Max Displacement X-dir	Base shear X-dir	Max Displacement Y-dir	Base shear Y-dir
	mm	kN	mm	kN
Building with attached retaining wall	29.5	2100	29.2	2057
Building with retaining wall cantilever slab	32	2754	31.3	2666
Building with retaining wall 1m away	36.5	1277	36.4	1223

Table-3 Comparison of maximum displacement and base shear by response spectrum method of analysis.

Title	Max Displacement X-dir	Base shear X-dir	Max Displacement Y-dir	Base shear Y-dir
	mm	kN	mm	kN
Building with attached retaining wall	23.4	1984	23.2	1918
Building with retaining wall cantilever slab	26	2311	26.2	2248
Building with retaining wall 1m away	29	1178	30.2	1127

Table-4 Comparison of maximum displacement and base shear by Time history method of analysis.

Title	Max Displacement X-dir	Base shear X-dir	Max Displacement Y-dir	Base shear Y-dir
	mm	kN	mm	kN
Building with attached retaining wall	15.4	1955	15.3	1895
Building with retaining wall cantilever slab	19.5	2219	19	2192
Building with retaining wall 1m away	24	1170	23.6	1115

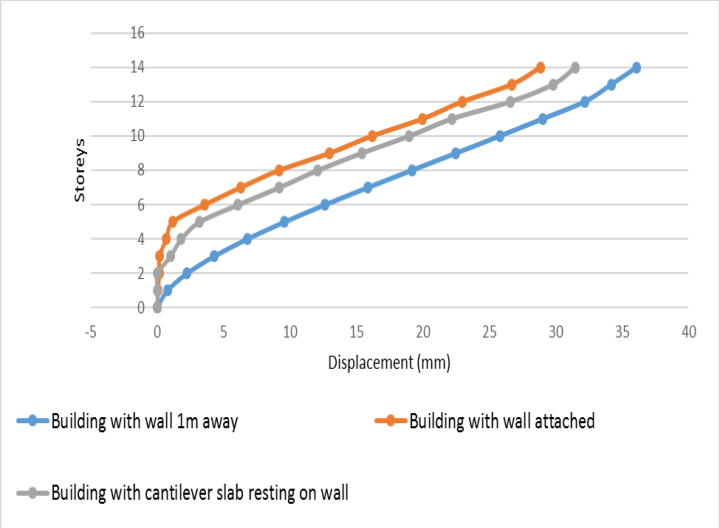

Fig. 7: Displacement of building for equivalent static analysis

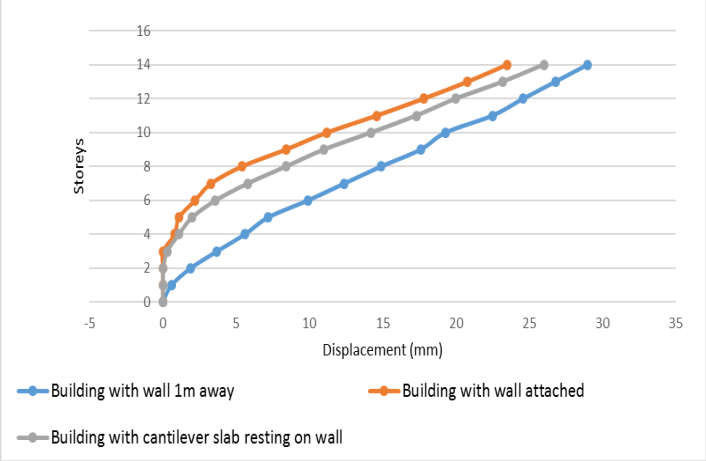

Fig. 8: Displacement of building for Response spectrum analysis

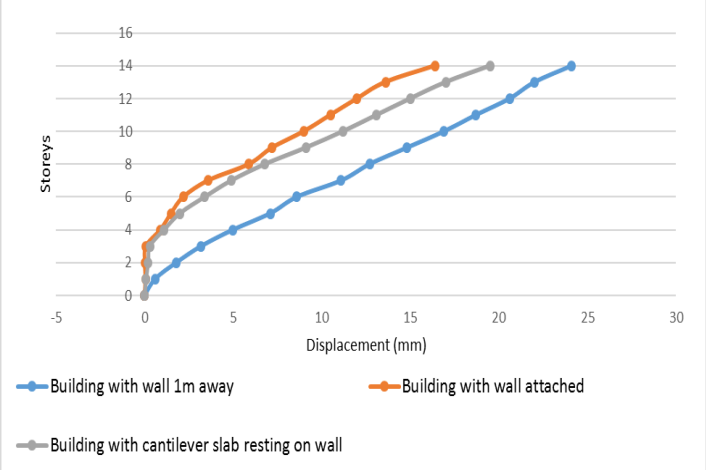

Fig. 9: Displacement of buildings for time history analysis

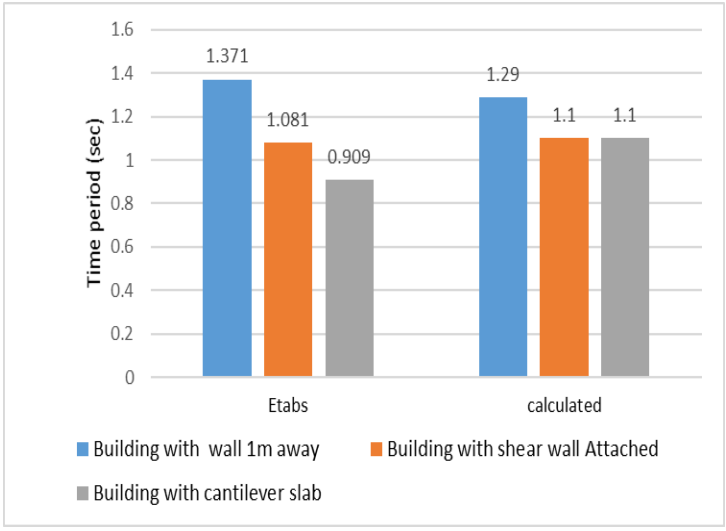

Fig. 10: Time period for different types of building

Table 2 , 3 & 4 represents the maximum displacement and base shear, Figs. 7,8 & 9 shows pattern of displacement of building for different storeys and , Fig. 10 represents the time period for building with retaining wall attached to column, building with retaining wall 1m away from column and building with retaining wall 1m away cantilever slab resting on the wall subjected to equivalent static, response spectrum and time history method of analysis.

Deflection of the building with wall attached is found to be 12.6% lesser than building with cantilever slab which is further 10% lesser to building with wall 1m away. Building with wall attached and building with cantilever slab shows negligible deflection for bottom 4 storeys, this is caused due to the retaining wall attached to the column increases the structural stability to the building.

Base shear of Building with cantilever slab resting on wall was observed to have 24% higher base shear compare to building with wall attached to column and further 30% to building with wall 1m away, this is because of higher mass due to cantilever portion and building with retaining wall 1 m away has least base shear because framed structure is isolated from the retaining wall which carries earth pressure.

Time period of building calculated manually and by Etabs found to be similar. Time period for building with wall attached is 21% lesser compare to the building with cantilever slab and further 16% lesser compare to the building with wall 1m away .

5. CONCLUSIONS

Based on the work carried out the following conclusions can be drawn.

1. It has been found that geometric placement of retaining wall at underground storeys can be successfully used to reduce the deflection of the building.
2. It is observed that building with retaining wall attached to columns has least deflection as the retaining wall at underground storeys resists the deflection at the bottom storeys indeed causing overall deduction in deflection
3. Building with cantilever slab has highest base shear because of extra load due to cantilever portion and building with wall 1m away has least base shear as the building is isolated from the retaining wall carrying earth pressure
4. The variation in time period is due to the higher stiffness achieved by building with wall attached to columns as compared with building with wall1m away
5. Time period of building with cantilever slab is higher due to the extra load because of cantilever portion.
6. Building with cantilever portion and building with wall attached shows a similar response to seismic loads.
7. The most economical way of construction of building with underground storeys is to have retaining wall attached to columns as the provide higher stability to the building.
8. The building with retaining wall attached to column is found to be more effective in terms of deflection base shear and time period compare to building with retaining wall 1m away and cantilever wall attached to retaining wall.

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