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SEISMIC PERFORMANCE IMPROVEMENT OF FLAT PLATE STRUCTURES BY PROVIDING SHEAR WALL

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ABSTRACT

The slab system that is supported by columns without any column line beams is known as flat plate. Board strips of the slabs centred on the column lines in each direction serve the same function as the beams. Flat slab systems are also susceptible to significant reduction in stiffness resulting from cracking that occurs from construction loads, service loads, gravity loads and lateral loads. The brittle punching failure due to transfer of shear forces and unbalanced moments between slabs and columns in flat plate structures causes serious problems. Flat plate construction is mainly used as the vertical load carrying system in structures where shear wall is responsible for lateral capacity of structures. During earthquake shaking, when the crack forms, the sections are transformed from elastic to plastic state. So, Performance Based Analysis or Pushover Analysis was done here to find actual behaviour of the structure in earthquake. As a result of using of shear wall the capacity spectrum curve meets with demand spectrum curve at less deformation representing the performance evaluation of shear wall. Shear wall increases the lateral (earthquake) capacity of flat plate structures tremendously.

Keywords: Pushover analysis; capacity spectrum curve; demand spectrum curve

INTRODUCTION

Now a days, flat plate structure is widely used due to the many advantages it possesses over conventional moment-resisting frames. It provides low building heights, unobstructed space, architectural flexibility, easier framework and shorter construction time. However it suffers low transverse stiffness due to lack of deep beams. This may lead to potential damage even when subjected to earthquake with moderate intensity. Bangladesh is situated adjacent to the plate margins of India and Eurasia where devastating earthquakes occurred in the past. Widespread damage of structures and loss of thousands of life in the country will happen due to earthquakes. The primary focus of the present study is structural damage estimation of flat plate building with shear wall and without shear wall designed as per BNBC (2006). The objective of this study is to find out the efficiency of shear wall as a solution for flat plate structures against earthquake loading and the effective way to model shear wall in ETABS 9.6.

METHODOLOGY

Some medium rise i.e. five storied, ten storied and fifteen storied flat plate structures are modeled and analyzed with the help of finite element software ETABS 9.6. The building is 3X3 bays residential building, located in Dhaka. Length of each bay is 20 feet. There are sixteen columns in the flat plate structure. Typical storey height is 10 feet. The height from ground level to the bottom of foundation is 6 feet. Earthquake load are calculated automatically by the program. Wind load is calculated according to BNBC. Standard load combinations are taken according to BNBC (2006). At first flat plate buildings are were analyzed without shear wall , then were analyzed with shear wall as wall element and at last shear wall was modeled as column whose length and width were equal to shear wall . The flat plate buildings were also analyzed as beam column frame where beam depth was taken as equal to slab depth and beam width was taken as the slab width for which uniform rotation across its width gives the same column displacement as the original slab. Capacity spectrum method (ATC 40) is employed for finding performance situation of the flat plate structures. Pushover analysis is used to evaluate the nonlinear behavior of the structure. To define hinge in shear wall false storey has been created of three feet height.

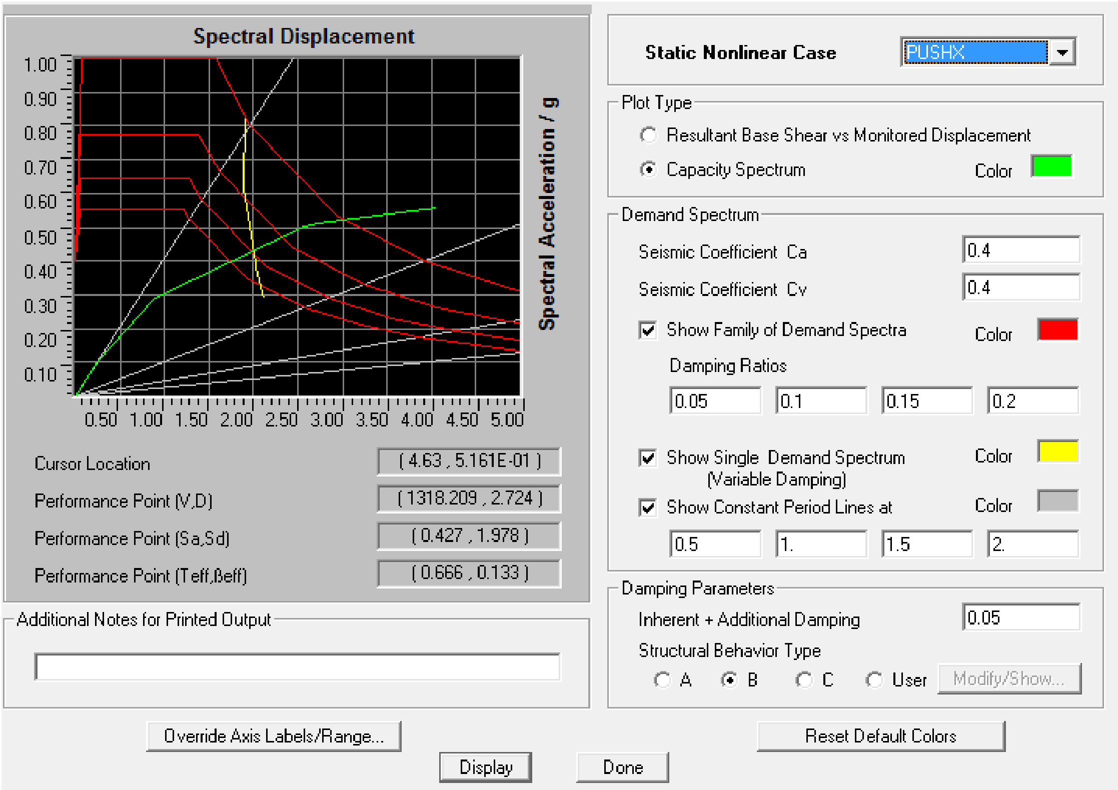

Fig. 1: Spectral acceleration vs. spectral displacement for five storied flat plate structure with shear wall as wall element

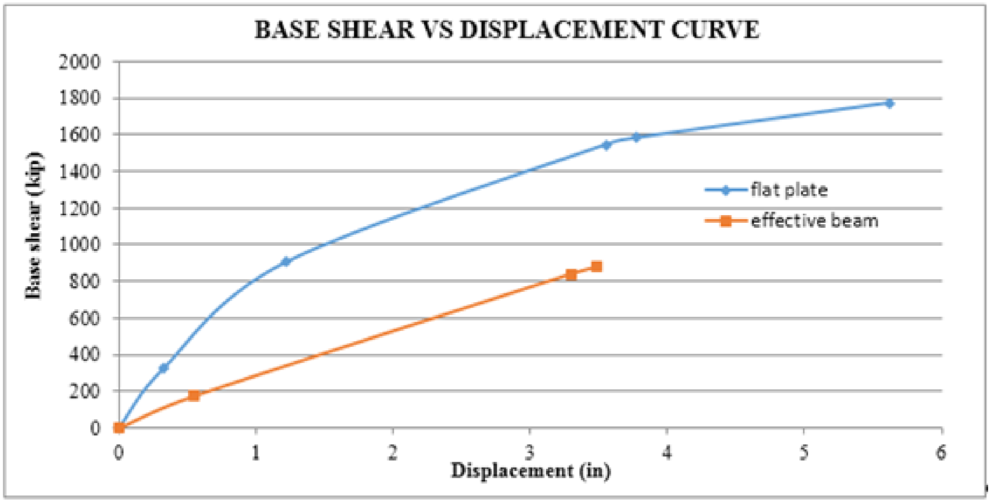

Fig. 2: Comparison of capacities between flat plate and beam column frame for five storied structure with shear wall modelled as wall element

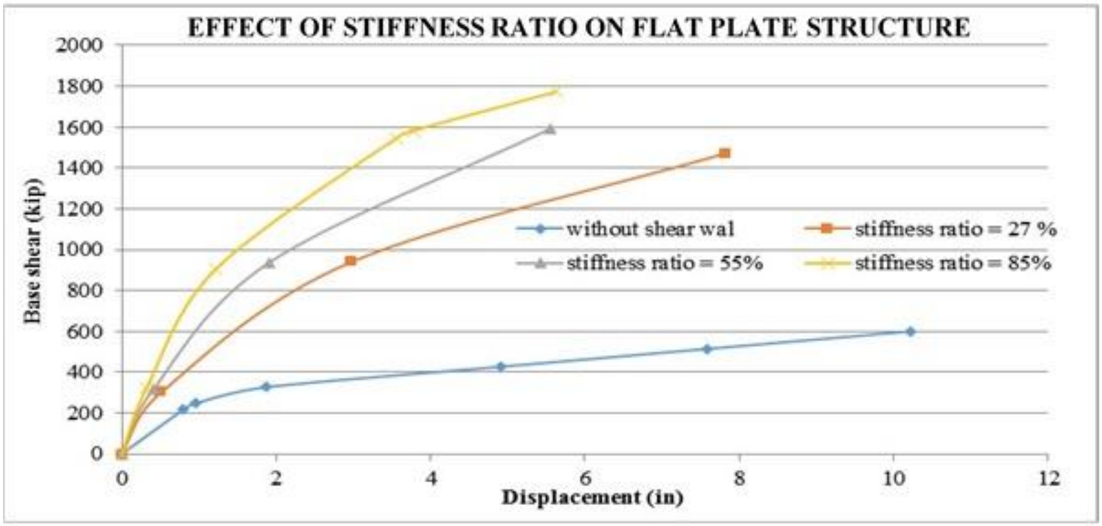

Fig. 3: Increasing trend of capacity for five storied flat plate structure with respect to stiffness ratio by shear wall modeled as wall element

Table 1: Design details of structural members

Member	Size (Inch)	
	Designed as purely flat plate	Designed as beam-column frame
Slab	5	Absent
Beam	24 X 18 (perimeter beam)	38 X 5 (exterior beam) and 67 X 5 (interior beam)
Column	25 x25	25 x25
Grade beams	18 x 18	18 x 18

$$b_{eff} = K_{eff} * l \quad (1)$$
$$q_z = C_c C_I C_z V_b^2 \quad (2)$$
$$p_z = G_z C_P q_z \quad (3)$$

Equation [1] is the formula for the calculation of effective beam width. Effective beam width (b_{eff}) is a fraction of span length (l) where span length and beam width must be in the same direction. K_{eff} is the effective beam width coefficient. Equation [2] and Equation [3] have been used for wind load calculation. In these equation q_z, C_c, C_I, C_z, V_b, p_z, G_z and C_P are sustained wind pressure at height z in KN/m^2, structure importance coefficient, velocity to pressure conversion coefficient, combined height and exposure coefficient, basic wind speed in km/hr, design wind pressure at height z in KN/m^2, gust coefficient and pressure coefficient for structures respectively.

RESULTS AND DISCUSSIONS

Fig. 1 shows that the up to displacement of 1.2 inch the structures behaves elastically. At performance point spectral displacement is 1.978 inch and spectral acceleration is 0.427g. At performance point effective damping is 13.3 % and the effective time period of the structure is 0.666 sec. So, performance point falls in inelastic range. From Fig. 2 it is obvious that flat plate structures should not be modelled as equivalent beam-column frame (effective beam concept) rather it should be modelled as flat plate structures because in case of beam-column frame it shows less capacity as well as less ductility compared to flat plate structures. When shear wall is modelled as column it gives less capacity than that of wall element. So, shear wall should be modelled as wall element. As a result of using of shear wall the capacity spectrum meets with demand spectrum curve with less deformation representing the performance evaluation of shear wall. Though shear wall increases the lateral load (earthquake load) capacity, it decreases the ductility of the flat plate structures. With the increasing height of flat plate buildings capacity of the structure against earthquake load reduces while ductility increases. For all other cases either the structure is structure ten storied or fifteen storied the curve shape remains same; the difference is that the value varies. Also the results in X-direction is only shown in the figure. As the structure is symmetric it will give same results in Y-direction. So, the interpretation on those cases have not been shown here.

CONCLUSIONS

It is economical to use shear wall to the amount corresponding to 25% - 30% stiffness ratio (ratio of the stiffness of shear wall to the stiffness of all column including shear wall).

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Book

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