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Comparing the Storey Displacements of Different Types of Building Using Linear Dynamic Analysis

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Abstract: **-- A comparative study of a regular concrete frame building frame with flat plate and frame with flat slab & drop panel is presented in this paper. The IS456:2000 and IS 1893:2000 standards have been used for the loading purpose. All four zones of an earthquake are considered and the storey displacement is computed using the equivalent static method and response spectrum method. The software used for the analysis is ETABS. The initial analysis and design for a particular dimension of column and beam are carried on, later based on some failed trials the changes on dimensions are provided, reanalysed and compared. From the analysis and result it can be concluded that flat slab with drop panel shows minimum storey displacement compared to the flat plate model and regular concrete frame model while the flat plate model shows the highest storey displacement. The related graphs are plotted for the comparison purpose.**

Keywords**: - Response Spectrum, Flat Slab, Flat Plate, Storey Displacement.**

I. INTRODUCTION

A regular building contains good number of beams and columns with different dimensions in breadth and depth is a common phenomenon in moment resisting frames. Usually when the height of the structure increases demand for beams with larger depth also increases, hence these needs to be provided, but on providing beams with depth beyond certain values will result in limiting the effective utilization of the entire height of the building. Under these situations flat plate and flat slab with drop panels etc comes into the picture. It was during the early 20th century the idea of flat slab was introduced mainly using conceptual ideas during that period many slabs were casted and load tested between, by 1914 a proposed method of analysis of flat slab based on a simple statistics. This is the method which is used even today for the design and analysis of flat slab and flat plate and is known as direct design method. Another type of method which the structural engineers commonly uses equivalent frame method which was proposed by Jacob S Grossman. Flooring systems consisting of flat slabs are very popular in place where cast in construction are predominant. Flat slabs are mainly used in office buildings a due to reduced formwork cost, fast excavation and ease in installations. Flat slabs with drop panel and Flat plate possess several advantages and some disadvantages over the normal building. Flat slab is a reinforced concrete slab without beams which is supported directly over columns. In Flat plate and flat sheer load of the slab is being concentrated on the supporting columns or on a square slab panel called drop panels. Drop panels play a major role here as they improve the overall capacity and sturdiness of the flooring system thereby improving the cost effectiveness of construction. The height of the drop panel is usually twice the height of the slab. Here for the comparative analysis and study the software ETABS is used IS 456:2000 is the code which is used for the analysis and design of building, a G+6 multi-storey building is modeled with a symmetrical plan which is shown below and analysis and design is performed. Plot for, storey displacement is obtained for all the four zones as per IS 1893:2000.

A particular column cross- section of 600x600mm is fixed and a beam cross-section of 230x400mm is used for all the three types of building in all the four zones and analysis and comparison is done, irrespective of considering the chances for failure during the design process. Later the dimensions of column and beam are increased as per the requirements that got inferred from the initial analysis done before and a similar comparative study is performed. Thickness of slab is kept to be 150mm in all three types of building and in all zones, while the thickness of drop in flat slab is taken to be 300mm. characteristic compressive strength of concrete (f ck) is taken to be 30N/mm2 and yield strength of steel is taken to be 415N/mm2.

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II. METHODOLOGY

Initially a plan of 30x30m is fixed for the G+6 building as shown in the below figure. Each panel is of 5x5m in size. The same plan and cross-section is used for both the flat plate and flat slab.

a. Dimensions

Plan = 30 m x30 m
Column size =600 mm x 600mm
Beam size =230mm x 400 mm
Slab thickness =150 mm
Drop thickness (in flat slab) =300 mm
Depth of foundation=1.5 m
Height of each storey =3.5 m
Drop size (in flat slab) =2 m
Total height =21 m

b. material property

Strength of concrete = 30N/mm^2
Strength of steel = 415N/mm^2
Soil type = type II
Importance factor =1
Response reduction factor =5

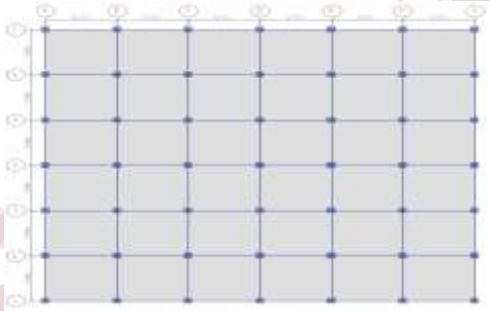

Fig 1: plan for regular concrete frame building

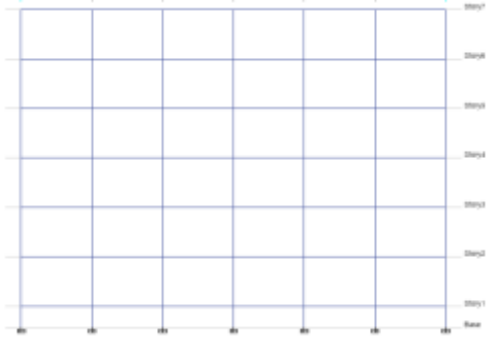

Fig 2: elevation for the regular concrete building

The above two figure shows the common plan and elevation for the building. In the case of flat plate and flat slab the only difference in the elevation and plan will be that beam will be present only at the plinth level and not on any other level.

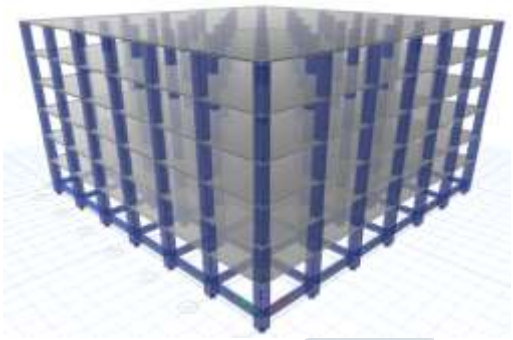

Fig 3(a) :3D view ofregularconcrete frame building

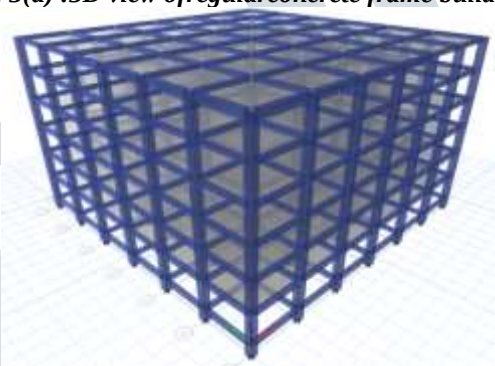

Fig 3(b):3D view of flat plate building

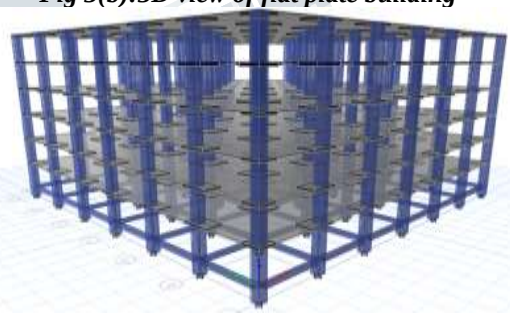

Fig 3(c): 3D view of flat slab with drop models

The above shown three 3D picture (Fig 3(a) –Fig 3(c)) represents the three dimensional views of regular concrete frame building, concrete frame with flat plate and concrete frame with flat slab and drop panel obtained from ETABS

c. Load applied

Dead load= 3kN/m^2 (on roof)
Dead load = 4kN/m^2 (on floors)
Live load =2kN/m^2 (on roof)
Live load =4kN/m^2 (on floors)

d. Load combinations

Dead load (DL) Live load (LL) Seismic load in x direction(EX) Seismic load in y direction (EY) these are the four loads used in the load combinations.

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1.5*(DL+LL)
1.2*(DL+LL+EX)
1.2*(DL+LL-EX)
1.2*(DL+LL+EY)
1.2*(DL+LL-EY)
1.5*(DL+EX)
1.5*(DL-EX)
1.5*(DL+EY)
1.5*(DL-EY)
0.9*DL+1.5*EX
0.9*DL-1.5*EX
0.9*DL+1.5*EY
0.9*DL-1.5*EY

Initially a column dimension of 600x600mm and beam dimension of 400x400mm is fixed for the building. Normal concrete frame building in all 4 zones along with flat plate and flat slab is modelled and analyzed in the initially chosen dimension and the results are compared .among the twelve developed models about six models were not passing in design as per ETABS, as a result the dimensions for column and beam in those cases has been increased until it passes the design criteria. Then the new set of obtained results is also compared in this paper.

III. RESULTS AND DISCUSSION

The below are the maximum storey displacement for regular concrete frame building with same dimensions.

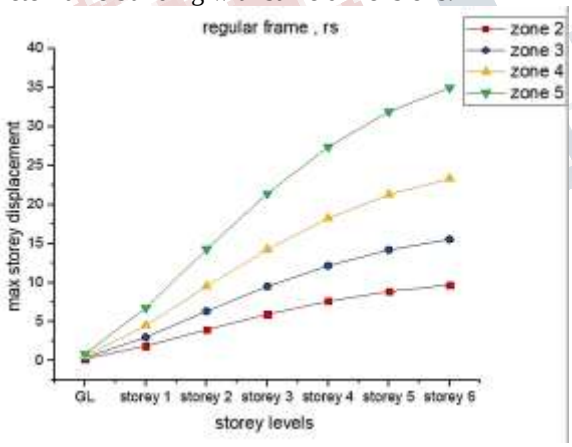

Fig 4. Maximum storey displacement (in mm) plot for normal concrete frame building in all zones

Here as expected the lowest value of storey displacement is found at zone 2 which is 9.7186mm,and the maximum storey displacement was found at zone 5 to be 35.0026mm this result is based on response spectrum analysis , but as per equivalent static method of analysis the lowest storey displacement is found at zone 2 which is 15.1754mm while highest is in zone which with the value 54.6558mm.

The below shown are the maximum storey displacements of flat plate in all zones with the initial dimension suggested. Since being flat as there is no beams there has been a large increase in shear and moment at the column region resulting in design failure at all the four zones as per ETABS

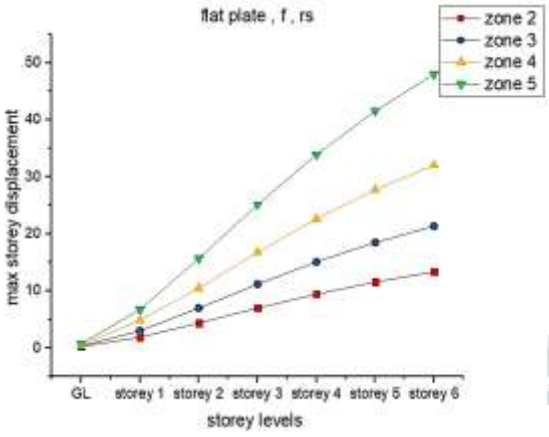

Fig 5(a) : maximum storey displacement(in mm) for failed flat playe in all zones

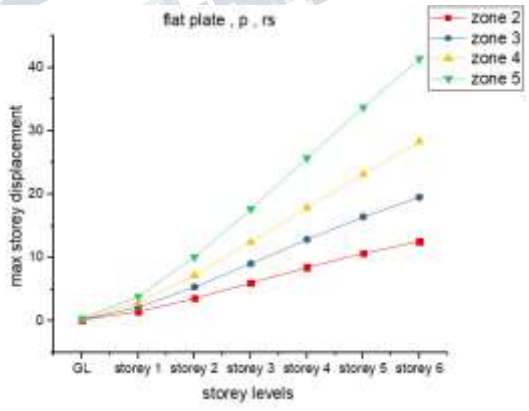

Fig 5(b): maximum storey displacement(in mm) plot for flat plate in all zones

Here the maximum storey displacement for flat plate under initially provided column and beam dimensions is occurring as expected at zone 5 and the value is 48.0429mm , since flat plate at all the four zones are not passing the design there has been an updating on the size of columns and beams so that it passes the design check in all zones , and in the newly obtained result the maximum displacement was found to be 41.4631mm at zone 5 as per

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response spectrum and 76.052 as per equivalent static method.

Now the next plot will be the maximum storey displacement for all zones in flat slab. Here the maximum storey displacement is obtained at zone 5 as expected and the value is 29.3524mm as per response spectrum method and 44.6682mm as per equivalent static method. The interesting conclusion obtained from flat slab analysis is that, with the initial column and beam dimensions provided there was no failure in any of the four zones. And the maximum storey displacement is less than that of the regular concrete frame building at zone 5

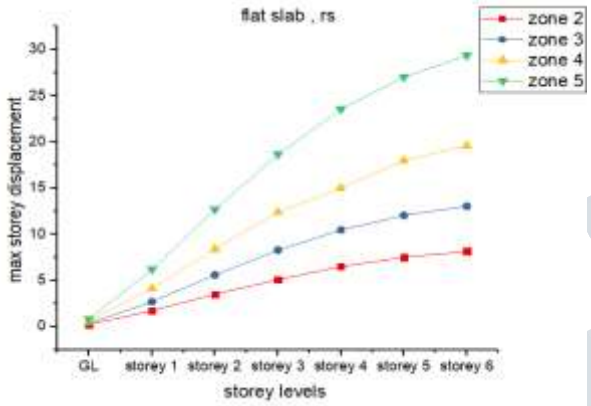

Fig 6: maximum storey displacement (in mm) plot for flat slab in all zones

Now the next part of the result and discussion will be mutual comparison of regular concrete frame with flat plate and slabs at each zone separately

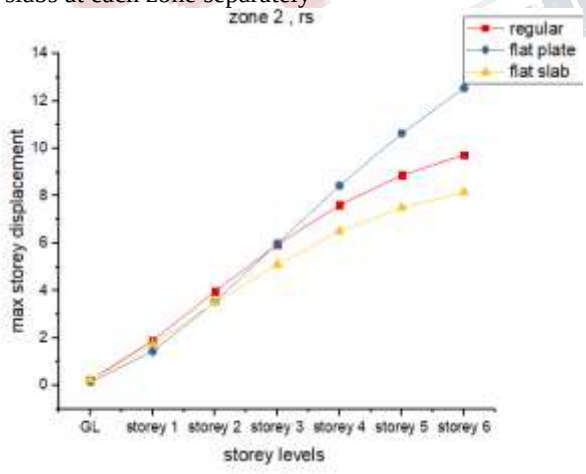

Fig 7(a):mutual comparsion of regular frame, flat plate and flat slab in zone 2

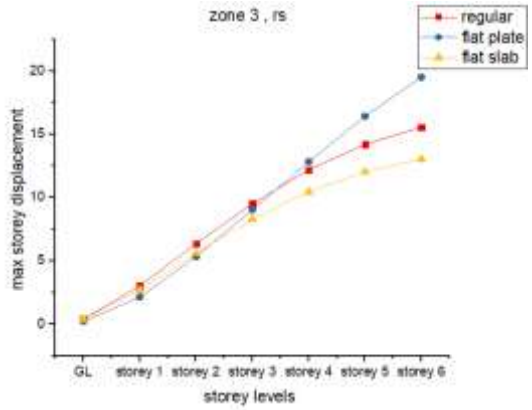

Fig 7(b) : mutual comparison of regular frame , flat plate and flat slab in zone 3

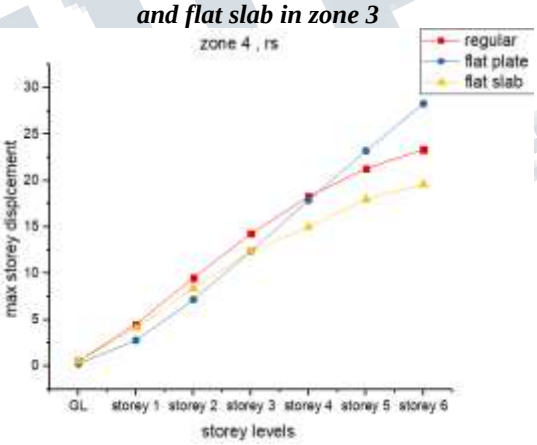

Fig 7(c) : mutual comparison of regular frame ,, flat plate and flat slab in zone 4

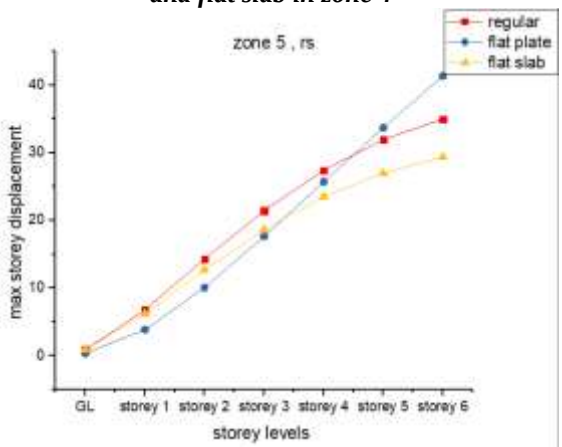

Fig 7(d): mutual comparison of regular frame, flat plate and flat slab in all zones 5

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Here from analyzing the graph one could say that maximum storey displacement in flat plate Is way higher compared to the regular frame and flat slab. This is basically because there is no beam present In them , beams are not found in flat slab as well but the 2mX2m size drop provided above every column in flat slab will account for the resistance contributed by the beam.
On comparing the maximum storey displacement values obtained from equivalent static method and response spectrum method the below table shows the percentage variation between them

Table 1: max storey displacement comparison between response spectrum method to equivalent static method

RS method and LS method comparison	Storey displacement
Types of building	Percentage variation
Regular concrete frame	RS=68%ES
Flat plate	RS=58%ES
Flat slab	RS=70.5%ES

IV. CONCLUSIONS

From the maximum storey displacement comparison of three types of buildings in all four zones as per IS456:2000 and IS1893:2000 following conclusions were drawn
1. The storey displacement was highest in zone 5 and lowest in zone 2 in all types of buildings
2. The displacement was found higher in flat plate while the displacement was found the lowest in flat slab.

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