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STUDY OF SEISMIC BEHAVIOUR OF BUILDINGS WITH FLAT SLAB

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Abstract - *The word "flat slab" is better understood as the slab without beams resting directly on supports. In case of flat slab, large bending moment and shear forces develops near the columns. Due to this, stresses are developed leading to cracks in concrete which may be further responsible for the failure of slab. Therefore in order to avoid this, flat slab are usually provided with drop and column head or capitals. Two models are prepared. First model is a commercial building consisting of flat slab with drop and second model is a commercial building consisting of slab without drop. Firstly, the behavior of both buildings were studied and analyzed separately for all seismic zones and then finally, a comparison between both structures was made. Analyses were carried out using Response Spectrum method with the help of ETAB version 15.2.0. In order to study the behaviour, only maximum values were considered for the parameters like Storey Displacement, Storey Shear, Storey Drift, Storey Acceleration and Overturning Moment. From the results generated, it is quite clear that the building consisting of flat slab with drop shows better seismic performance*.

Key Words: **Flat slab, drop, Seismic performance, Response spectrum analysis, ETAB**

1. INTRODUCTION

Earthquakes are one of the most destructive natural phenomenon and their occurrence is beyond human control. Most of these earthquake are man-made. Thus, we human beings are responsible to provide protective and safety measures to withstand this earthquake to some extent. Human being faced a large number of natural disaster like earthquake, floods, tornadoes, hurricanes and volcanic eruptions from time to time. Though the disaster caused by floods, tornadoes, hurricane and volcanic eruptions are much more severe than those of earthquake, but the occurrence of earthquake are totally unexpected. Most of the earthquake in the present scenario is mainly due to high rise buildings in the developing countries with huge number of population. The disaster caused during the earthquake are not because of the earthquake itself but because of human acts of poorly designed constructed buildings. In the present work, the performance of flat slab with and without drop for various loads at all seismic zones have been studied.

2.1 LITERATURE REVIEW

Many Research works has been carried out to know the Seismic response of a flat slab building since from many decades. Flat slab are preferred by both architects and clients due to their aesthetic and economic advantages. Literature survey for the seismic behavior of flat slab buildings has also been concealed.

K. S. Sable et al (2012), compared the seismic behavior of multistoried flat slab building and conventional reinforced concrete framed structure. The modelling and analysis of the structure have been performed using STAAD Pro 2007. Certain analysis were also made for the analysis such as the height of the structure was kept 17.5m, 25m, 32.5m, 39.5m and from ground these buildings are of 5 storey, 7 storey, 9 story and 11 story. Zone II was considered for the analysis. The author concluded that natural time period will increase as the height of structure increases for both but it will be same if they are provided with shear wall. As the height of the structure increases, the base shear also increases. The Conventional RCC building has less base shear as compared to the flat slab structure. The flat slab structure has more story drift then that of conventional RCC building.

Pradip S. Lande and Aniket B. Raut (2015), carried out a parametric investigation to identify the seismic response of system considering Zone V. They have considered the following elements for their works- (a) building with flat slab, (b) flat slab with parametric beam, (c) flat slab with shear walls, (d) flat slab with drop and (e) conventional building. Analyses were carried out using ETabs nonlinear version 9.7.3 for determining the seismic performance of the structure. They considered G+6 and G+12 storied building. Column size 450mm x 450mm and beam size 230mm x 400mm were considered for G+6 and column size of 650mm x 650mm and beam size 230mm x 500 mm were considered. On the basis of the work carried out, the author concluded that the storey displacement is found to be maximum for flat slab building as compared to conventional RCC building. The maximum storey drift found for G+6 building was 0.04 % of height.

Basavaraj and Rashmi B. A (2015), considered G+4 and G+8 storied building for their work. In their model they have also added parameters like perimeter beam, infill walls, shear walls and they have also increased the cross sectional area of the columns. The outer beam and column size provided was

0.4m x 0.4m for G+4 storied building and for G+8 storied building, the column provided up to 5th story was 0.5m x 0.5m and from 5th to 9th story 0.4m x 0.4m column was provided and the outer beam provided was 0.4m x 0.4m. They considered Seismic Zone II for their analysis and soil type II (medium). From the analysis they concluded that the fundamental natural period of the building decrease with increase in storey stiffness due to the presence of infill walls, shear walls and perimeter beam. The presence of infill's can significantly reduce the lateral drift. Base shear will increases with increase in mass and stiffness of building, also the shear wall is very effective to resist horizontal forces during earthquake and wind forces etc.

R. P Apostolka et al (2008), carried out the analysis for six type of structural system for a prototype of a residential building in Skopje. To determine the seismic behavior and resistance of a flat slab structural system, they considered B+GF+4 residential building. The analyses have been carried out using finite element method and SAP 2000 version 10.0.9 software. From the analysis, they concluded that the purely flat slab RCC structural system are more flexible for the horizontal loads then other traditional RCC frame structure. Structural element modification will improve the low bearing capacity and deformability and will also increase the seismic resistance of a purely flat slab structure.

Salman I khan and R. Mundhada (2015), carried out the dynamic analysis of three different multistoried building i.e., 12, 15, 18 story. They considered all the four Seismic Zones using response spectrum method and the analyses were performed using ETabs version 9.7.3. From the analysis they concluded that the choice of the system for slab in case of multistoried RCC building is very important for resisting the internal forces. From the analysis it was found that the base shear of building with flat slab will be greater as compared to building with grid slab at the terrace level. Also the lateral displacement will be less for grid slab than those of flat slab structure. The storey drift and time period will also be more for flat slab than the grid slab.

Sukanya Sawant and K.R Dhabhekar (2016), have reviewed the behavior of flat slab under dynamic loading. To carry out the analysis they considered five different model i.e. (a) commercial slab, (b) flat slab, (c) flat slab with drop, (d) flat slab with column head and (e) flat slab with column head and drop. They have worked out using ETabs considering linear static analysis and response spectrum method. Lot of research were done on flat slab building using dynamic analysis and finally they came to a conclusion that the punching shear will be more at the column support. To avoid these drop should be provided. They came to a conclusion to provide flat slab with drop and head in the Seismic Zones and the ductile detailing have to be carried out for the structure.

Mohana H. S and Kavan M. R (2015), have performed a comparative study of flat slab and conventional slab building using ETabs for all the Seismic Zones. They considered G+5 multistoried commercial building having a flat slab and conventional slab. They have carried out the analyses for base shear, storey drift, axial force and displacement. On the basis of result obtained, it is observed that the storey shear will be maximum at the ground level and will be minimum at the top storey. The axial force intensity at Zone II, III in case of conventional slab will be more as compared to flat slab. Displacement depends on the height and slenderness of building. They also found out that the displacement of structure with flat slab is slightly more as compared to the conventional slab for all Earthquake Zone. The displacement variation was 4mm for each Seismic Zone for both flat slab and conventional slab.

B. L. Gupta and Amit Gupta, has published a book on principles of Earthquake Resistance Design of Structures and Tsunami. This book deals with the basic Principles of earthquake resistant construction of structures. They have written with a view to spread awareness of mass destruction of structures due to earthquakes and safe guards against this destructions.

2.2 OBJECTIVES OF PRESENT INVESTIGATION

The Main objectives of the present investigation are as follows:

(i) Examine the behaviour of a commercial building having flat slab with and without drop for the response parameters like storey displacement, storey drift, storey shear, storey acceleration and overturning moment.
(ii) Comparing the result of the commercial building having flat slab with and without drop at all the Seismic Zones.
(iii) Comparing the results of both structure having flat slab with and without drop at all Seismic Zones.

3. METHODOLOGY

To examine the seismic behaviour of flat slab building with and without drop, comparative analytical study has been carried out between the models using response spectrum method. The analyses have been performed using ETAB version 15.2.0. In response spectrum method, for the calculation of displacement and member forces, only the maximum values are considered in the model using smooth design spectra that are the average of several Earthquake movements.

3.1 DESCRIPTION OF MODELLING

The detailed description of the model considered for the analysis is as follows:

3.1.1 Structural Plan Details

Structure type	R.C.C (SMRF)
No. of stories	G+9
Height of each storey	3 m
Total Height of structure	36 m
Plan Dimension	30 m x 24 m
Area of the building	720 m²

3.1.2 Material Properties

[1] Grade of Concrete	M_{25}
[2] Young's Modulus	25000MPa
[3] Shear Modulus	10416.67MPa
[4] Density	76.9729kN/m³
[5] Poisson's Ratio	0.2
[6] Co-efficient of thermal Expansion	0.0000055 1/°c
[7] Rebar	HYSD 500
[8] Young's Modulus	2 x 10^5MPa
[9] Co-efficient of thermal Expansion	0.00000177 1/°c

3.1.3 Section Properties

Columns	800mm x 1750mm
Beams	230mm x 450mm
	300mm x 750mm
Slab	150mm
Flat Slab	375mm
Drop	500mm
Plinth Beam	300mm x 300mm

3.1.4 Load Consideration

1. Gravity Load

Live Load	5kN/m²
Floor Finish	1.5kN/m²
Partition Load	1kN/m²

2. Lateral Loads

Seismic Zone	II, III, IV, V
Zone Factor	0.1, 0.16, 0.24, 0.36
Importance Factor	1.5
Response Reduction Factor	5
Damping Ratio	0.05
Type of Soil	Medium
Wind Speed Vb	33m/Sec
Design Wind Pressure Pz	1.6kN/m2
Time Period	$0.075h^{0.75}$

4. RESULTS AND DISCUSSION

Response spectrum analysis is carried out for two different models consisting of flat slab with and without drops for all Seismic Zones of India for both G+9 storey buildings. The results obtained from the analysis are tabulated and graphs are prepared for the response parameters like storey displacement, storey drift, storey shear, storey acceleration and overturning moments. The Results obtained from the analysis are shown in the form of charts.

4.1 Comparison of Commercial building consisting of Flat Slab with Drop at all four Seismic Zone

Comparisons are carried out for all zones for the flat slab with drop. Storey displacement, storey shear, and storey acceleration will be maximum at the top and least at the base. The storey shear and storey acceleration will be more at the base and least at the top storey. This values changes as the seismic intensity increases. Graph of height verses Storey displacement, Storey drift and overturning moment are shown in chart 1, chart 2, and 3 respectively. Further a Graph of number of Storey verses Storey shear, Storey acceleration are shown in chart 4 and 5.

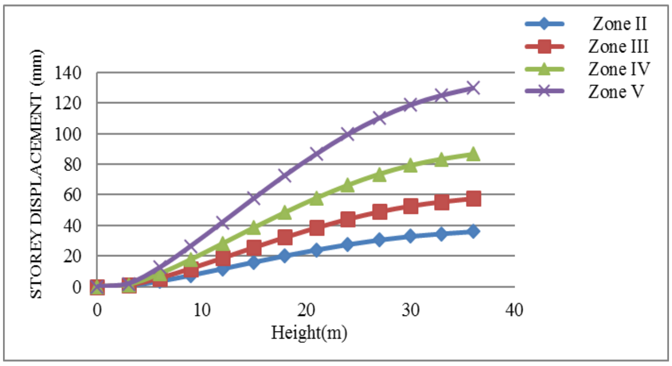


Chart 1: Storey Displacement verses Height for Flat Slab with Drop

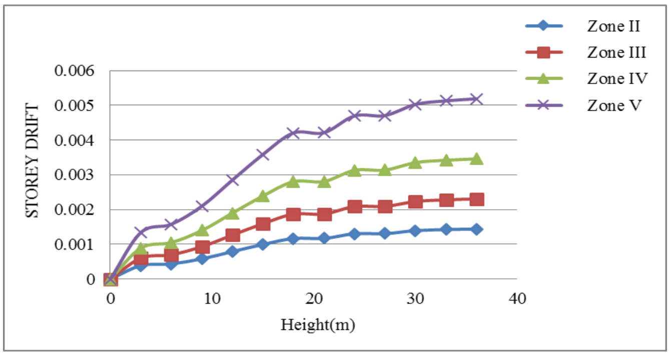


Chart 2: Storey Drift verses Height for Flat Slab with Drop

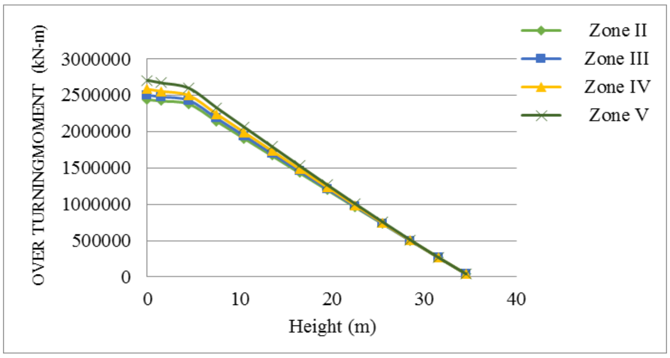
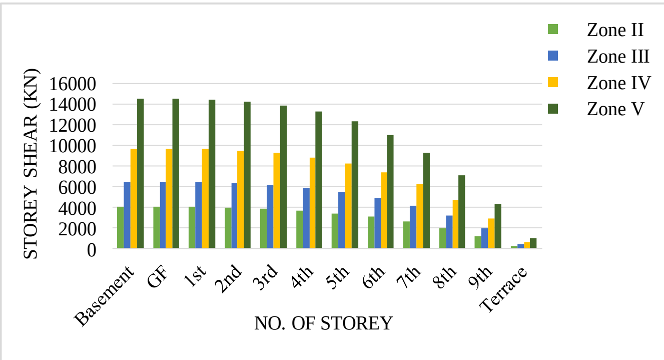


Chart 3. Overturning Moment verses Height for Flat Slab



with Drop

Chart 4: Storey Shear verses Number of Storey for Flat Slab with Drop

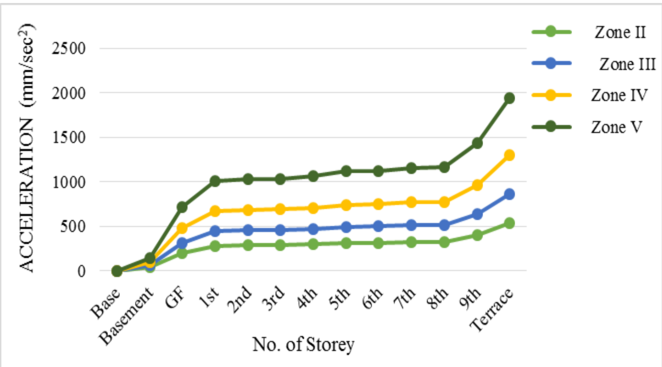


Chart 5: Acceleration verses Number of Storey for Flat Slab with Drop

From the above charts, it is observed that the storey displacement, storey drift and storey acceleration will be less at the base and more at the top storey. The average storey displacement for the flat slab with drop is nearly 2.6mm. As per IS 456:2000, Cl. 20.5, the lateral sway at the top should not exceed H/500, where H is the total height of the building which is 72mm. This values are more in case of zone IV and V as per the work carried out for the flat slab with drop. The storey drift as per IS 1893(Part -I) Cl. 7. 11. 1, the minimum storey drift should not exceed 0.004 mm times the storey height which is 0.144 as per the work carried out. This conditions are satisfied in all cases. The overturning moment at Zone V will be 9% more compared to Zone II, 7% more compared to Zone III and 4% more compared to Zone IV. The storey shear and storey acceleration will be more at the base and less at the top storey. As per IS 456:2000, Cl. 20.2, the structure shall have a factor against sliding of not less than 1.4 under the most adverse combination of the applied characteristic forces, which is more in case of Zone V.

4.2 Comparison of commercial building consisting of flat slab without drop at all four Seismic Zones.

Graph of height verses Storey displacement, Storey drift, overturning moment is as shown in charts 6, 7, 8 and Graph of number of Storeys verses Storey shear, acceleration is as shown in chart 9 and 10 respectively.

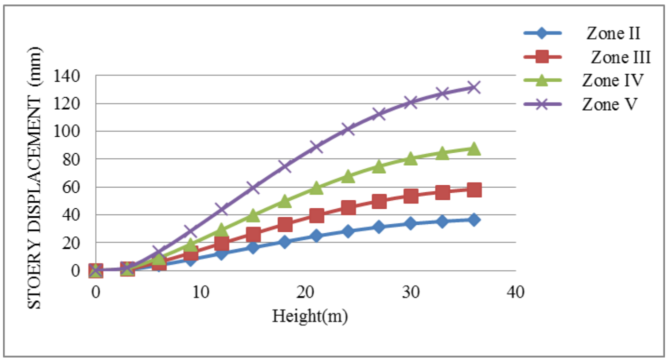


Chart 6: Storey Displacement verses Height for flat slab without Drop

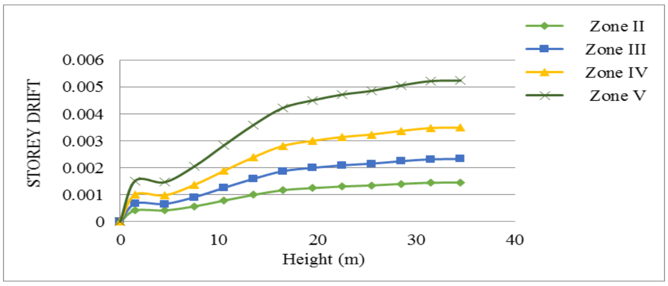


Chart 7: Storey Drift verses Height for Flat Slab without Drop

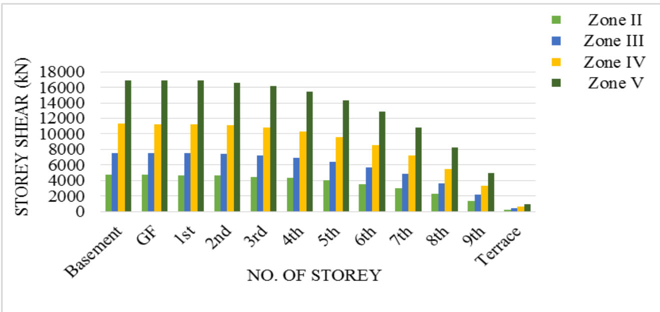


Chart 8: Storey Shear verses Number of Storey for Flat Slab without Drop

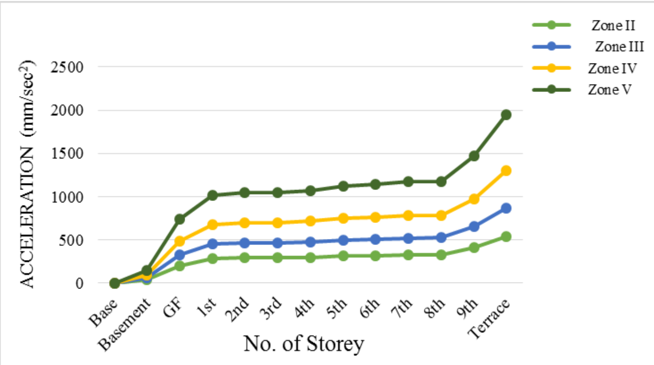


Chart 9: Acceleration verses Number of Storey for Flat Slab without Drop

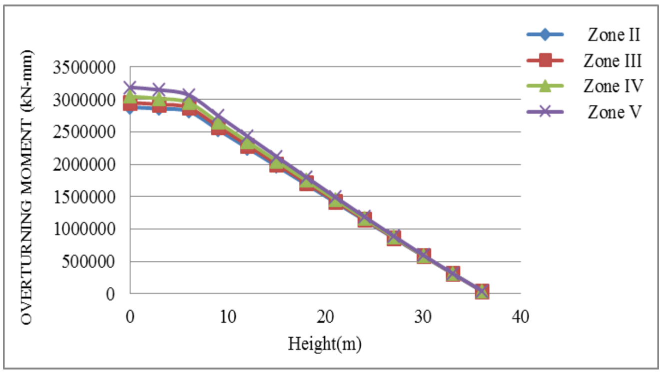


Chart 10: Overturning Moment verses Height for Flat Slab without Drop

From the above charts, it is observed that, as the seismic intensity increases all the above parameter increases. The average storey displacement for the flat slab without drop is nearly 2.1mm. Compared to all Zones, the displacement are more at Zone V. As per IS 456:2000, Cl. 20.5, the lateral sway at the top should not exceed H/500, where H is the total height of the building which is 72mm. This values are more in case of Zone IV and V. The storey drift and acceleration are more at the top storey and least at the bottom storey for both flat slab with and without drop. As per IS 1893 (Part I):2002, Cl, 7.11.1, the minimum storey drift should not exceed 0.004 times the storey height which is 0.144 as per the work carried out. This conditions are satisfied in all cases for the flat slab without drop. Storey acceleration depends mainly on the amount of drift taking place in the building. The storey shear is maximum at the bottom and decreases as the height of the structure increases for both flat slab with and without drop. The overturning moment at Zone V will be 9% more compared to Zone II, 7% more compared to Zone III and 4% more compared to Zone IV. As per IS 456:2000, Cl. 20.5, the stability of structures in case of overturning should not be less than 1.2 times the maximum overturning moment due to the characteristic dead load and 1.4 times the characteristic imposed loads. This values are more at Zone IV and V for the flat slab without drop.

4.3 Comparison of commercial building consisting of flat slab with and without drop

Comparisons were made for all the parameters at all Seismic Zones. The response parameters shows significant variations at Zone V compared to all other Seismic Zones. Also, as the height of the structure increases, these values will also increase. In case if additional moments are developed, the buildings should be provided with columns that are specially designed to resist such moments cause by the drift. This difference will be less if the building width provided is more. The results obtained from the analysis are shown in the form charts Viz: 11, 12, 13, 14 and 15 respectively.

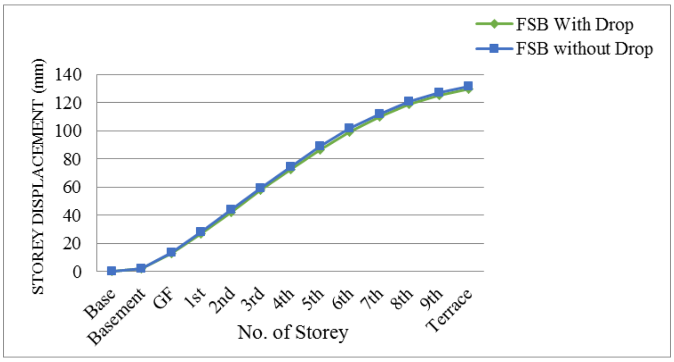


Chart 11: Storey Displacement verses Number of Storey for FSB with and without Drop at Zone V

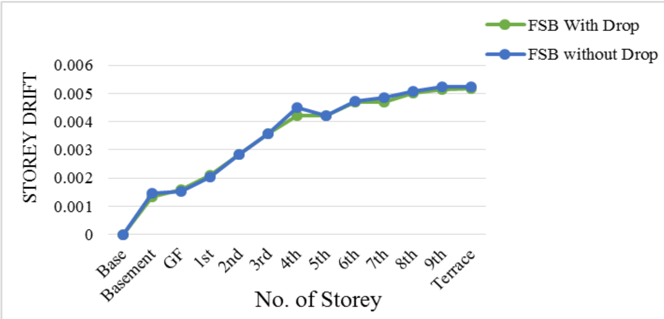


Chart 12: Storey Drift verses Number of Storey for FSB with and without Drop for Zone V

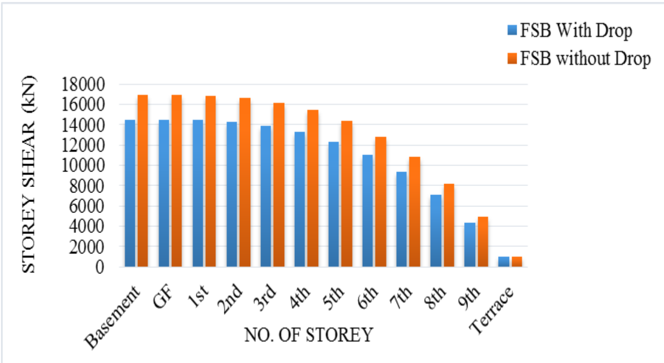


Chart 13: Storey Shear verses Number of Storey for FSB with and without Drop for Zone V

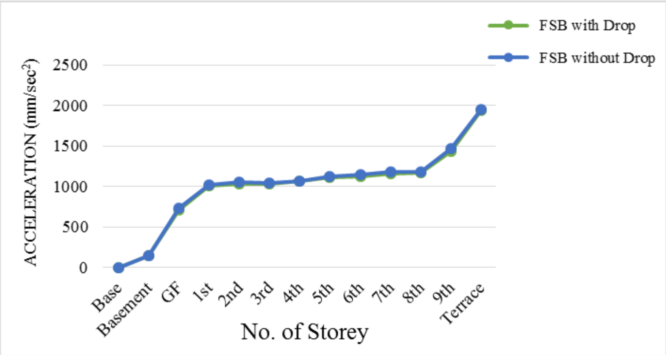


Chart 14: Acceleration verses Number of Storey for FSB with and without Drop for Zone V

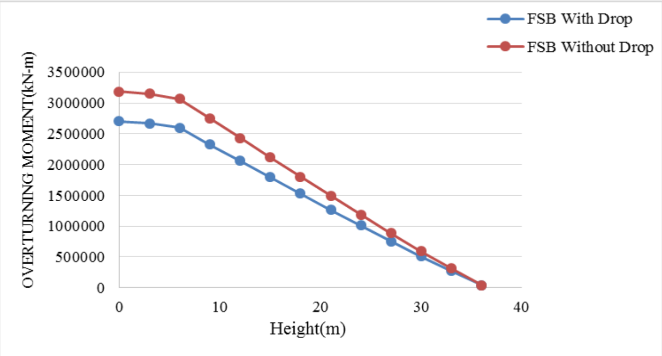


Chart 15: Overturning Moment verses Height for FSB with and without Drop for Zone V

From the above Chart, it is observed that the difference in storey displacement for flat slab with and without drop is 1.7mm at the terrace level. As per IS 456:2000, Cl. 20.5, the lateral sway at the top should not exceed H/500, where H is the total height of the building which is 72mm. This values are more in case of Zone IV and V for both flat slab with and without drop. As per IS 1893 (Part I):2002, Cl, 7.11.1, the minimum storey drift should not exceed 0.004 times the storey height which is 0.144 as per the work carried out. This conditions are satisfied in all cases for both the structure. The decrease in the storey drift for the structure consisting of flat slab with drop is 8% at the bottom storey and 1% at the top storey when compared to flat slab without drop. The increase in storey shear for flat slab without drop was 14% at the basement and 0.5% at the top storey when compared to flat slab with drop. The structure consisting of flat slab without drop will experience 4% more storey acceleration at the bottom storey and 0.5 % at the top when compared to the structure consisting of flat slab with drop. As per IS 456:2000, Cl. 20.2, the structure shall have a factor against sliding of not less than 1.4 under the most adverse combination of the applied characteristic forces, which is more in case of zone v. As per IS 456:2000, Cl. 20.5, the stability of structures in case of overturning should not be less than 1.2 times the maximum overturning moment due to the characteristic dead load and 1.4 times the characteristic imposed loads. This values are more at Zone IV and V. The Overturning moment will be more for flat slab without drop as compared to flat slab with drop with a percentage difference of 15%.

5. CONCLUSIONS

The important conclusions drawn on the basis of analysis are as follows.

[1] The storey displacement is less for the flat slab with drop as compared to the flat slab without drop with an average of 2mm displacement variation in each zones. The difference between the two structures will be minimum if the width provided is more.

[2] The storey drift is 8% more in case of flat slab without drop as compared to flat slab with drop for all seismic zones. The additional moments developed can be avoided by providing a suitable column considering the additional moments caused by the drifts or by increasing column stiffness.

[3] The storey acceleration will be 0.5% more for the flat slab without drop as compared to flat slab with drop at all seismic zones. The storey acceleration will be maximum at the top and minimum at the base.

[4] The storey shear for flat slab without drop is 14% more as compared to flat slab with drop for all seismic zones. The storey shear is maximum at the base and minimum at the top storey.

[5] The overturning moment for the flat slab without drop is 15% more as compared to the flat slab with drop for all seismic zones. The overturning moment will be maximum at the base and minimum at the top storey.

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