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ANALYSIS AND SEISMIC DESIGN OF FLAT SLAB R.C.C. STRUCTURES

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Abstract— Latest earthquake in which many flat slab concrete building have been badly destructed or collapsed, have require the necessity to study seismic analysis of flat slab structure. We can't repudiate upcoming earthquakes, but awareness and not dangerous building construction execution can positively diminish the level of destruction and harm. Flat slab buildings are the building in which slab without beam directly resting on the column. These building provide decent aesthetic view, flawless light visibility and much more improvement as parallel to other building in terms rapidity of construction, frugality etc. But these types of buildings are generally avoided due to their deprived performance during earthquake.

This dissertation presented herein can be considered into two main aspects.

In the first aspect behavior of flat slab building is compare with the conventional and a camouflage model. Frequency analysis, response spectrum analysis are compared with each other. Nonlinear pushover analysis also performed in order to get the performance of flat slab building and compare the result with conventional and a camouflage model. This dissertation also shows a relative study on the base of cost of flat slab building, conventional building and a camouflage model. All the models are providing with identical floor area and height. The charge per unit area for finishing thing remain equal for all only concrete volume and steel are assessed and lastly cost are related.

In the second aspect the plot between the base shear vs. displacement of the structure, so-called pushover curves are implemented on the flat slab structure by means of the most ordinary software SAP 2000 after designing the flat slab by different code such as IS 456, ACI 318, NZS 3101 etc. The pushover curves is plotted in both x and y directions. By carry out this push over study, we can recognize the weak regions in the building and formerly we will adopt whether the specific portion of the building is retrofitted or changed according to the requirement. Time history analysis is also performed on the flat slab building in order to get the dynamic response which varies according to the stated time function..

***Keywords*— Flat Slab, Concrete Strength, R.C.C Column, SAP 2000**

1.0 INTRODUCTION

Reinforced concrete flat slab building represent decorous and easy to constructed floor system. These kinds of structure are preferred by equally architects and client for the reason that they provide decent artistic view, flawless light visibility and much new improvement as parallel to other building in terms rapidity of construction, frugality etc. Flat slab building are the building in which slabs is directly supported by columns. The column head is occasionally enlarges so as to reduce the punching shear in the slab. The enlarged portion is called column head. Moment in the slab is more nearby the column. Hence the slab is thickened nearby the columns by providing the drops so-called as drop panel.

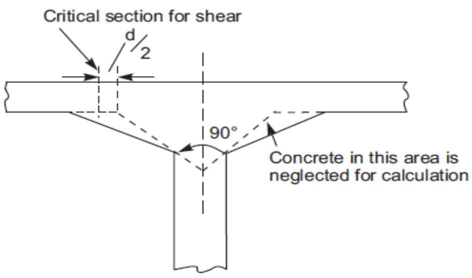
Flat slab are of following categories

(a) Slab without drop plus column with column head

(b) Slab with drop plus column without column head.

(c) Slab without drop plus column with column head

(d) Slab without drop plus with column head.



(a) Slab without drop plus column with column head

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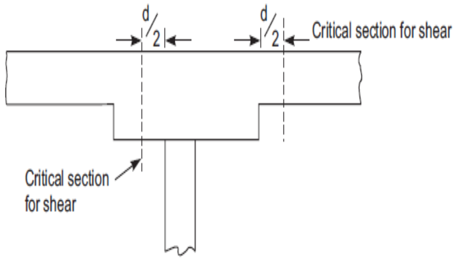
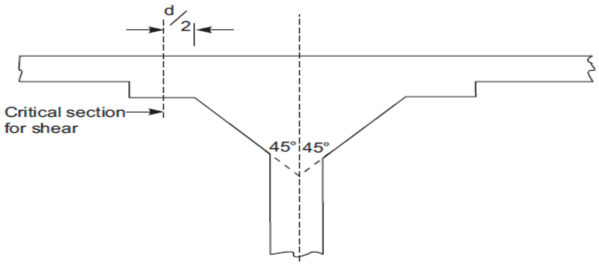
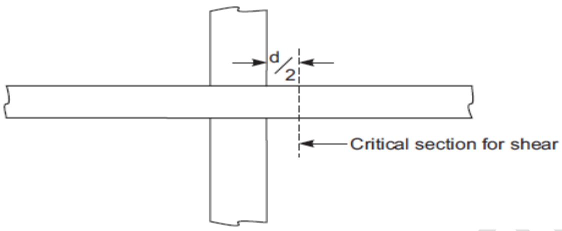


(b) Slab with drop plus column without column head



(c) Slab without drop plus column with column head



(d) Slab without drop plus column head

1.1 BEHAVIOUR OF FLAT SLAB BUILDING DURING EARTHQUAKE

The behavior of this kind of structure systems with flat slab show significant drawbacks such as the non-dissipative characteristics of their seismic reaction. Enactment of the flat slab building during earthquake is not acceptable. Due to their flexibility flat slab structure shows large displacement under lateral loading. The most important determinant effect on the structure is caused by lateral component of the earthquake on the flat slab building. Earthquake loading effect on structures are quite varying as compare to gravity loading and it effect the structure more as the height of the structure increases. Most of the low and midrise structure having good structural system carry earthquake loading while the structure having not appropriate structural system fail. Stability of the structure depends on the overturning moment and hence depends upon the height of the building. Hence Stability and rigidity of the structure gets varies as height of the structure increases

.

Ancient practices show that the flat slab buildings are subjected to abrupt failure when it is acted upon by the earthquake loading. Flat slab structure collapse due to punching shear failure is shown in Fig 1.2 when it is subjected to Northridge earthquake (1994)

Fig- Failure of flat slab building [Pipers' row cark park, Wolverhampton, UK, 1997]

1.2 MODES OF FAILURE OF FLAT SLAB BUILDING.

There are some issues which are considered during the failure of flat slab building one of the most important issue is the brittle punching failure .In case of flat slab building generally two kinds of failure modes happens punching shear failure and flexure failure. Flexure failure occurs is a yielding way of failure which is always wanted for this type of structure as related to punching shear failure .But flat slab building generally fail in punching shear failure which is brittle mode of failure .The instant flat slab building are acted to gravity load and lateral load then and there reaction are condensed nearby the support. Punching shear stress at the critical segment nearby the column supports is produced due to transferal gravity load and unbalanced moment on slab column joint. Gravity load causes the even distribution of punching shear stress at the critical sections. Some portion of unbalanced moment is transmitted as torsion in slab column junction. When obtained punching shear stress exceed the permissible value of punching shear stress of flat slab building then failure of slab column junction takes place.

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1.3 OBJECTIVE OF THE STUDY

a) To study seismic performance of flat building and compare the result with conventional and a camouflage model. Response spectrum analysis, Frequency analysis is done in order to compare the result.

b) To study the cost of flat slab building on the basis of concrete volume and steel requirement and compare the result with other model.

c) To study the seismic behavior of flat slab structure designed by different codes. Nonlinear pushover analysis is performed on flat slab building and computes the target displacement.

To study the seismic performance of flat slab building with or without edge beam.

2.0 MODELLING OF FLAT SLAB BUILDINGS

The difference in behavior of flat slab structure with the frame structure lies in the load transfer mechanism At any column support in case of flat slab at the junction of column and slab transfer of part of moment which is unbalanced partially through increase of non-even shear stresses in the region of the column head. Total unbalanced part of moment are resisted by column in fraction using the relative stiffness's over and underside

As per ATC 40 Clause 9.4.2.2 for a column-slab frame element must be effectively detailed in order to show the stiffness, strength, and deflection capability of columns, slabs, slab-column joint, and other constituent which may be considered as part of the building frame.

Slab as well as column apparatuses must be modeled by consider shear as well as flexural rigidities, even though later might be ignored in certain cases. Potential failure of splices AS well as anchorages possibly will entail modeling of these aspect as well. Column-slab joints which are common in column and slab in terms of volume of concrete together with column capital can be considered to be rigid.

2.1 MODELLING APPROACHES

Different type of modelling approaches for analyzing the flat slab is:

1. Finite element approach
2. Equivalent frame approach
   a. Effective beam width procedure
   b. Transverse torsional member method
      i. ACI equivalent frame method
      ii. Extended equivalent column method
      iii. Extended equivalent slab method
      iv. Explicit transverse torsional member method

3.0 BUILDING DESCRIPTION

3.1 BUILDING CONFIGURATION

Building considered herein is a four storied Flat Slab building and all other model are also have symmetrical plan configuration. The building is having a dimension 40.70 m long, 11.5 m width and 14.05 m high. The plan and elevation of the building is shown in Fig.4.1 and Fig. 4.2.The floor area of the building is same for all floors. The building used in this report is taken from Tata Steel Guidelines for earthquake resistant design prepared by the department of earthquake engineering.

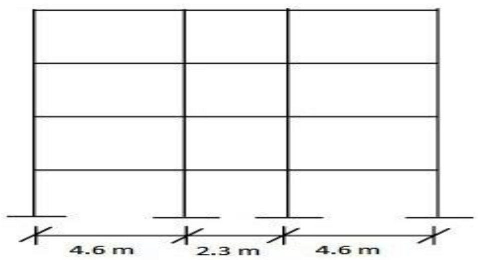

Figure 3.1: *Elevation*

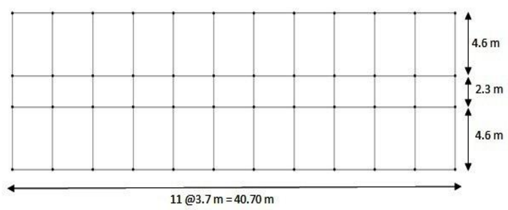

Figure 3.2: *Plan of the Building*

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3.2 SITE PROPERTIES

Seismic Zone: IV

Soil condition = Medium soil

3.3 GEOMETRIC PROPERTIES OF COMPONENTS

3.3.1 Model 1 Conventional Building

Slab Thickness = 120 mm External wall thickness = 250 mm

Internal wall thickness = 150 mm Ground storey height = 4.0 m

Floor to floor height = 3.35 m Beam: 300 mm X 450 mm

Exterior Column: 300 X 530 mm Interior Column: 300 X 300 mm

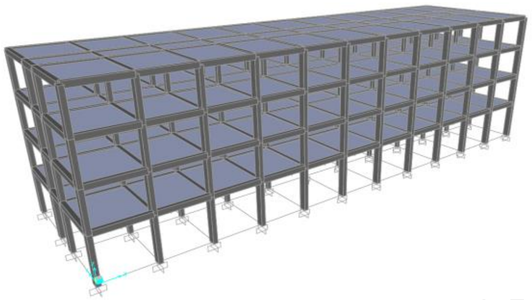

Figure 3.3.1: *Conventional 3D model*

3.3.2 Model 2: Camouflage

Slab Thickness = 120 mm External wall thickness = 250 mm

Internal wall thickness = 150 mm Ground storey height = 4.0 m

Floor to floor height = 3.35 m Beam: 300 mm X 120 mm

Exterior Column: 300 X 530 mm Interior Column: 300 X 300 mm

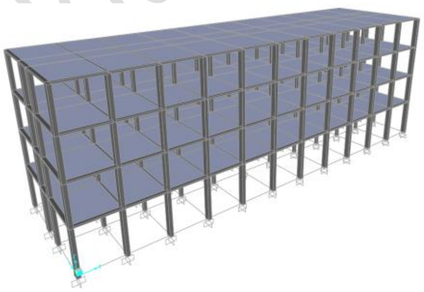

Figure 3.3.2 *Camouflage 3D model*

3.3.3 Model 3: Flat slab

Slab Thickness = 250 mm, External wall thickness = 250 mm.

Internal wall thickness = 150 mm Ground storey height = 4.0 m

Floor to floor height = 3.35 m Exterior Column: 300 X 530 mm

Interior Column: 300 X 300 mm

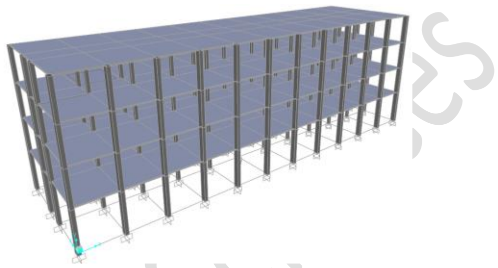

Figure 3.3.3 : *Flat Slab Building 3D model without perimeter beam*

3.3.4 Model 4: Flat slab with edge beam

Slab Thickness = 250 mm External wall thickness = 250 mm

Internal wall thickness = 150 mm Ground storey height = 4.0 m

Floor to floor height = 3.35 m Exterior Column: 300 X 450 mm

Interior Column: 300 X 300 mm Size of edge beam=300 mm x 450 mm

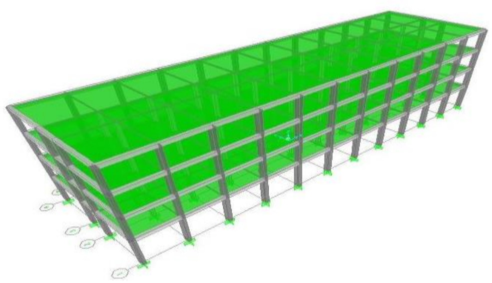

Figure 3.3.4: *Flat slab building with perimeter beam*

4.0 SUMMARY:

All the models are designed and analyse by using the software SAP 2000.Firstly flat slab building is compare with the two other model conventional building and camouflage model. Modal analysis is performed in order to compare the fundamental period, base shear and other factor.

Flat slab building is designed by using the different codes and results are compared in order to conclude that which code gives better result. Nonlinear pushover analysis is performed in order to get the performance of the structure.

Flat slab building is considered with or without edge beam as flat slab building generally fail in punching. So performance of flat slab building is compare with or without edge beam.

5.0 RESULT AND DISCUSSION

In this unit seismic analysis of building is carried out by considering the live load (L.L), dead load (D.L) and the earthquake load in the both direction i.e. sway to left (-EL) and sway to right (+EL) by the software SAP 2000 vs.14.The various load combination which are considered during the analysis of building design by IS 456:2000 are according to cls.6.3 of IS 1893 2001 and are given as Table 5.1.This chapter include seismic behavior of flat slab building design by different code IS 456 :2000,ACI 318-02,Eurocode 2:2004 and NZS 3101 .Pushover analysis of flat slab building is also studied in this chapter.

5.1 DIFFERENT LOAD COMBINATION

Flat slab building is designed for different load combination as per IS 456:2000 as shown in Table 5.1

Table 5.1: *Load combination suggested by IS 456:2000*

Load Case	Load cases
1	1.5(DL+LL)
2	1.2(DL+LL+EL)
3	1.2(DL+LL-EL)
4	1.5(DL+EL)
5	1.5(DL-EL)
6	0.9DL+1.5 EL
7	0.9DL-1.5EL

5.2 DESCRIPTION FOR LOADING

The loading on the buildings is considered as per following calculations

5.2.1 Calculation of Load

5.2.1.1 Dead Loads

External wall load = 0.25x (3.35-.45) x 20 = 14.5 kN/m

Internal wall load = 0.15x (3.35-.45) x 20 = 8.7 kN/m

Weight of the slab having thickness 120mm = 25 x 0.12 = 3 kN/m

Self-weight of building is automatically considered by the SAP software.

5.5.2 Live Loads

The live load of 3.5 kN/m^2 is considered on the buildings.

5.5.3 Earthquake Forces Data

Earthquake loading for the different model have been estimated as per IS-1893-2002:

Zone (Z) = II

Response reduction factor (RF) = 5 for SMRF. [IS-1893 (Part I):2002] Table-7

Importance factor (I) = 1 [IS-1893 (Part I):2002 Table-6]

S_a/g = Average response acceleration coefficient for various soil sites as given by Fig. 2 of IS-1893 (Part I): 2002 based on appropriate natural periods and damping of structures.

Time period of the building from the code has presented in Table-5.3

Table-5.3: *Time period and horizontal seismic coefficient*

Direction	Height (m)	Lateral dimension (m)	Time period (Sec)	S_a/g	A_h
X	14.05	40.70	0.198	2.5	0.06
Y	14.05	11.50	0.373	2.5	0.06

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5.4 MODAL ANALYSIS OF FLAT SLAB BUILDING

Table-5.4: *Section details of different model including flat slab building*

Model no.	Slab thickness (mm)	Beam (mm)	Column Size(mm)
Model-1 (Conventional)	120	300 x 450	Interior 300 x300 Exterior 300 X 530
Model-2 (Camouflage)	120	300x120	Same as above
Model-3 (Flat Slab)	250	No	Same as above

Modal analysis of flat slab building is accomplished using the modal load cases in SAP 2000.

Table 5.5: *Vibration characteristics of flat slab building based on different code.*

Fundamental Period	IS 456:2000	ACI 318	EURO CODE	NZS CODE
First mode	1.183133	1.27567	1.05678	1.21345
Second mode	1.140301	1.17568	1.01356	1.17686
Third mode	0.980374	1.03566	0.90988	1.00765
Fourth mode	0.358591	0.39807	0.31076	0.38765
fifth mode	0.33475	0.36098	0.29876	0.34789
Sixth mode	0.278935	0.29078	0.22346	0.29886

Table 5.6: *Vibration characteristics of flat slab building and flat slab building with edge beam*

Fundamental period	Flat slab building	Flat slab building with edge beam
First mode	1.183133	1.04
Second mode	1.140301	0.87554
Third mode	0.980374	0.749447
Fourth mode	0.358591	0.340826
fifth mode	0.33475	0.27867
Sixth mode	0.278935	0.239352

Table 5.7: *Comparison of base shear in flat slab building with other model.*

Parameter	Flat slab building	Conventional building
Base shear	1110 kN	1290 Kn
Roof displacement	28 mm	15mm

6.0 PUSHOVER CURVE OF FLAT SLAB BUILDING DESIGNED BY DIFFERENT CODE

6.1 PUSHOVER ANALYSIS FOR FLAT SLAB BUILDING WITHOUT PERIMETER EDGE BEAM AS PER BUILDING DESIGN BY IS 456:2000

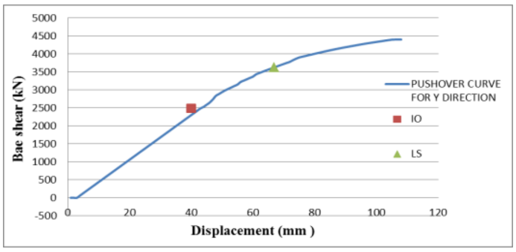

Figure 6.1: *Capacity curve in y direction for flat slab without perimeter beam as per IS456 2000*

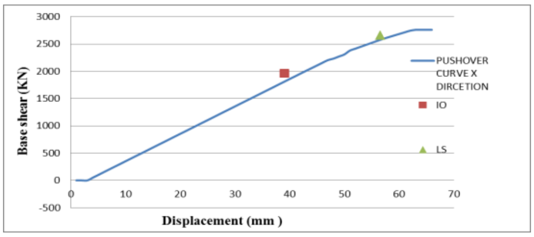

Figure 6.1.1: *Capacity curve in x direction for flat slab without perimeter beam as per IS456 2000*

6.2 PUSHOVER ANALYSIS FOR FLAT SLAB BUILDING WITHOUT PERIMETER EDGE BEAM AS PER BUILDING DESIGN BY ACI CODE

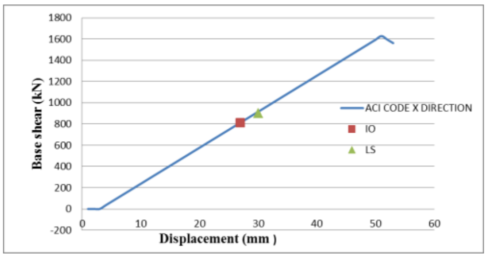

Figure 6.2: *Capacity curve in x direction for flat slab without perimeter beam as per ACI Code*

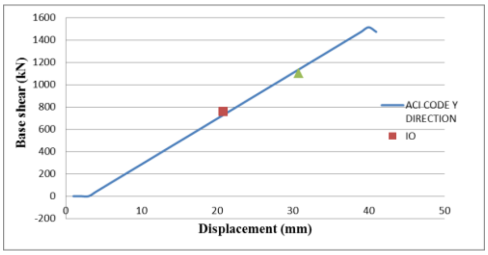

Figure 6.2.1: *Capacity curve in y direction for flat slab without perimeter beam as per ACI Code*

6.3 PUSHOVER ANALYSIS FOR FLAT SLAB BUILDING WITHOUT PERIMETER EDGE BEAM AS PER BUILDING DESIGN BY EURO CODE

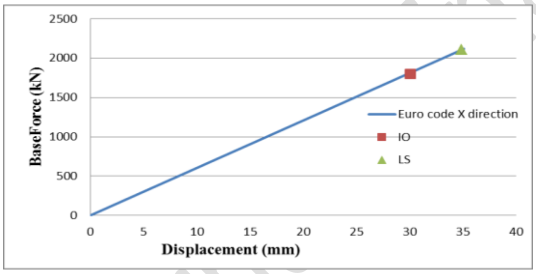

Figure 6.3: *Capacity curve in x direction for flat slab without perimeter beam as per Euro code*

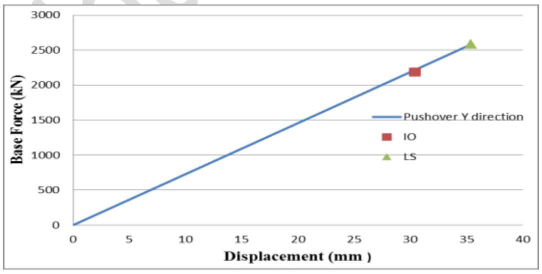

Figure 6.3.1: *Capacity curve in x direction for flat slab without perimeter beam as per Euro code*

6.4 PUSHOVER ANALYSIS FOR FLAT SLAB BUILDING WITHOUT PERIMETER EDGE BEAM AS PER BUILDING DESIGN BY EURO CODE

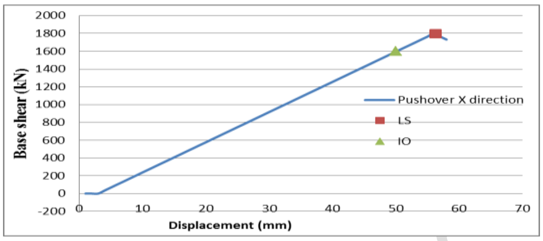

Figure 6.4: *Capacity curve in x direction for flat slab without perimeter beam as per NZS code*

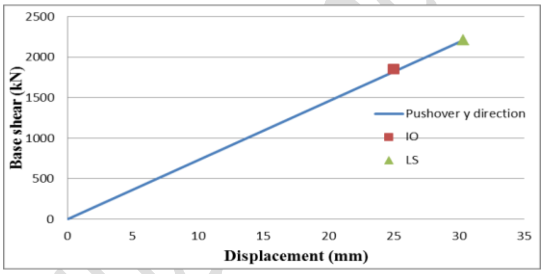

Figure 6.4.1: *Capacity curve in Y direction for flat slab without perimeter beam as per NZS code*

7.0 COMPARISON OF CAPACITY CURVE OF FLAT SLAB STRUCTURE BASED ON DIFFERENT CODE:

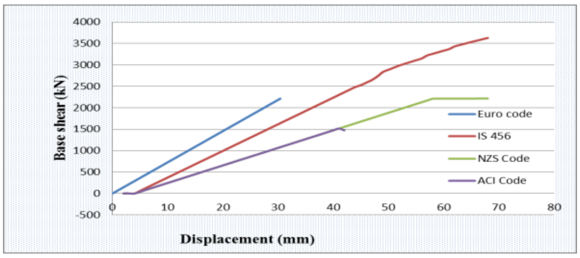

Figure 7.0: *Capacity curve in Y direction for flat slab without perimeter beam designed by different code*

The above pushover curve is for G +3 flat slab building without perimeter edge beam designed by different codes shows that performance of building designed by any codes is not good however a building designed by euro code show more base shear and can resist more roof displacement .However from the Fig to Fig shows that all the G +3 building shows that the designed building is safe as it is lies within the CP range. but building designed by different code shows that in all the LS exist and after that there is no CP point is getting so all the building does not show any collapse prevention point and collapse of structure takes place which is avoided as in case of flat slab building punching shear failure occurs. Performance of the building design by the IS 456 lies within the Euro code and NZS code and hence we conclude that a building design by Euro code is better as relate to other code but still that building is not safe as these building does not show any collapse prevention (CP).

8.0 CONCLUSION

Seismic analysis of flat slab building has been studied in this dissertation. Flat slab building, Conventional building and a camouflage model has been designed as per the provision of IS 456:2000 and the result of all the three model are compare. Flat slab building with rectangular plan is considered and designing the flat slab building is done by using different code such as IS456:2000, EC 2:2004, ACI 318-08 and NZS 3101 Part1 -2006.And the result are compare base on different codes .Flat slab building is designed by considering the flat slab without perimeter beam and with perimeter beam and different result are compare. Behavior of building is compare based on the nonlinear static pushover analysis for MCE peak ground acceleration of 0.24 on soil type II as per IS 1893:2002 part 1.The three story flat slab building is taken from guidelines for earthquake resistant building prepared by the department of earthquake engineering .Following are the main conclusion from the study of seismic analysis of flat slab building:

- Flat slab building, conventional building and a camouflage model with rectangular plan have been considered. And it is found that flat slab building is more flexible and less resistant to lateral loading however conventional building is the best one. Camouflage is the good alternative if it is required the building for good aesthetic and light visibility point of view.
- Fundamental period of flat slab building is the maximum among all model considered in this dissertation. However if a flat slab building is designed by different code then it is found that fundamental period calculated by Euro code is having the minimum value and ACI code has the maximum ones. So it is found that a flat slab building designed by Euro code gives the good result for lateral loading as compare to other code.
- Based on the comparison of cost of flat slab building with the other building it is found that Flat slab building being the good in aesthetic and other advantage in terms of architecture point of view are found to be less economical as compare to other model .Camouflage model designed by euro code serve the purpose if it is require to designed the building which is economical and looks like the flat slab.
- Performance of flat slab building is found to be unsatisfactory due to lateral loading as it is generally fail in punching shear and the failure propagate from the exterior column to the interior ones. So flat slab with perimeter beam is better as compare to flat slab without beam. However it is also not perform better during lateral loading.

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