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PARAMETRIC STUDY OF MULTISORIED R.C.C. FLAT SLAB STRUCTURE UNDER SEISMIC EFFECT HAVING DIFFERENT PLAN ASPECT RATIO AND SLENDERNESS RATIO

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ABSTRACT

Flat-slab building structures possesses major advantages over traditional slab-beam-column structures because of the free design of space, shorter construction time, architectural –functional and economical aspects. Because of the absence of deep beams and shear walls, flat-slab structural system is significantly more flexible for lateral loads then traditional RC frame system and that make the system more vulnerable under seismic events. The critical moment in design of these systems is the slab-column connection, i.e., the shear force in the slab at the connection, which should retain its bearing capacity even at maximal displacements. The behaviour of flat slab building during earthquake depends critically on 'Building Configuration'. This fact has resulted in to ensure safety against earthquake forces of tall structures hence, there is need to determine seismic responses of such building for designing earthquake resistant structures. Response Spectrum analysis is one of the important techniques for structural seismic analysis. In the present work dynamic analysis of 15 models of multi-storied RCC Flat slab structure is carried out by response spectrum analysis.

KEYWORDS: Aspect Ratio, Slenderness Ratio, Response Spectrum Analysis, Drift , Displacement, Storey shear, SMRF R.C.C. flat slab structure.

I. INTRODUCTION

A slab is a flat, two dimensional, plane structural element having thickness small compared to its other two dimensions. It provides a working flat surface or a covering shelter in buildings. It supports mainly transverse loads and transfers then to support primarily by bending element just like flat plate. Common practice of design and construction is to support the slabs by beams and support the beams by columns. This may be called as beam-slab construction. The beams reduce the available net clear ceiling height. Hence in warehouses, offices and public halls sometimes beams are avoided and s labs are directly supported by columns. These types of construction are aesthetically appealing also. These slabs which are directly supported by columns are called Flat Slabs.

A. Components of flat slab

1) ***Panel:*** Panel is defined as a part of a slab bounded on-each of its four sides by the centre-line of a Column or centre-lines of adjacent-span
2) ***Drops:*** The drops when provided shall be rectangular in plan, and have a length in each direction not less than one-third of the panel length in that direction. For exterior panels, the width of drops at right angles to the non- continuous edge and measured from the centre -line of the columns shall be equal to one -half the width of drop for interior panels.
3) ***Column Head:*** Where column heads are provided, that portion of a column head which lies within the largest right circular cone or pyramid that has a vertex angle of 90^0 and can be included entirely within the outlines of the column and the column head, shall be considered for design purposes.
4) ***Column Strip:*** Column strip means a design strip having a width of $0.25L_2$, but not greater than $0.25L_1$, on each side of the column centre-line, where L_1 is the span in the direction moments are being determined, measured centre to centre of supports and $L_2$is the span transverse to $L_{1,}$measured centre to centre of supports.

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5) ***Middle Strip:*** Middle strip means a design strip bounded on each of its opposite sides by the column strip.

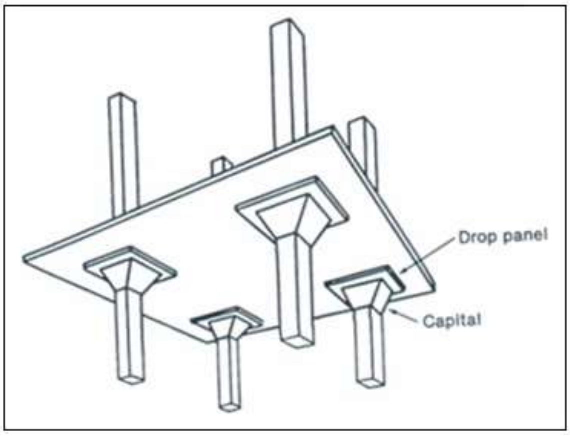

Fig .1 Showing Drop pannel of flat slab

II. LITERATURE REVIEW

The literature survey is carried out in following major areas. These are:

- Research papers on response of buildings (regular or irregular configuration) under seismic loading,
- Importance of Indian seismic design codes and their introduction in brief.
- Discussion about Building configuration.
- Literature based on behavior of structure under Seismic condition.

The first part of this chapter is devoted to a review of published literature related to behavior of building configuration under seismic loading. The response quantities include storey drift, lateral displacement, fundamental modal time period, fundamental frequencies, lateral forces, base shear and mode shapes.

The second half of this chapter is devoted to a review of design code perspective on Building configuration, Seismic analysis of structure using Response Spectrum method and seismic effect on structure. This part describes different parameters used in analysis of structure and their importance, which will aid in framing the outcomes of analysis.

The research paper and literatures collected on the various topics is listed below.

1. K S Sable (2012)
2. Mohit Sharma, SavitaMaru, (2014)
3. Rucha S. Banginwar and M. R. Vyawahare, (2012
4. Arun Solomon (2013)

III. MATERIALS AND METHODS

Table 1- IS Code Used

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SR	CODE	TITLE
1	IS 1893:2002	CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES _
2	IS 4326:1993	EARTHQUAKE RESISTANT DESIGN AND CONSTRUCTION OF BUILDINGS
3	SP 22	HANDBOOK ON CODES FOR EARTHQUAKE ENGINEERING (1893 & 4326)
4	IS 13920:1993	DUCTILE DETAILING OF REINFORCED CONCRETE STRUCTURES SUBJECTED TO SEISMIC FORCES

Data assumed for the current study is categorized as followed and presented in tabulated form

- Material properties and geometric parameters
- Load considered for designing building
- Seismic design data

A. Material Properties

M-30 grade of reinforcing steel are used for all the frame models used in concrete and Fe-415 grade of this study. Elastic material properties of these materials are taken as per Indian Standard IS 456 (2000). The short-term modulus of elasticity (*Ec*) of concrete is taken as:

$$Ec = \sqrt{5000fck}\text{MPa}$$

Where, f*ck*= characteristic compressive strength of concrete cube in MPa at 28-day.For the steel rebar, yield stress (*fy*) and modulus of elasticity (*Es*) is taken as per IS 456 (2000)

Table-2 Material Properties and Geometric Parameters

Sr. No.	Design Parameter	Value
1	Unit weight of concrete	25 kN/m^3
2	Characteristic strength of concrete	30 MPa
3	Characteristic strength of steel	415 MPa
4	Modulus of elasticity of steel	2 x e^5 MPa
5	Plan area	900 square meters
6	Slab thickness	200 mm
7	Drop thickness	300 mm
8	Depth of foundation	3.5m
9	Floor height	3.6m

Table -3 Load Considered For Analysis Of Building

Sr.No.	Load Type	Value

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1	Self-weight of Slab and Column	As per Dimension and Unit weight of concrete
2	Dead load of structural components	As per IS 875 Part-1
3	Live Load	As per IS 875 Part -2
4	Live load : on Roof and Typical floor	4.0 kN/m^2
5	Floor Finish	2.0 kN/m^2

Table-4 Seismic Design Data

Sr.No.	Design Parameter	Value
1	Earthquake Load	As Per IS 1893 (Part 1)-2002
2	Type Of Foundation	Isolated Column Footing
3	Depth Of Foundation	3.5m
4	Type Of Soil	Type II, Medium As Per IS 1893:2002
5	Bearing Capacity Of Soil	200 kN/m2
6	Seismic Zone	IV
7	Zone factor (Z)	0.24
8	Response reduction factor (R)	5
9	Importance Factor	1
10	Percentage Damping	5%
11	Type Of Frame	Special Moment Resisting Frame

Table-5 Cross Sectional Dimension for Column

Sr. No.	Type of Structure	Column sizes
1	G+ 3 (5 storey structure)	600 mm X 600 mm
2	G+ 5 (7 Storey structure)	600 mm X 600 mm
3	G+ 7 (9 Storey structure)	600 mm X 600 mm
4	G+ 9 (11 Storey structure)	600 mm X 600 mm
5	G+ 11 (13 Storey structure)	600 X 600 mm

B. *Modeling of Structural Element*

Beam and columns are modeled as frame elements available in ETABS 15 structural analysis software, with central lines joined at nodes. Column slab joint are considered as rigid slab-column joints. The floor slabs are assumed to act as diaphragms, which ensure integral action of all the vertical lateral load resisting elements. The weight of the slab was distributed as shell load distribution. The columns ends are fixed. A response spectrum analysis applied for analysis of all the 25 models.

C. Method Of Analysis

The Present Study Done for the Below Mentioned Analysis

1) Equivalent static analysis Method
2) Response spectrum method.

The steps undertaken in the present study to achieve the above-mentioned objectives areas as follows:

- Carry out extensive literature review, to establish the objectives of the research work.

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- Select an exhaustive set of R.C.C. flat slab building models with different number of storey (4 to 12 storeys), Aspect ratio (1to 5) in plan and constant plan area. (900 m2)
- Perform Response Spectrum Analysis for each of the 25 models.
- Analyse and compare the result obtained from response spectrum analysis of models which are base shear, storey drift, stiffness, natural time period, and frequency of earthquake. Drop from the slab to the column at it support.
- To resist this negative moment the area at the support needs to be increased, this is facilitated by providing column capital/heads flat slab.
- The drops when provided shall be rectangular in plan.
- To resist the punching shear which is predominant at the contact of slab and column Support, the drop dimension should not be less than one -third of panel length in that direction.

1) Equivalent static analysis

All design against seismic loads must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings. This procedure does not require dynamic analysis, however, it account for the dynamics of building in an approximate manner. The static method is the simplest one-it requires less computational efforts and is based on formulate given in the code of practice. First, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The lateral forces at each floor levels thus obtained are distributed to individual's lateral load resisting elements.

2) Response spectrum method

In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions.

Response spectra are curves plotted between maximum response of SDOF system subjected to specified earthquake ground motion and its time period (or frequency). Response spectrum can be interpreted as the locus of maximum response of a SDOF system for given damping ratio. Response spectra thus helps in obtaining the peak structural responses under linear range, which can be used for obtaining lateral forces developed in structure due to earthquake thus facilitates in earthquake-resistant design of structures.

Usually response of a SDOF system is determined by time domain or frequency domain analysis, and for a given time period of system, maximum response is picked. This process is continued for all range of possible time periods of SDOF system. Final plot with system time period on x-axis and response quantity on y-axis is the required response spectra pertaining to specified damping ratio and input ground motion. Same process is carried out with different damping ratios to obtain overall response spectra.

D. Building Geometry

The study is based on three dimensional R.C.C. building with varying plan aspect ratio and slenderness ratio, but with a constant plan area. Different building geometries were taken for the study. These building geometries represent varying dimensions of regular configuration square and rectangular building.

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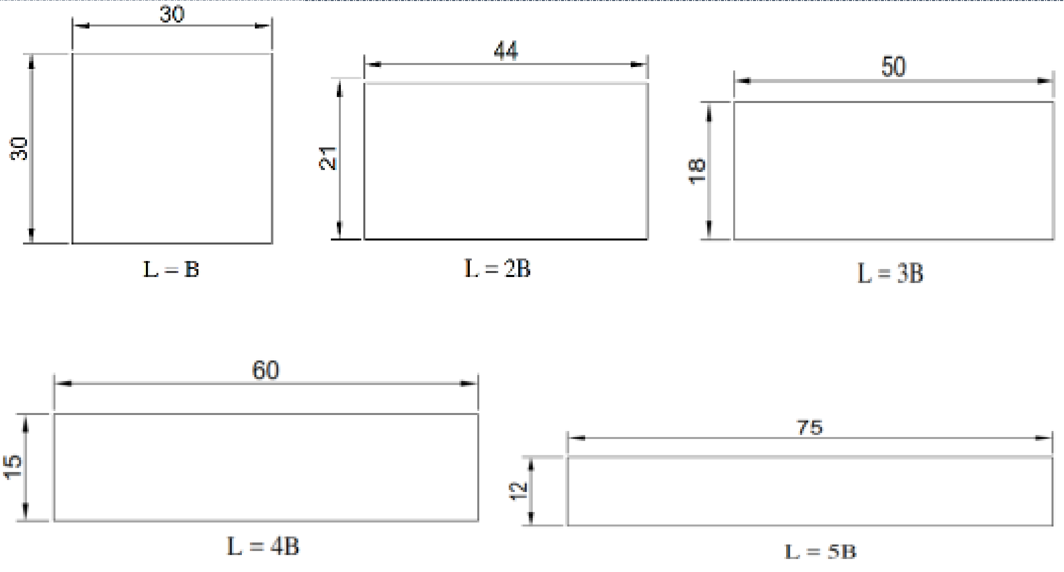

Fig.2: Plan Aspect Ratio (Dimensions are in Meter)

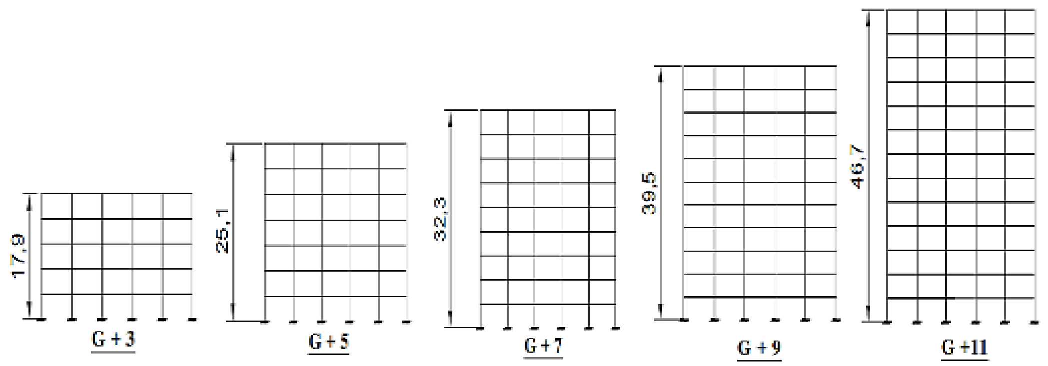

Fig.3 : Storey Variation in Each Plan Aspect Ratio (Dimensions in Meter)

IV. PARAMETER FOR COMPARATIVE STUDY

Following parameters are considered for comparative study of software analysis results of all 25 models.

- Base shear
- Storey drift
- Storey stiffness
- Maximum storey displacement
- Modal frequency and natural time period

Results obtained from software analysis of all 25 models were filtered and then arranged to compare it with respective values of other models. Results for individual model are shown first in tabular form then compared with models of same slenderness ratio and same aspect ratio in the form of graphical representation.

A. Observation For Same Slenderness Ratio

1) ***Base shear***: For same storey height i.e. same slenderness ratio, as the aspect ratio increases base shear increases.In case of same number of storey base shear does not increases linearly with linear increase in aspect ratio.

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2) ***Storey drift* :**In case of flat slab structure Storey drift in x direction is more as compared to Storey drift in y direction for same slenderness ratio

Maximum value of Storey drift was found out to be at second storey level in case of G+3, G+5, G+7 structures where as in case of G+9 and G+11 storey structure the maximum Storey drift was found on third storey level

As per limitation laid by IS 1893 (Part 1) 2002, the maximum drift should not be more than 0.004 times storey height which is 0.0144 m. This drift limit has not been exceeded in any model

3) ***Stiffness:***In case of same slenderness ratio size of column are fixed but as the aspect ratio increases lateral displacement in y direction decreases and in x direction increases.
4) ***Natural time period****:* The value of time period of decreases up to aspect ratio 3 and starts increasing for aspect ratio 4 & 5

V. CONCLUSION

Based on the work done in this dissertation following conclusions are drawn:

- Limiting plan aspect ratio is L/B =5 and slenderness ratio is 3.32.
- In earth quake prone area narrow and tall structure are not recommended, having aspectratio more than L/B = 4 and slenderness ratio 2.88 without infill elements.

Structure with aspect ratio more than 3 has higher magnitude of design base shear along both X and Y direction though their seismic weight is lesser than structure with aspect ratio 3.

- Curtailment in column size reduces the seismic weight of structure, hence less seismic weigh and less base shear.
- Buildings having square plan shape i.e. aspect ratio 1, is safest because:
- Lower and equal amount of base shear is acting along both X and Y direction.
- Fundamental time period for square plan structure is comparatively lesser than rectangular plan building. Hence it will perform well during earthquake with higher frequencies.
- Lateral deformation (i.e. lateral displacement and storey drift) for all the storey level is same along both X andYdirection.

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