Analysis Of Behavior Of Flat Slab And Conventional Slab Structure Under Seismic Loading

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Abstract- *Recent earthquakes in which many concrete structures have been severely damaged or collapsed, have indicated the need for evaluating the seismic adequacy of buildings. About 60% of the land area of our country is susceptible to damaging levels of seismic hazard. We can't avoid future earthquakes, but safe building construction practices can certainly reduce the extent of damage and loss. As being one of the special reinforced concrete structural forms, flat-slab systems need further attention. They possess many advantages in terms of architectural flexibility, use of space, easier formwork and shorter construction time. However the structural efficiency of the flat-slab construction is hindered by its poor performance under earthquake loading. This undesirable behavior has originated from the insufficient lateral resistance due to the absence of deep beams or shear walls in the flat-slab system. This gives rise to excessive deformations that cause damage in non-structural members even when subjected to earthquakes of moderate intensity.*

The main objective of this work is to study the behavior of flat slab structure under seismic loading and compare the behavior with a conventional beam-column structure. The analysis is carried out in STAAD PROs software. To achieve the objective conventional R.C.C. structure and flat slab structure of different heights are modeled and analyzed for the different combinations of static loading. The comparison is made between the conventional R.C.C. structure ad flat slab structures situated in seismic zone V.

Keywords- STAAD PROs, seismic loading, shear wall.

I. INTRODUCTION

1.1 General

As being one of the special reinforced concrete structural forms, flat-slab systems need further attention. They possess many advantages in terms of architectural flexibility, use of space, easier formwork and shorter construction time. However the structural efficiency of the flat-slab construction is hindered by its poor performance under earthquake loading. This undesirable behavior has originated from the insufficient lateral resistance due to the absence of deep beams or shear walls in the flat-slab system. This gives rise to excessive deformations that cause damage in non-structural members even when subjected to earthquakes of moderate intensity.

Flat plate slabs are economical since they have no beams and hence can reduce the floor height by 10-15%. Further the formwork is simpler and structure is elegant. Hence flat plate slab construction has been in practice in the west for a long time. However, the technology has seen large-scale use only in the last decade and is one of the rapidly developing technologies in the Indian building industry today. Material advances in concrete quality available for construction, improvement in quality of construction; easier design and numerical techniques has contributed to the rapid growth of the technology in India.

It is widely known that the slab-column connection is a critical component in the slab-column frame system as shown in Figure 1.1. This is the region of slab immediately adjacent to the column that has to transmit large torsion, shear and bending moments between slab and column and is therefore susceptible to punching shear failure

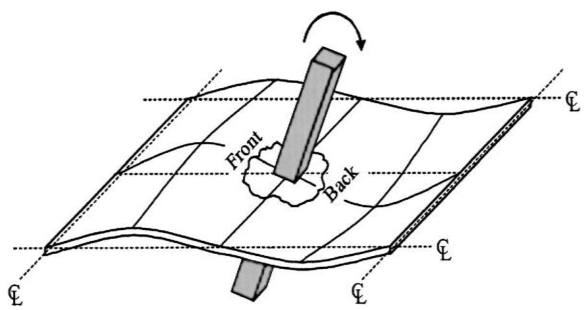


Figure 1.1: Behavior of Slab-Column Connection in Flat Slab Structure

In India, slab-column connections are typically not designed and detailed for seismic effects. No shear reinforcement (such as stirrups or stud-rails) is provided at slab-column connections. Although slab bottom reinforcement bars are provided in an orthogonal mesh to satisfy a minimum requirement for temperature and shrinkage effects, there may be no continuous bottom bar passing through the column to protect against progressive collapse after punching shear failure. Furthermore, due to the congestion of reinforcement bars in the column section, prestressing tendons are normally arranged such that none of them passes through the column.

Despite the rapid growth of flat plate/slab construction, literature and tools available for designers to design and engineer flat plate/slabs in India, has been limited in terms of both Indian standards and Indian research papers. Indian engineers often have to resort to other standards to design flat plate/slab.

1.2 Necessity

Even though flat slab construction is not a new concept in the Indian environment, its widespread use especially with Post Tension (PT) application is fairly recent especially in high earthquake zones of the country. And since no comprehensive Indian standards exist on the subject, Structural Engineers working in high seismic zones have been eyeing this type of design and construction with skepticism. Modern concrete construction in high seismic zones of India has traditionally been done using Special Moment Resisting Frames (SMRF)—ref IS 1893-2002, with or without shear walls. The columns are designed to be stronger than the beams. Ductile detailing provisions of IS (13920-1993) ensures this. After the Bhuj earthquake of 2001 the compliance with these standards has become in vogue. The code allows the response reduction factor (R) to be as high as 5 for SMRF to 4 for buildings with shear walls alone taking base shear more than 75%, and 5 for "dual systems" ie buildings in which both shear walls and SMRF exist while the latter take at least 25 % of the base shear. As there are no beams, flat slab structures do not strictly fall in the category of frames—at least as per all existing Indian standards. Hence providing shear walls is mandatory in buildings to take the entire lateral seismic force. However there is an argument that the basis of flat slab design assumes an "equivalent frame" in orthogonal directions of the building so it may be considered as a frame for earthquake purposes as well. To address this view point it is useful to look at provisions of some codes like ACI-318 05, ASCE- 41-06, that are based on more recent research on the subject.

Post-tensioned flat slab construction is popular in India for medium to high rise buildings such as office buildings, hospitals, residential buildings and parking buildings. A slab-column frame is normally designed to carry only gravity loads, while the lateral wind load is assumed to be taken care of by concrete shear walls. The slab-column frame is neither designed for lateral seismic load nor checked for lateral deformation compatibility with shear walls

Figure 1.2: Flat Slab Post-Tensioning of High-Rise Building in Las Vegas

Figure1.3: Solaris

The Solaris, Mumbai was designed as a 40 storey flat slab structure with high floor heights, a large floor plate and a strong, central shear wall core.

1.3 Objective

The present work consists of analysis of reinforced concrete building systems. The main focus is to compare the seismic behavior of two types of multistoried buildings, one is conventional building i.e. slab, beam & column the other one is flat slab building. Building of different number of storeys is analyzed and a comparative analysis is carried out.

II. THEORATICAL CONTENT

2.1 General

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 slabs are directly supported by columns. These types ofconstruction are aesthetically appealing also. These slabs which are directly supported by columns are called Flat Slabs. Fig. 2.1 shows a typical flat slab.

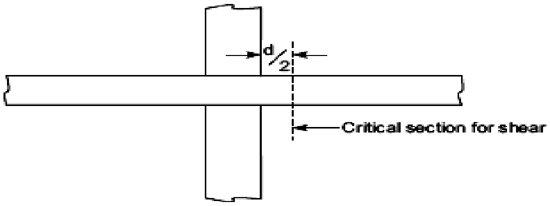


Figure.2.1: A Typical flat slab (without drop and column head)

The column head is sometimes widened so as to reduce the punching shear in the slab. The widened portions are called column heads. The column heads may be provided with any angle from the consideration of architecture but for the design, concrete in the portion at 45º on either side of vertical only is considered as effective for the design [Ref. Fig. 3.2].

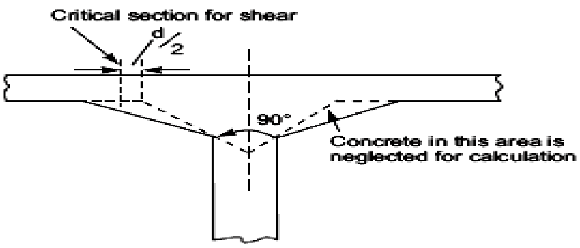


Figure 2.2: Slab without Drop and Column with Column Head

2.3 Proportioning of Flat Slabs

IS 456-2000 [Clause 31.2] gives the following guidelines for proportioning.

2.2.1 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 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 of the width of drop for interior panels.

2.2.2 Column heads

Where column heads are provided, that portion of the column head which lies within the largest right circular cone or pyramid entirely within the outlines of the column and the column head, shall be considered for design purpose as shown in Figs. 3.2 and 3.4.

2.2.3 Thickness of flat Slab

From the consideration of deflection control IS 456-2000 specifies minimum thickness in terms of span to effective depth ratio. For this purpose larger span is to be considered. If drop as is provided, then the maximum value of ratio of larger span to thickness shall be

= 40, if mild steel is used
= 32, if Fe 415 or Fe 500 steel is used

2.3 Methods of Seismic Analysis of Building

2.3.1 General

Earthquakes are nature's greatest hazards to life on this planet. The hazards imposed by earthquakes are unique in many respects, and consequently planning to mitigate earthquake hazards requires a unique engineering approach. An important distinction of the earthquake problem is that the hazard to life is associated almost entirely with man made structure expect for earthquake.

2.3.2 Equivalent static force analysis

These are approximate methods which have been evolved because of the difficulties involved in carrying out realistic dynamic analysis. Codes of practice inevitable rely mainly on the simpler on the simpler static force approach, and incorporate varying degree of refinement in an attempt to simulate the real behavior of structure. Basically they give total horizontal force (Base Shear) V, on a structure:

$V = ma$ Where,
m is mass of structure
a is seismic horizontal acceleration (Generally in the range of 0.05g to 0.2g)
V is applied (fig 3.5) to the structure by a simple rule describing its vertical distribution. In a building this generally consist of horizontal point loads at each concentration of mass, most typically at floor level as shown in Fig3.10. The seismic forces and moments in the structure are then determined by any suitable analysis and the results added to those for the normal gravity load cases. V=F1+F2+F3

2.4 Dynamic analysis

For large or complex structure static methods of seismic analysis are not accurate enough. Various methods of differing complexity have been developed for the dynamic seismic analysis of structures.

(I) Direct integration of the equation of motion by step by step procedure
(II) Normal Mode Analysis
(III) Response spectrum Technique

III. RELEVANCE TO THE PRESENT NATIONAL AND GLOBAL SCENARIO OF CONSTRUCTION INDUSTRY

3.1 General

Even though flat slab construction is not a new concept in the Indian environment, its widespread use especially with Post Tension (PT) application is fairly recent especially in high earthquake zones of the country. And since no comprehensive Indian standards exist on the subject, Structural Engineers working in high seismic zones have been eyeing this type of design and construction with scepticism. Modern concrete construction in high seismic zones of India has traditionally been done using Special Moment Resisting Frames (SMRF)—ref IS 1893-2002, with or without shear walls. The columns are designed to be stronger than the beams. Ductile detailing provisions of IS (13920-1993) ensures this.

IV. STRENGTH & WEAKNESS

4.1 General

Flat slab are used in many buildings due to its advantages over other other reinforced concrete floor system in different cases. The most important strength of flat slab are given below. There are some strengths and weaknesses of modal spectrum analysis of structure as given below.

4.2 Strength of Flat slab:

1. Flexibility in room layout:
Partition wall can be placed anywhere.
Offers variery of room layout to owner
False ceiling can be avoided
2. Reinforcement placement is easier.
3. Building height can be reduced.
As no beam is used, floor height can be reduced and consequently the building height will be reduced.
Approximately 10 % in vertical member could be saved
Foundation load will also reduce.
4. Ease of formwork installation
Big table formwork can be used in flat slab
5. Less construction time.
Use of big table formwork helps to reduce construction time

4.3 Weakness of flat slab:

1. Span length is medium
In flat slab system, it is not possible to have large spans
2. Not sutable for supporting brittle (masonry) partition
3. Use of drop panel may interfere with larger mechanical ducting
4. Critical middle strip deflection
In flat slabs, the middle strip deflection may be critical.
5. Higher slab thickness
Compared to typical reinforced concrete two way slab system, the thickness of flat plate slab are higher.

4.4 Strength of modal spectrum analysis of structure

The major advantages of modal response spectrum analysis are as follows

1. The size of the problem is reduced to finding only the maximum response of a limited number of modes of the structure, rather than calculating the entire time history of responses during the earthquake. This makes the problem much more tractable in terms both of processing time and (equally significant) size of computer output.
2. Examination of the mode shapes and periods of a structure gives the designer a good feel for its dynamic response.
3. The use of smoothed envelope spectra makes the analysis independent of the characteristics of a particular earthquake record.
4. Response spectrum analysis can very often be useful as a preliminary analysis, to check the reasonableness of results produced by linear and non-linear time-history analyses.
Offsetting these advantages are the following limitations

4.5 Weakness modal spectrum analysis of structure

1. Response spectrum analysis is essentially linear and can make only approximate allowance for nonlinear behaviour.
2. The results are in terms of peak response only, with a loss of information on frequency content, phase and number of damaging cycles, which have important consequences for low-cycle fatigue effects. Moreover, the peak responses do not generally occur simultaneously; for example, the maximum axial force in a column at mid-height of a moment-resisting frame is likely to be dominated by the first mode, while its bending moment and shear may be more influenced by higher modes and hence may peak at different times.
3. It will also be recalled that the global bending moments calculated by response spectrum analysis are envelopes of maxima not occurring simultaneously and are not in equilibrium with the global shear force envelope.

4. Variations of damping levels in the system (for example, between the structure and the supporting soils) can only be included approximately. ASCE 4-98 (ASCE 1998) section 3.1.5 discusses ways of achieving this.
5. Modal analysis as a method begins to break down for damping ratios exceeding about 0.2, because the individual modes no longer act independently. .

V. PERFORMANCE ANALYSIS

5.1 General

The main objective of the analysis is to study the behavior of flat slab structure under seismic loading and compare the behavior with a conventional beam-column structure. The analysis is carried out in STAAD PROs software.

5.2 Modeling of Building

For In present work, G+5 and G+10 building frame models with conventional beam-column and flat slab will be analyzed by using STAAD PRO software. For seismic zone-II and zone-III.

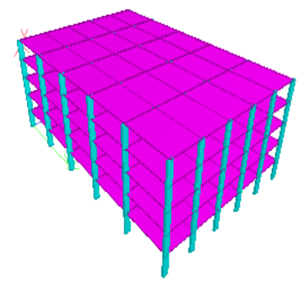
Plan and Data to be assumed are as follows:

Plan Area: 24m x 37.5m
Building: G+5 And G+10 RC Building
Size of beam: B1=250 x 500 mm
B2=290 x 600mm
Size of column: 230 x 750 mm
Slab thickness: 150 mm for conventional slab
125 mm for flat slab.
Live load: 4 KN/m2
Seismic load as per IS 1893- 2012
M20 Grade Concrete, Fe 500 steel

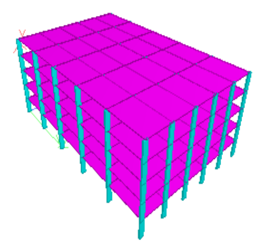
Assumptions :

- All materials are homogenous and isotropic
- For modeling of flat slab plate element is used
- For modeling of beam and column beam element is used
- The load from slab directly transferred to column

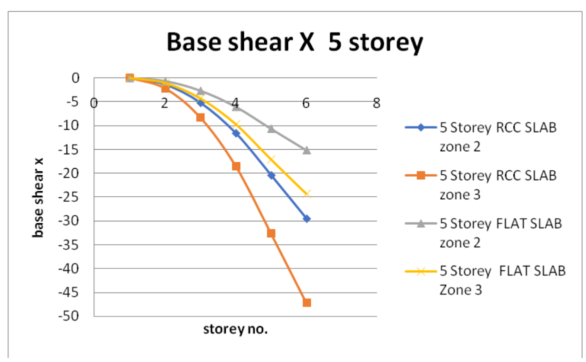
Model 1 A 5 storey conventional R.C.C. structure (ZONE 2)
Model 2 A 5 storey flat slab R.C.C. structure (ZONE 2)
Model 3 A 5 storey conventional R.C.C. structure (ZONE 3)
Model 4 A 5 storey flat slab R.C.C. structure (ZONE 3)
Model 5 A 10 storey conventional R.C.C. structure (ZONE 2)
Model 6 A 10 storey flat slab R.C.C. structure (ZONE 2)
Model 7 A 10 storey conventional R.C.C. structure (ZONE 3)
Model 8 A 10 storey flat slab R.C.C. structure (ZONE 3)

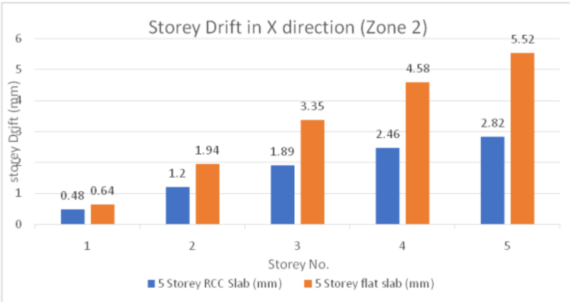


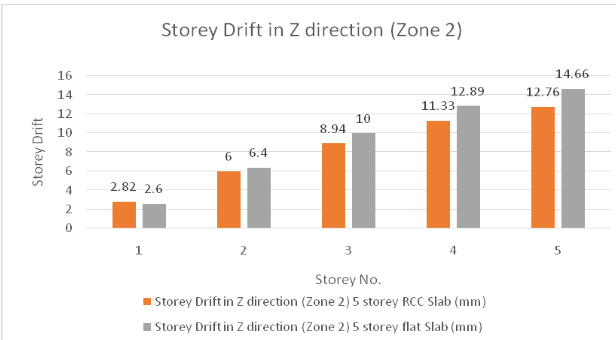
3 D View of 5 Storey Conventional Slab



3 D View of 5 Storey Flat Slab







VI. CONCLUSION

In this work a comparative study of conventional beam-column building and a flat slab building subjected to seismic forces is carried out. The main objective of study is to understand the behavior of flat slab buildings under seismic loading. Based on this analytical study following conclusion can be drawn:

1. The natural time period of increases as the height building (No. of stories) increases, irrespective of type of building viz. conventional structure, flat slab structure.
2. In comparison with the conventional RCC building to flat slab building, the time period is more for flat slab building than conventional building.
3. For all the structure, base shear increases as the height increases.
4. Base shear of conventional RCC building is more than the flat slab building
5. Storey displacement in building with flat slab construction is significantly more as compared to conventional RCC building.

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