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Exploring Divergence and Deviations of Seismic Performance of Set-Back Structures

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ABSTRACT

The Indian subcontinent comes under the category of the world's most disaster prone areas with a population of more than 121 crores. The geographical statistics of India show that about 34% of the land is susceptible to earthquake. Further classification of the earthquake prone land shows that 12% of land is prone to very severe earthquake, 18% of land is prone to severe earthquake and 25% of land is prone to damageable earthquake. The effects of some of the worst earthquake which took place in various countries are defined below which emphasis on the events which are of interest to structural and civil engineers. The 1971 San Fernando Earthquake occurred in early morning of February 9 in the foot hills of the San Gabriel Mountains in California. The surprising thrust earthquake had a moment magnitude of 6.5 or 6.7 and had a maximum Mercalli Intensity of XI (Extreme). The Olive View Hospital, which nearly collapsed due to excessive deformation in the 1st two storeys during this earthquake and was subsequently demolished due to discontinued shear walls. The Turkey Earthquake: The earthquake that struck in the northern Turkish region of Kocaeli the strong ground shaking produced by this earthquake was not usually high, reaching around 40% of the acceleration of gravity in the epicentral region, but the quake was of long duration 45 seconds so the shaking was significant factor in the degree of structural damage sustained. The majority of the housing and commercial buildings built in Turkey had soft storeys at the first-floor level which were frequently used for commercial purposes. These storeys were normally enclosed with glass windows as a replacement for of brick infill walls so as to be used as showrooms. As many as 115,000 of these building some engineered, some not were unable to survive the strong ground shaking and were either badly smashed or collapsed completely. A massive earthquake of magnitude M_L=6.9 on Richter scale occurred on the morning of 51st Republic Day of India (January 26, 2001, Friday) at 08:46am (Indian standard time) as reported by Indian Meteorological Department (IMD), New Delhi. The earthquake is subsequently referred to as Bhuj earthquake. The earthquake ranks as one of the most destructive events recorded so far in India in terms of death toll, damage to infrastructure and devastation in the last 50 years. RCC multi-storey building in India, for the first time, has been subjected to a strong ground motion shaking in Bhuj earthquake. It has been observed that the principal reasons of failure may be accounted to soft storey, floating column (infill walls that are present in upper floors are discontinued in the lower floor), mass irregularities, poor quality of construction material and faulty construction practices, stiffness and strength irregularity, inconsistent earthquake response, soil and foundation effects and pounding of adjacent structures.

Keywords:-*Compressive strength, Sugarcane Bagasse Blended Concrete, split tensile strength, air permeability.*

INTRODUCTION

Population growth in urban areas has surpassed population growth since the industrial revolution. More recently, in the last 50 years, the migration of people from rural areas to big cities has become so dramatic that it has put a lot of pressure on residential and office buildings. This has led to vertical construction.

Starting from the 1950's and especially after the 1960's a whole new series of construction projects was undertaken with the aim of eliminating the traditional cost of lateral load effects. This phase is now defined by building 40 to 60 storeys high with lots going up to 100 floors or more.

In low- to medium-sized structures, analysis and design in relation to lateral forces often has the process of considering a vertical load resistance system to be able to withstand lateral force. However, in remote construction the vertical load resistance system cannot withstand the lateral force properly. From an economic, structural and structural considerations, it is important that the lateral force-resistant system is carefully considered in the first phase of design and integrated as key elements of a complete construction. Therefore, to make the framework economically feasible, various construction plans have been introduced in a multi-storey building depending on the member level. The lateral force resistant to a seismic force is known as the lateral force resisting system (LFRS). This layout plan may be of different types. The most common types of these systems in buildings are occasional resistance frames, shear walls and two shear-shear wall systems. Damage to a building usually starts where weak planes are present in the construction plans. These weaknesses can lead to structural defects and further deterioration which can result in the collapse of the building. This weakness is often due to the instability of the building in terms of its strength, mass distribution, structural strength and structure. Architectural disadvantages can be considered as structural instability as well as direct structural instability.

VERTCAL IRREGULARITIES IN STRUCTURES

According to IS: 1893-2002, direct vertical alignment in buildings is classified as follows:

o Multiple Errors - According to the Indian Standard, if the working net weight of any upper floor is more than 200% of its lower floor net, that malfunction is known as Mass Irregularity.

o Unusual durability - The nature of this abnormality includes the following two conditions related to the variability in durability and durability:

• Stretch stiffness of the building less than 70% of the lateral hardness of the adjacent floor;

• The elasticity of the structure of the structure is less than 80% of the total lateral hardness of the three stories above in the same structure.

Any of the above conditions can be satisfactory to meet the conditions of durability. Such structures are known as Soft Storey Structures or Stilt Structures.

o Geometric or Parameter Disorders - In these species, the lateral magnitude and length of the LFRC on any constructed floor is more than 150% of that number on any of the above, or adjacent floors.

o Weak floor - If the lateral floor strength is less than 80% of its upper or lower floor strength, the floor is called the weak floor.

The lateral strength of any storey represents Base Shear and its distribution among all potential earthquake-resistant structures that share shear forces in a certain way.

STRUCTURAL FRAMING SYSTEMS

Loads are included in gravity loads such as dead and live loads and Lateral loads such as Wind or Earthquake loads. These loads are transferred to the ground through a system of connected building members. While most frames are designed to carry gravity loads, certain frames in the structure are identified to carry lateral load effectively. In tall buildings, a major challenge arises from controlling lateral migration within the functional limit.

The various structural framing systems currently in use for design of multi-storey buildings are as follows:

- Rigid Frames
- Shear Walls
- Cross Wall Construction
- Shear Wall acting with Frames
- Coupled Shear Walls
- Framed Tube Systems
- Tune in Tube Systems
- Bundled Tube Systems
- Staggered Wall Frame Systems
- Suspended Systems
- Braced Frames

MATERIAL PROPERTIES

The approximate size of all the columns and beams is taken and using the striking and experimental methods. Of all the independent models in the current study, M30 concrete grades and Fe 415 reinforcement marks are widely used. All the material properties are taken based on the IS: 456 – 2000. The short-term modulus of elasticity of concrete (E_c) is taken as:

$$E_c = 5000\sqrt{f_{ck}}$$

Where, f_{ck}=characteristic strength of concrete at 28-days in MPa (30 MPa in this case). For the steel rebar, yield stress (f_y) and modulus of elasticity (E_s) is taken as per IS : 456 – 2000.

Types of Loads

The following types of loading may be subjected to the frames during designing:

- Deadload – It includes the self weight of the members or structure itself.
- Live Load – It consists of Super-imposed load.
- Lateral loads – It considers the loads subjected to wind or seismic forces.

ANALYSIS AND METHODS

Based on the requirements, the frames are designed on the basis of STAAD.Pro V8i. The seismic stability of the structures are evaluated when subjected to the various load combinations in accordance with IS : 1893 - 2002. The design and analysis of frames by the STAAD.Pro V8i is based on the stiffness matrix method of structural analysis.

IS: 1893 - 2002 CODAL PROVISIONS

Dynamic Analysis

- To determine the strength of the earthquake, and to distribute it at different levels according to the height of the building, a powerful analysis was performed in the following structures:
- Typical Buildings - Those over 40 meters high in Zone IV and V and those over 90 meters high in Nations II and III.
- Unusual buildings - All buildings with a frame over 12 meters in Zone IV and V and those over 40 meters high in Tier II and II.

Response Spectra

The response spectra measured according to the Indian Standard design is shown in Figure 1 where the consideration of a different type of soil is based on the appropriate natural time and structural reduction and these curves correspond to free earth movement. The spectral acceleration coefficient i.e. (Sa / g) taken in terms of IS: 1893 (Part 1): 2002 is as follows, responsible for the design of the structure.

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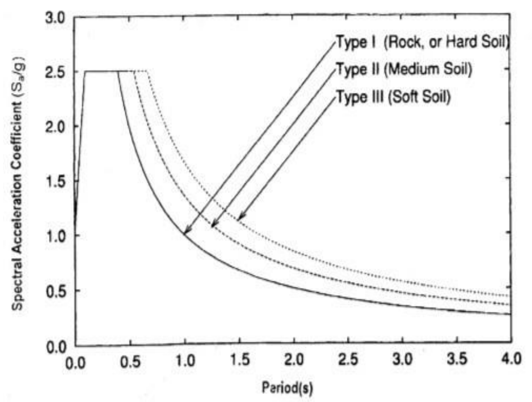

Fig.1:-*Response Spectra for Rock and Soil Sites for Damping 5% [IS: 1893 – 2002*

DESCRIPTION OF THE BUILDING FRAMES

The earthquake response of the twenty-five RCC frames at the top of the stage is considered. The building has a 20x40m plan. The height of the floor is 3.50 m uniform to the level of the roof. The total height of the building is considered to be 87.5 m for all 25-storey buildings. Nodal relocation methods and measuring floors are measured with the most critical and best A / L scale for height change where the scale and height affecting the structure have a high and negligible value among all cases with different soil conditions i.e., hard soil, medium soils and soft V in the earthquake zone. All designs are made as STAAD Pro.V8i software. Following Table 1 shows the definition of all models with a different A / L value with a change in height.

Table 1:-*Description of Model*

S. No.	A/L Ratio	Along the Height	Designation
1	0.25	H=4/25	M1 A
		H=8/25	M1 B
		H=12/25	M1 C
2	0.50	H=4/25	M2 A
		H=8/25	M2 B
		H=12/25	M2 C
3	0.75	H=4/25	M3 A
		H=8/25	M3 B
		H=12/25	M3 C

All the structures have 25 storey with set-back at 4^{th}, 8^{th}, and 12^{th} floor along X direction.

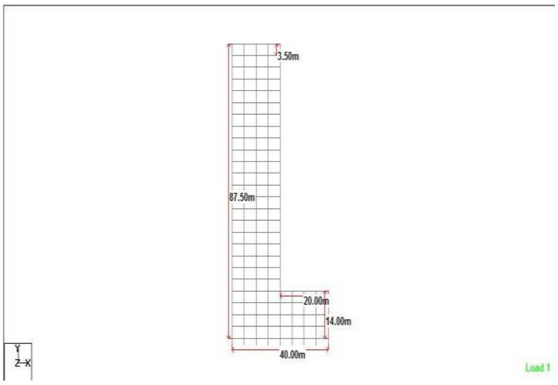

Fig.2:-*Model M1 A I,e, A/L=0.25 atH=4/25*

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For model M1, width of set-back storey is 10 m (A) and total width of ground storey is 40 m (L). For model M2, width of set-back storey is 20 m (A) and total width of ground storey is 40 m (L). For model M3, width of set-back storey is 30 m (A) and total width of ground storey is 40 m (L). Hence A/L=0.25, 0.50 and 0.75.

As per IS:1893 2002, structure is vertically geometric irregular structure. Following figures shows the details of three models i.e. M1 A, M2 A, M3 A.

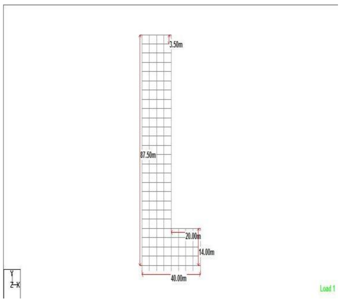

Fig.3:-*Model M2 AI.e. A/L=0.5 at H=4/25*

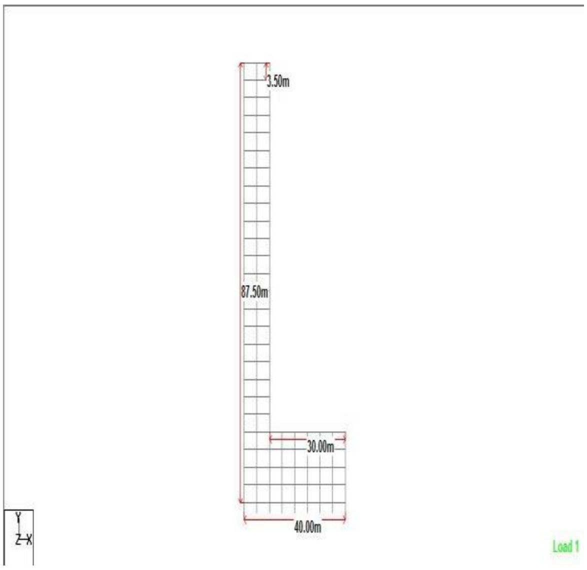

Fig.4:-*Model M3 A I,e, A/L=0.75 at H=4/25*

LOADINGS

Gravity Loads (DL+LL)

The loading intensities of the various floor levels and roof levels for a commercial building are listed below:

Table 2:-*Description of Floor loads*

Description	**Load Calculations**	**Load in KN/m^2**
Weight of slab 200mm thick	1 X 0.20 X 25	5KN/m^2
Weight of floor finishing	1X0.050X20.80	1.04KN/m^2
Weight of plaster	1X0.012X20.80	0.2496KN/m^2
	Total Dead Load	**6.3KN/m^2**
Floor load at terrace		**7.3KN/m^2**
Live load as per IS: 875 – 1987 (Part – II)	1X1X4	4KN/m^2
Live load as per IS: 875 – 1987 (Part – II)	1 X 1 X 1.5	1.5KN/m^2

***Table 3:**-Description of Wall load*

Description	Load Calculation	Load in KN/m
Weight of wall	3.05 X 19.2 X 0.25	14.64KN/m
Weight of plaster	0.035 X 20.8 X 03.5	2.548KN/m
	Total load	**17.18KN/m**
Parapet wall load	1 X 19.2 X 0.25	4.8KN/m
Weight of plaster	0.035 X 20.80 X 1.0	0.728KN/m
	Total load	**5.528 /m**

SEISMIC LOADS

As per IS-1893 2002, earthquake analysis of the structure is performed. The design horizontal seismic coefficient A_b for the structure has been computed by taking the following values of the factors:

- Zone factor,Z=0.36
- Importance factor,I=1.5
- Response Reduction factor,R=5.0

LOAD COMBINATIONS

As per IS:1893 (Part 1) 2002, the following load combinations have been accounted for:

- 1.5(DL+LL)
- (DL+LL±EL)
- 1.5(DL±EL)
- 0.9 DL±1.5EL

When earthquake forces are considered on a structure, these loads shall be combined as per clauses 6.3.1.1 of IS:1893 (Part 1) 2002.

***Table 4:**-Load Combinations*

S No.	Load Combination
1	1.5(DL+LL)
2	1.5DL+EQX
3	1.5DL-EQX
4	1.5DL+EQZ
5	1.5DL-EQZ
6	1.2DL+1.2LL+1.2EQX
7	1.2DL+1.2LL-1.2EQX
8	1.2DL+1.2LL+1.2EQZ
9	1.2DL+1.2LL-1.2EQZ
10	0.9DL+1.5EQX
11	0.9DL-1.5EQX
12	0.9DL+1.5EQZ
13	0.9DL-1.5EQZ

INPUT DATA

Tentative size/thickness for all the slab, beams and columns are taken as per IS Code. And accordingly minimum allowable size of all the elements is found out.

THICKNESS OF SLAB

As per IS: 456 - 2000, thickness of slab is nearly taken as L/32 + cover in mm.

Where L is the length of one bay i.e. 5000mm and cover for slab is taken as 20 or 25mm. Hence thickness of slab is 5000/32+25=181.25mm ~ 200mm.

SIZE OF COLUMN

P_u/A_g=12 (Axial load on column as per SP: 16)For taking as a safer side, 10KN/m^2 load is acting on a column. Hence 5m X 5m X 10KN/m^2= 250KN is the total load is acted upon a column as shown in figure.

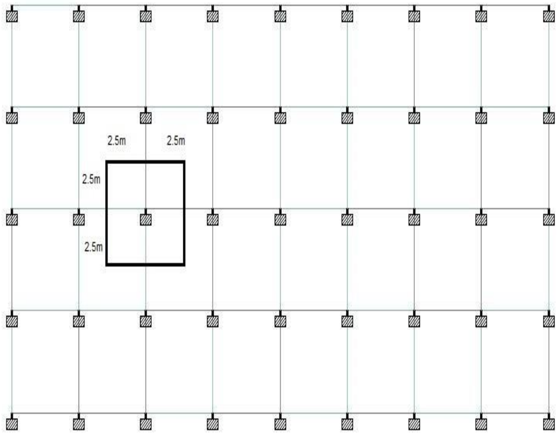

Fig.5:*-Axial Loading in Column*

For the lower storeys load acted upon a column is
P_1=250 X 12 (no. of storeys)=3000 KN
For storeys above that presence of set-back remaining load on the same column is
P_2=2.5 X 2.5 X 10 X 13 (no. of remaining storeys)=812.5 KN
Hence total load $P=P_1+P_2$ = 3000 KN + 812.5 KN =3812.5 KN.
Factored Load, P_u= 1.5xP = 1.5x3812.5 KN = 5718.75 KN.
Hence $P_u/12=A_g$i.e. $5718.75x10^3/12$ = $476.54x10^3$ =A_g
Let one side of column is L_1= 700 mm, other side is L_2= $476.54x10^3/700$ = 680 mm. L_1 = 700 mm ~ 750 mm and L_2 = 680 mm ~ 750 mm.

SIZE OF BEAM

As per IS: 456 - 2000, tentative depth of beam is taken as L/10 to 12 + cover in mm. Where L is the length of one bay i.e. 5000 mm and cover for beam is taken as 25 mm.
Hence depth d= 5000/10 +25 = 525 mm ~ 650 mm and width b of beam is assumed 450mm.

Table 5:*-Dimension detail of elements in a structure*

S. No.	Elements	Dimension in mm
1.	Slab	200 mm
2.	Column	750 mm x 750 mm
3.	Beam	450mm x 650 mm

As per above table, all structures are modeled in STAAD.Pro and property assigned by taking the tentative size of all the elements.

CONCLUSION

This present study acts as an attempt to determine and study the nodal displacement criteria for most critical set-back ratio and the most optimum value of set-back ratio at different soil condition with varying height of set-back in seismic zone V. The dynamic analysis of structure is done using commercial software STAAD.Pro V8i

The comparative study of various cases formed by using STAAD.Pro V8i has led to the following conclusions:
Critical set-back ratio for both the nodal displacement and the lateral storey drift point of view is at A/L=0.25 and H=12/25 for all kind of soil i.e. hard, medium and soft soil for seismic forces along the Z direction. However, for seismic forces along X direction it is observed that the critical setback ratio is 0.75 and H=4/25, which shows that critical value is depends on the geometry of the structure not upon the soil type.
At A/L=0.25 and H=8/25, there we notice

a sudden variation of storey drift which signifies the jumping of the forces due to unequal distribution of mass along the plan as well as along the height.

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