Analysis of Seismic Behavior in Stiffness-Irregular Structures

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***Abstract*—The Indian Standard code IS-1893:2002 (Part-I) lists a number of structural irregularities and suggests many analytical techniques for them. According to Table 5 of the regulation, stiffness irregularities—which include soft storey and severe soft storey conditions—are types of vertical abnormalities that rely on the lateral stiffness ratios between neighboring storeys. Soft storey abnormalities are often cited in reconnaissance reports since they are a major contributor to building damage in previous earthquakes. High-rise structures frequently require the incorporation of soft levels to accommodate social, aesthetic, and practical requirements including parking, lobbies, and service floors because of their elevated storey heights. On the other hand, dramatic differences in stiffness resulting from abrupt changes in the number of infill walls between storeys can also generate soft storeys due to vibrations caused by earthquakes. The purpose of this study is to comprehend, in accordance with IS-1893:2002 (Part-I), how soft storeys affect a 15-story reinforced concrete framed structure's reaction to seismic stress. In order to reduce buckling caused by slenderness, building designs and layouts were chosen based on height-to-width ratios and element size. The attributes of members in certain storeys were changed, most notably by raising the storey height by 46.87%, introducing irregularities. ETABS was used to evaluate the response characteristics of the idealized 15-story model with different soft storey placements, and the Seismic Coefficient Method was used to compare the results with human computations. Five different scenarios were examined, ranging from a structure with four soft storeys on the fifth, tenth, twelve, and fifteenth floors to one with none at all. The outcomes, which comprise displacement and stiffness, In the report's findings section, displacement and inter-storey drift were assessed and displayed as response charts.**

***Index Terms*—Multi Storied Buildings; Conventional Buildings; Staad Pro; Steel Take-off; Tapered Sections.**

I. INTRODUCTION

A significant portion of the infrastructure of contemporary cities is made up of irregular structures. The team responsible for erecting the building's facilities, comprising the owner, architect, structural engineer, contractor, and local government agencies, makes contributions to the overall design, structural system selection, and system configuration. This might result in constructions with uneven mass, stiffness, and strength distributions across the building's height. The structural engineer's job is made more difficult when these structures are situated in an area with a high seismic zone. Because of this, the structural engineer must be well-versed in how irregular structures react to earthquakes. Numerous studies have been conducted recently to assess how irregular structures respond. Spokes of weakness are where structural breakdown begins during an earthquake. The discontinuity in the structure's mass, rigidity, and geometry is the cause of this weakness. Irregular structures are those that exhibit this discontinuity.

A significant amount of urban infrastructure is made up of irregular structures. During earthquakes, vertical abnormalities are a key cause of structure collapses. The most noteworthy constructions to collapse, for instance, were those with soft storeys. Thus, the impact of vertical abnormalities on a structure's seismic performance becomes critical. The dynamic properties of these buildings differ from those of a typical building due to variations in stiffness and mass between heights. The concept of irregular buildings in IS 1893:

The irregularities in the building structures might result from different mass, strength, and stiffness distributions along the building's height. The analysis and design are more difficult when such buildings are built in high seismic zones.

Two categories of irregularities exist.

i. Vertical irregularity;
ii. Plan irregularities.

II. METHODOLOGY

Recyclability and adaptability. The fundamental component of materials utilized in pre-engineered steel buildings is steel. The negation comes from local sources. Steel is a material that embodies the principles of sustainable development and is infinitely recyclable. based on the findings of the analysis and design of conventional and pre-engineered steel structures.

In order to fulfill the goals and accomplish the purpose of the research, the following actions were taken:

Objective 1: Modelling of Structure

Structure Type and Form:

The structure was envisioned as a three-dimensional, framed, moment-resistant reinforced concrete structure. The lateral load resisting system was selected because the primary structural system of an R.0 building is its framework, which is made up of pieces that are monolithically coupled and resist lateral pressures largely through flexure. This technique is advised for structures up to thirty stories because relative displacements, or inter-story drifts, are proportionate to the shear distribution, shear forces, and drift restriction. The modeled building is only fifteen stories high, and dual systems made up of moment-resisting frames that are either braced or have shear walls were not taken into consideration for the research due to drift limitation guidelines.

Building Configuration:

In order to prevent tensional reaction under lateral stimulation, the fifteen-story reinforced concrete framed structure was kept symmetrical in both orthogonal directions in plan. By supplying the proper plan and vertical dimensions, that is, by supplying a height to base ratio (slenderness ratio) of fewer than four, buckling reaction was also prevented.

According to IS 456: 2000's recommendations, structural components including slabs, beams, and columns were given preliminary dimensions in relation to the allowable limits for slenderness and serviceability limit state.

Walls, internal partitions, and exterior cladding were not taken into account in the research since they can change the stiffness of the storey as well as the distribution of lateral loads.

Function and Loading

Multi-story structures with the same designs as indicated for the investigation are primarily present in urban regions of India.

Although their primary uses are as office or residential buildings, these structures frequently serve a variety of purposes by combining several occupation classifications.

Form followed function was used in this research, with the assumption that the structure will serve as an office building subject to planned loads in compliance with IS: 875-1987 for dead and imposed loads. We took into account seismic loadings and combinations of loads in compliance with IS: 1893(Part 1): 2002.

Construction Materials and Structural Element Properties:

The M25 concrete and Fe 415 grade steel reinforcement, which had certain qualities in accordance with IS 456: 2000, made up the R.0 frame. Masonry walls add to the loadings on the building, but because of their unpredictable behavior, they were not modeled into the structure for study.

Objective 2: Analysis of Idealized Model:

The structure was then studied using the ETABS tool to assess the response of the seismically generated lateral force distribution in seismic zone 5. The structure was deemed irregular in accordance with 1893(Part 1): 2002, hence linear dynamic analysis was conducted; yet, the outcomes of this analysis were contrasted with those of linear static analysis. Given that we are talking about concrete structures, the damping value was set at 5% of the critical value, and it was expected that the building would be erected on type II (medium-soil) soil.

P-Δ effect was taken into consideration in the analysis. By adjusting the position and mix of the soft storeys, the response of the structure—including sway, interstorey drift, stresses, and deformation in members, especially those in the soft storey—was compared. The load combinations followed 1893(Part 1): 2002, and seismic forces were concurrently taken into account in one direction.

Objective 3: Review of models, Observations and Conclusions:

The 3-D framed models were analyzed and then reexamined for any differences that could have arisen from the various combinations of soft storey places.
The analysis's results were given in a way that was necessary in order to draw logical conclusions and offer suggestions for the design of R.C. buildings with soft storeys, as well as to enable the making of generalized observations about the structure's reaction.

III. RESULTS AND DISCUSSION

The distribution of the interstorey drift along the structure's height for each example of the Response Spectrum Method using ETABS is displayed in Figures 5.5.1 and 5.5.2. The distribution moves in a wave-like manner, changing abruptly where the soft storeys are located.

The curve rises steadily from the first floor level to the maximum interstorey drift, then gradually decreases and again raises until the drift reaches its minimum value at the fifteenth floor. As can be seen, the interstorey drift is much increased on that specific storey exclusively due to the soft level on that particular storey. Furthermore, the distribution of drift is essentially the reverse of the stiffness variation; at the designated storey, soft storey increases drift while decreasing stiffness. Because of the significant shears and deformations on the lower floors, drift increases as stiffness decreases; on the upper stories, on the other hand, drift decreases as stiffness decreases because of the lesser shears and deformations at those levels.

With the exception of the 15th storey, which saw no change, soft storey on the 5th floor results in an increase in interstorey drift at the 5th storey (4%) and a general decrease in drift throughout the building. Drift at the @10thFloor (37.98%) increases as a result of the soft story on the tenth level. overall decrease in drift across the building, with the exception of the fifteenth story, where there was no change with the exception of the 15th floor, which saw no change, the 12th storey results in an increase on the 12th (62.81%) and a general decline throughout the construction. produce a rise in drift across the building starting on the fifteenth story, peaking at the ninth level before beginning to decrease all the way to the fifteenth. on the fifteenth floor (37.17%), The interstory drift diminishes in direction of the However, because of the variations in stiffness, shearing, and deformation at different story levels, the fifteenth storey is not linear. The distribution of interstorey drift is altered by the change in stiffness brought about by the presence of soft storeys, producing a wave-like pattern and a notable increase in drift at the level of the soft story. The storey number vs storey drift plot is displayed in Figures 5.5.3 to 5.5.14.

Stiffness values of Reg & Irrg Structure in X dir

STOREY	REG. STRUCTURE	IRREGULAR STR. @5th STOREY	IRREGULAR STR. @10th STOREY	IRREGULAR STR. @12th STOREY	IRREGULAR STR. @15th STOREY
15	244558	251533	240918	229866	126765
14	350423	355724	348042	339555	344440
13	367528	371371	365553	344650	364208
12	371438	373688	368357	152021	369293
11	374260	375135	355564	356956	373318
10	378312	379099	183418	375915	377528
9	382762	384111	418291	382489	381975
8	444999	446711	442417	445140	444345
7	451437	451327	450206	451416	450952
6	457567	437087	456708	457244	457046
5	464390	288763	463736	463840	463971
4	532965	605705	532652	532289	532713
3	547116	657826	547099	546844	546919
2	700739	702299	700694	700922	700323
1	1058559	1060000	1058406	1059152	1057909

Stiffness ratio of Irrg structure wrt to Reg. structure in X dir

STOREY	REG. STRUCTURE	IRREGULAR STR. @5th STOREY	IRREGULAR STR. @10th STOREY	IRREGULAR STR. @12th STOREY	IRREGULAR STR. @15th STOREY
15	1.00	1.03	0.99	0.94	0.52
14	1.00	1.02	0.99	0.97	0.98
13	1.00	1.01	0.99	0.94	0.99
12	1.00	1.01	0.99	0.41	0.99
11	1.00	1.00	0.95	0.95	1.00
10	1.00	1.00	0.48	0.99	1.00
9	1.00	1.00	1.09	1.00	1.00
8	1.00	1.00	0.99	1.00	1.00
7	1.00	1.00	1.00	1.00	1.00
6	1.00	0.96	1.00	1.00	1.00
5	1.00	0.62	1.00	1.00	1.00
4	1.00	1.14	1.00	1.00	1.00
3	1.00	1.20	1.00	1.00	1.00
2	1.00	1.00	1.00	1.00	1.00
1	1.00	1.00	1.00	1.00	1.00

Stiffness values of both Reg & Irrg structure in Y dir.

STOREY	REG. STRUCTURE	IRREGULAR STR. @5th STOREY	IRREGULAR STR. @10th STOREY	IRREGULAR STR. @12th STOREY	IRREGULAR STR. @15th STOREY
15	235299	241331	231890	221074	122196
14	337313	341953	335076	326623	331567
13	353858	357300	351956	331396	350851
12	357792	359946	354750	147071	355877
11	360609	361649	342311	343765	359801
10	364521	365500	177231	362174	363867
9	368734	370187	401783	368411	368080
8	427495	429273	425164	427574	426971
7	433555	433901	432664	433555	433190
6	439397	425241	438861	439197	439005
5	445851	283548	445476	445479	445550
4	510155	586399	510075	509647	510018
3	523011	626638	523181	522790	522939
2	661286	663104	661465	661400	661062
1	1003902	1006020	1004095	1004337	1003545

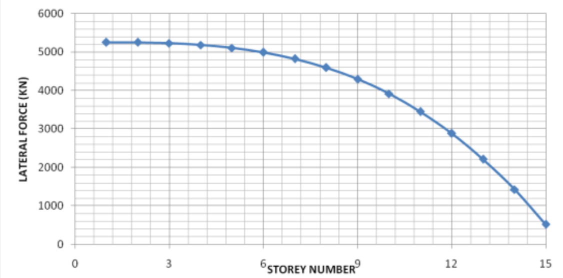


Fig. 5.3.14 Lateral Force plot storey number Vs Lateral Force of Reg.in X Dir.

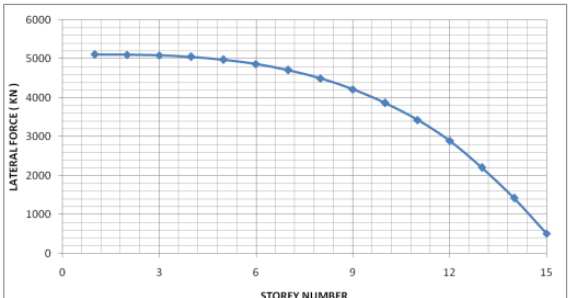


Fig. 5.3.20 Lateral Force plot storey number Vs Lateral Force of Irrg. @ 12th in X Dir.

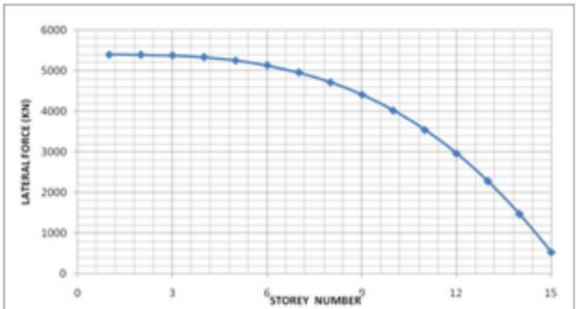


Fig. 5.3.15 Lateral Force plot Storey Number Vs Lateral Force of Reg.in Y Dir.

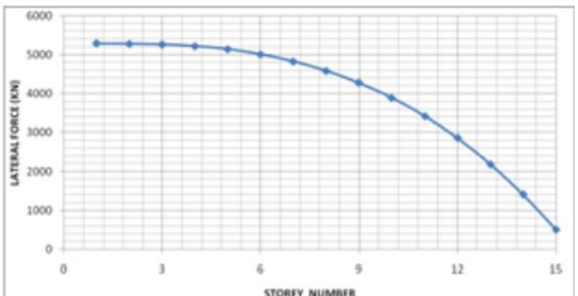


Fig. 5.3.17 Lateral Force plot storey number Vs Lateral Force of Irrg. @ 5th in Y Dir.

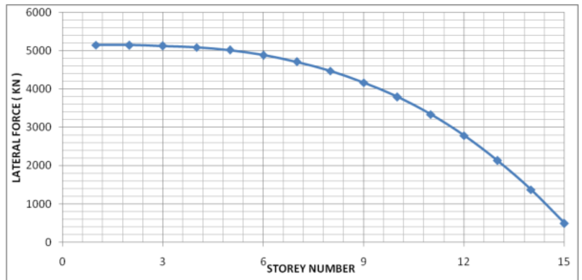


Fig. 5.3.16 Lateral Force plot storey number Vs Lateral Force of Irrg. @ 5th in X Dir.

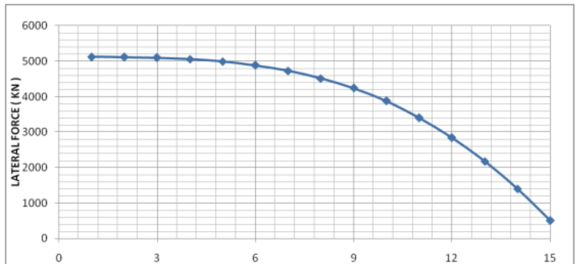


Fig. 5.3.18 Lateral Force plot storey number Vs Lateral Force of Irrg. @ 10th in X Dir.

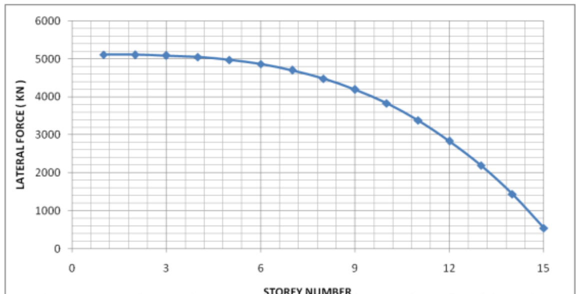


Fig. 5.3.22 Lateral Force plot storey number Vs Lateral Force of Irrg. @ 15th in X Dir.

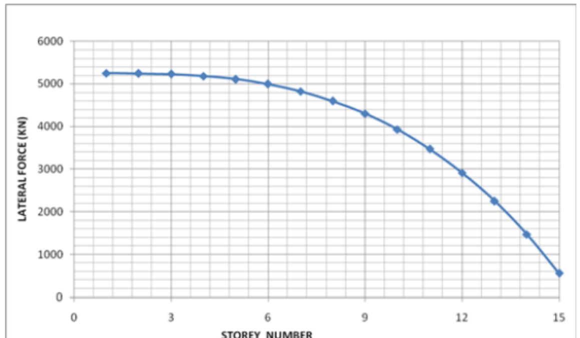


Fig. 5.3.23 Lateral Force plot storey number Vs Lateral Force of Irrg. @ 15th in Y Dir.

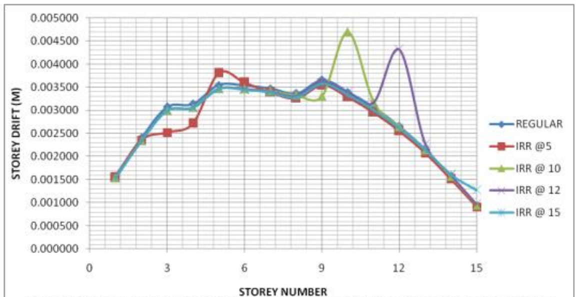


Figure 5.5.13. Storey Drift Plot: Storey Number Vs Storey Drift of both Reg & Irreg Str. in X Dir

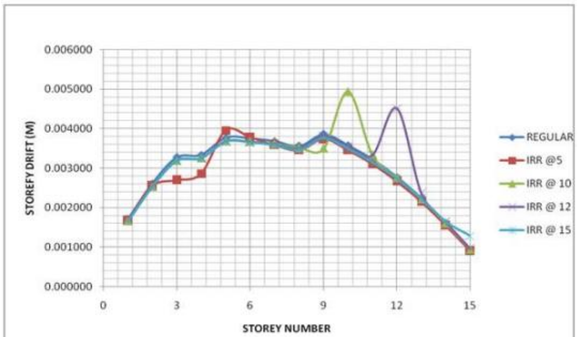
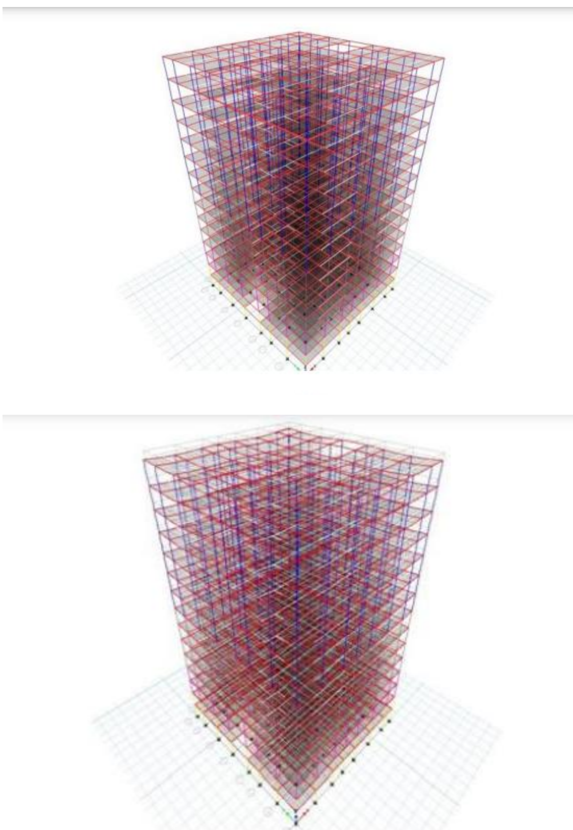


Figure 5.5.14. Storey Drift Plot: Storey Number Vs Storey Drift of both Reg & Irreg Str. in Y Dir



Displacement Due to Self-Weight in 3 Dimensional Views

IV. CONCLUSION

Using the pushover analysis, the performance of reinforced concrete frames was examined. Based on the analysis, the following results were reached:

Through the use of ETABS software and human inspection, compare the base shear values of regular and irregular structures.

As the storey level rises, the stiffness diminishes, reaching its maximum values at the first floor and continuing all the way to the fifteenth. Lateral pressures diminish as storey level increases for the fifth, tenth, twelve, and fifteen storeys when comparing regular and irregular soft storey buildings.

The displacement of the bottom storey remains constant under all circumstances, whereas the displacement of the upper storeys remains constant for both regular and soft floors up to the fifteenth level. Comparing other soft story examples to regular storey, there is not much of a difference.

There is a noticeable increase in drift at the level where the soft storey occurs due to the change in stiffness brought on by the existence of soft storeys, which also causes changes in the distribution of interstorey drift that result in a wave-like pattern.

V. REFERENCES

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