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Seismic Analysis and Optimization of Regular and Irregular Structures using Mass Irregularity

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Abstract Previous earthquakes in India have discovered that most of the buildings aren't designed to be earthquake resistant. In general, buildings are designed taking into account just the gravity loads. Furthermore, the present look seismic codes are not completely practiced while developing a building. a thus a thus higher degree of damage might be expected during an earthquake in case the seismic resistance of the structure is insufficient. This paper examines the seismic performance of ten-story reinforced concrete (RC) frames, comparing one regular frame against nine irregular variants under Zone III earthquake loading per IS 1893:2002. Irregularities include soft stories, heavy loading, floating columns, and geometric changes, analyzed via equivalent static and response spectrum methods (RSM) using STAAD.Pro V8i. Results reveal higher storey drifts, shear forces, bending moments, and axial forces in irregular frames, with floating column configurations showing maximum vulnerability. Dynamic analysis provides refined outcomes over static methods, emphasizing the need for irregularity mitigation in design.

Keywords — Bending moment, earthquake loading, irregular frames, response spectrum, seismic analysis, soft storey

I. INTRODUCTION

Vertical irregularities in structures are extremely typical function in Area that is urban. In many of situations, buildings start to be vertically irregular within the planning phase itself as a result of several architectural and functional purposes. This kind of buildings demonstrated more vulnerability within the past earthquakes. The topics regarding of vertical irregularities have been in focus of research for many years. Numerous studies have been performed in this specific area in deterministic domain. Hence the focus of existing study is assessing the relative performances of typical vertically irregular structures in a Probabilistic domain.
This kind of irregularities arises because of unexpected reduction of strength or stiffness in a specific storey. For extremely high seismic zone area, irregularity in building is probably a great problem to an excellent structural engineer. A lot of vertical irregular buildings occur in modern-day urban infrastructures. Among them Open ground storey as well as stepped kinds of structures are extremely typical in Urban India. A common Open Ground Storey and a Stepped irregular framed building are revealed in Figure 1.1.

Figure 1.1 Vertically irregular buildings. (a) OGS Building (b) Stepped type building

II. LITERATURE REVIEW

A. Literature Review

Afarani and Nicknam et al. (2012) (1) observed the behavior of the vertically irregular building under seismic loads by Incremental Dynamic Analysis. They've talking about eight stories regular building using two bays with four m width in y direction has and four bays with three m width in x direction with three m storey height is believed. They considered Dead load as two ton/m is sent out on beams. In order to stay away from torsional effects they considered symmetric building and also steel moment resisting frames that are created based on IBC 2006 and ANSI/AISC 360-05

FEMA 440 et al. (2000) (2)studied Eighteen ground motion records from Pacific Earthquake Engineering

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Research Centre (PEER) database are collected from Far Field with distance far more than ten km from site as well as have Richter magnitudes of five to eight on firm soil. The structure is modelled in SeismoStruct-V5 software as a nonlinear dynamic analysis, Steel is modelled as Elastic Perfectly Plastic (EPP) hysteresis with no expertise of lateral and local buckling and the connections happened to be failure according to FEMA 440. Maximum inter story drift ratios and first mode spectral acceleration are calculated by Incremental dynamic analysis and IDA curved are plotted to get the collapse points. The evaluation of the structure is targeted on the collapse prevention limit state of the components. Fragility curves are generated by

using Cumulative Distribution Function via the lognormal distribution through collapse points

Elnashai and Jeong et al. (2006) (3) research the fragility analysis for an irregular RC building under bidirectional earthquake loading has studied by For the account of the irregularities in structure, bidirectional response and the torsion are used as 3d structural response features to represent the destruction states of the structure irregularities is provided through a reference derivation. A 3 story RC frame is obtained with asymmetric in plan with thickness of slab is 150 mm and beam depth is 500 mm to learn the damage assessments.

Tantala and Deodatis et al. (2002) (4) analysis a 25 story of reinforced concrete moment resisting frame Building having three-bays. generated fragility curves a they've a they've broad variety of ground motion intensities. They've utilized a bit of time histories are modelled by stochastic processes. Simulation is accomplished by power spectrum probability and duration of earthquake by conducting 1000 simulation for every parameter. The nonlinear analysis is done by considering the P-Δ effects and by ignoring soil-structure interaction. They have considered the nonlinearity in material properties in model with nonlinear rotational springs a bilinear moment-curvature relationship by since the stiffness degradation through hysteretic energy dissipation capacity over successive cycles of the hysteresis. They've utilized Monte Carlo simulation approach for simulation of the ground motion.

The simulation with the durations of effective ground motions is completed at two, seven and twelve second's labels to look at the consequences. They thought the consequences on the assumption of Duration and gaussianity. They've implemented stochastic process for modelling. The analyses have been carried out by utilizing DRAIN-2D like a dynamic analysis with inelastic time records data. The arbitrary material strengths have been simulated for virtually any column and beam using Latin Hypercube sampling.

Murat and Zekeria et al. (2006) (5) studied the yielding and also collapse behaviour of RC frame buildings in Istanbul was analysed through fragility analysis primarily based on numerical simulation. They've studied amount of accounts of buildings as three, five & seven storeys designed as per Turkish seismic design code (1975).The fragility curves have been designed with the assistance of the outcomes of regression analysis. They've examined with twelve artificial ground motions because of the evaluation. of stories was noticed though similar observation wasn't valid for the instant occupancy level.

Rota et al (2010) (6) observed the fragility curves for masonry buildings prototype of a three storey masonry building located in Benevento (southern Italy) that has built in1952 are analyzed primarily based on stochastic nonlinear analysis. The variables can be found out by Monte Carlo simulation by way of an application STAC for the evaluation. The structure used is basically tuff masonry many experimental tests have performed by Faella et al. The program TREMURI, a frame type macro element worldwide analysis program was developed by Lagomarsino and Gambarotta as well as further modified by Penna for any nonlinear pushover plus time history analyses on masonry Buildings.

Erberik et al. (2008) (7) studied the mid-rise and low-rise reinforced concrete (RC) buildings through Fragility analysis which qualities within the Duzce Damage database that affected by 2 devastating earthquakes in 1999 at Marmara region in turkey. They have considered the structures of amount of stories ranges between 2 and 6. In the analysis the structure having 2 and 3 stories are viewed as low rise (Buildings and lr) having 4 to 6 stories are viewed as mid-rise (MR).They have studied with twenty eight RC buildings obtained from a construction collection of around 500 buildings in Duzce. Post-earthquake damage assessments of the buildings had been readily available. The Duzce damage data source is widely used earlier by some other researchers.100 corrected ground motion records have collected from various regions of the planet with a selection of magnitude between 5.1 and 7.8 are employed for the evaluation. The ground motion set is split into twenty

Groups all of 5 with PGV time periods of five cm/s, the structures are modelled as bare frame or maybe infill frame. In the research they subdivided the structure as low rise bare frame type, low rise infill frame type, mid-rise bare frame style and also mid-rise infill frame type.

The mid-rise and low-rise RC structures are analysed as one level of independence process with the worldwide response statistics of simplified (or maybe equivalent) analytical models.

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Guneyisi and Altay et al. (2008) (8) observed the behaviour of current R/C office buildings through fragility curves thinking about the circumstances as before and also after retrofitted by fluid viscous (VS) dampers. Braced frames are viewed at the middle bay of the frame with passive fluid VS dampers at every brace. A 12 storey office building designed as Turkish seismic design code version (1975) from Istanbul. VS dampers are utilized for retrofitting specially designed as FEMA 273-274 with many different effective damping ratios of ten %, , and 15 % and 20%. Main structural method of the structure includes moment resisting R/C frames in 2 directions with 12-storey located at average seismic zone with fairly rigid soil type as per Turkish seismic design code has taken. The storey position of the structure is 2.75 m with 989 m2 floor area.

Samoah et al. (2012) (9) observed the fragility behaviour of non-ductile reinforced concrete (RC) frame buildings in lower - medium seismic areas and they've chosen at Accra that's the capital of Ghana, West Africa. The structural capability of the buildings is analysed by inelastic pushover analysis and seismic demand is analysed by inelastic time history analyses. Then the fragility curves are drawn. They've analyzed with three generic no ductile RC frame buildings using regular and symmetrical in each program and elevation are made based on BS 8110 (1985). The buildings taken into account are a 3- 3-bay and storey, a 2-bay and 4-storey and a 6 storey and three bay structures to get a suitable consequence. The structure was modelled using thirty five as well as sixty % of the yucky sectional areas of columns and beams. A macro element program IDARC2D (1996) was produced as the inelastic static and dynamic analysis of non-ductile RC frames. The evaluation for the non-ductile RC frame buildings, modelling are successfully done properly depending on the structural properties of theirs.

Rajeev and Tesfamariam et al.(2012) (10) analyzed the seismic overall performance of non-code conforming RC structures created for gravity loads. The analysis highlights the necessity for reliable vulnerability assessment and retrofitting. The vulnerability is compounded since the RC buildings are subject to various problems such as for instance weak storey, soft storey, plan irregularities sand various other types Fragility based seismic vulnerability of structures with consideration of very soft storey(SS) plus quality of construction(CQ) is evidenced on three, five, and also nine storey RC frames created prior to 1970s.

Menon and Davis et al. (2004)(11) examined the presence of masonry infill panels modifies the structural force distribution considerably within an OGS building. They considered verities of creating case studies by boosting the storey heights plus bays in OGS buildings to study the modification in the behaviour of the functionality of the structures with the increased the variety of bays and storey also the storey heights. They found that with the total storey shear force improves since the stiffness of the structure improves within the presence of masonry infill at top of the flooring of the structure. Furthermore, the bending moments in the ground the failure and floor columns increase is created because of delicate storey mechanism which would be the development of hinges in ground storey columns.

Scarlet et al. (1997) (12) identified the qualification of seismic forces of OGS buildings. A multiplication factor for base shear for OGS building was offered. The modelling the stiffness of the infill walls in the evaluation was focused. The result of in Multiplication element with the increased storey height was studied. He observed the multiplication factor ranging from 1.86 to 3.28 as the amount of storey increases from 6 to 20.

Hashmi and Madan et al. (2008) (13) conducted nonlinear time historical past plus pushover analysis of OGS buildings. They realized that the MF recommended by Is actually 1893 2002 for such buildings is enough for stopping collapse.

Sahoo et al. (2008) (14) observed the behaviour of open-ground-storey of Reinforced concrete (RC) framed buildings having masonry at above storey by employing Steel Caging along with Aluminum Shear Yielding Dampers. He's created an easy spring mass item for the layout of braces for enough power and stiffness needs of the strengthening program. A shot a five storey four bay non ductile RC frame having open ground storey for his observation. And furthermore decreased scale 1storey one bay RC frame was analysed experimentally under continual gravity loads and reversed cyclic slowly increasing lateral Displacement by Full strengthening technique.

Patel et al. (2012) (15) proposed both linear as the Equivalent Static Response and Analysis Spectrum Analysis as well as the nonlinear analyses as the Pushover Analysis and also Time History Analysis for Low rise open ground storey framed building with infill wall stiffness as being an equivalent diagonal strut model. The result on the infill wall is studied considering the Indian standard code Is actually 1893 2002 criteria mention for OGS buildings. She found that the evaluation results demonstrate a MF of 2.5 is pretty high to always be multiplied towards the beam and column forces of the soil storey of the structures. Their study determine that the

issue of open ground storey buildings can't be identified properly through elastic analysis since the stiffness of open ground storey creating along with a comparable bare frame

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construction are just about identical.

B. Research Gap

Overviews of guidelines for vertically irregular buildings are carried out in the first chapter. The review of the study indicates that there are numerous research efforts found on the seismic behaviour of RC buildings, OGS buildings also with regard to seismic performance of the vertically irregular buildings, there are few studies conducted. But all this studies are based on a deterministic approach. The main motivation is to study the performance of the vertically irregular buildings and to fine tune the design guidelines as per the Indian standards. For example, with regard to an OGS building, the IS 1893(2002) suggests a multiplication factor of 2.5 for ground storey columns. The multiplication factor proposed by IS 1893 (2002) needs to be more of rational than an empirical number The seismic hazard analysis is adopted for the OGS buildings and the stepped type buildings by considering the criteria from various codes by identifying the reliability index calculation for the buildings to evaluate the appropriate MF values for the design of the buildings belongs to various region of India.

III. METHODOLOGY

Analysis methods are broadly characterized as linear & nonlinear static as well as dynamic. Some of them the linear static as well as dynamic techniques are suitable once the structural loads are too small.

The primary distinction in between the equivalent fixed process as well as dynamic analysis process is based on the magnitude as well as distribution of lateral forces with the level of the buildings. In the dynamic analysis process the lateral forces are derived from qualities of the natural vibration modes of the structure that are based on the distribution of stiffness and mass over height. In the equivalent lateral force process the magnitude of forces is based on an evaluation of the essential time as well as on the distribution of forces as provided by an easy system which is proper just for standard buildings.

A. Modeling and Loads

Ten frames modeled in STAAD.Pro V8i: Frame-1 (regular), others irregular (e.g., Frame-2: soft 1st/2nd storeys sans slabs; Frame-6: ground soft via removed intermediates; Frame-10: geometric + column removal). Loads per IS 875: DL/LL as above; seismic via IS 1893:2002 (5% damping).

B. Analysis Procedures

Equivalent Linear Static: Assumes elastic response; base shear $V_B = A_H W$.

Linear Dynamic RSM: Modes derive lateral forces from stiffness/mass distribution; preferred for irregularities. Soft storey provisions applied post-analysis.

C. Ideal frame with Dimension

FRAME-1 : This is the basic and ten storey height of 3.5m and the bay width of 5m. The basic specifications of the building are: Dimensions of the beam = 0.450×0.25 m ; Column size = 0.30×0.30 ; Beam Length = 5 m ; Column Length = 3.5 m ; Dead load = 12 KN/m2 ; Live Load = 10KN/ m2

FRAME-2 : Frame having 1st and 2nd storeys soft. No floor slab has been provided which makes these two storeys less stiff, i.e., softer.

FRAME-3 : This frame has 4th and 5th storeys soft. No floor beams (Vertical) have been provided which makes these two storeys soft.

FRAME-4: Frame with heavy loading on 3rd and 6th storeys. Two storeys of the building, i.e. , 3rd and 6th storeys carry heavier loads, hence making the building irregular.

FRAME-5: The frame carries heavier loading on the Top story, e.g., in the top story swimming pool has been introduced hence making the top storey heavy, and the building becomes irregular.

FRAME-6: In this frame the intermediate columns are removed making the ground story soft and thus an irregularity is introduced in the building.

FRAME-7: The frame is made irregular by removing the end columns and placing the intermediate columns in it.

FRAME-8: This frame has 4th and 5th storeys soft. No floor beams (horizontal) have been provided which makes these two storeys soft .

FRAME-9: In this frame the geometry of building is changed by changing the height of building in three bays and hence introducing the irregularity in the building.

FRAME-10: In this frame along with geometric irregularity the intermediate columns are removed ,irregularity is introduced by doing so.

IV. RESULT AND DISCUSSION

A COMPARISON OF STRUCTURE

Every irregular structure is compared with the regular framework plus following variation is seen:

B STRUCTURE 1-2

In this particular section the comparison of structure one and structure two is completed. The beams in the setback i.e. Beam-31, Beam-35, Beam-39, Beam-43 are in contrast to the regular building structure as well as the bending moment diagram, shear force diagram as well as axial force diagram are drawn

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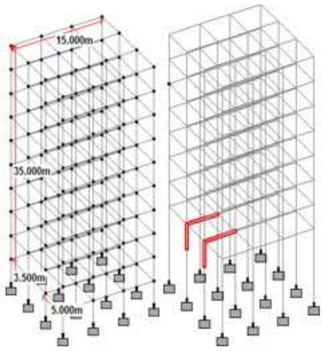

Fig.1.1 & 1.2 of Structure 1 and Structure 2

A. Force Comparisons

Irregular frames exhibit varied force amplifications. Tables compare key beams (e.g., at setbacks) versus Frame-1.

Table I: Shear Force (kN) Examples (Structures 1 vs. Irregular)

Member	Frame-1	Frame-2	Frame-3	Frame-10
31	130.07	114.9	-	-
51	78.8	-	391.66	-
168	97.38	-	-	235.77

Shear drops in Frame-2 (Beam-31: 130.07→114.9 kN) but surges in Frame-3 (Beam-51: 78.8→391.66 kN); Frame-10 peaks at Beam-168 (235.77 kN).

Table II: Bending Moment (kNm)

Member	Frame-1	Frame-2	Frame-3	Frame-10
31	268.19	626.9	-	-
51	140.42	-	804.3	-
168	271.68	-	-	437.05

Moments amplify significantly (e.g., Frame-2 Beam-31: 268→627 kNm; Frame-10 Beam-168: 272→437 kNm).

Table III: Axial Force (kN)

Member	Frame-1	Frame-2	Frame-3	Frame-10
31	1288	715	-	-
51	478	-	3600	-
211	916	-	-	152

Axial forces vary: reductions in Frame-2 (1288→715 kN), spikes in Frame-3 (478→3600 kN).

B. Storey Displacements (UX, X-Direction, mm)

Table IV: Top Storey Displacements (Storey 10)

Frame	UX (mm)
1	40.88
2	97.39
3	57.43
10	33.64

Frame-2 shows max drift (97.39 mm), exceeding Frame-1 by 138%; floating columns (Frame-10) moderate at top but amplify lower.

Dynamic RSM yields refined drifts over static, confirming irregularity unsafety: soft/floating types worst.

V. CONCLUSION

Irregular RC frames demand enhanced design (e.g., 2.5x shears for soft storeys) to curb amplified forces/drift. Avoid irregularities where possible; use RSM for accuracy. Future: nonlinear time-history with soil interaction

Considering the storey displacement, the frame and structure with floating columns (frame 2) may be the most fragile since it suffers the highest displacement as the base frame and structure exhibits the very least displacement. So far as storey drift is concerned, frame two (with bottom 2 soft storeys) may be the most fragile since it's the maximum storey drift which changes abruptly. Frame 8 also shows pattern that is similar for bottom 2 storeys. Storey shear is however maximum in frame four and structure four (with 3rd and 6th storeys major). It may be inferred naturally the frame and structure with floating columns represents the even worse situation since it faces the highest displacement and is very susceptible to damages under this particular lateral loading. While, on the flip side it could be observed that the base frame and structure contains the very least drift and displacement, hence least vulnerable to the harm. In this particular thesis different structures and frames having completely different irregularities but with exactly the same dimension were analysed to learn their behaviour when put through lateral loads. All of the frames and also components have been analysed with exactly the same technique as mentioned in is actually 1893 part 1: 2002. The starting frame and structure that is ideal develops least story drifts while the structure with floating column shows maximum storey drifts on soft story levels. Thus this's probably the most susceptible to damages under this particular type of loading. The many other structures with irregularities also proved unsatisfactory success to some degree. The frame with heavy loads produces maximum storey shears that should always be accounted for in design of columns suitably. The analysis reveals the dynamic approach provides us much more refined results as than static evaluation of the structure.

The evaluation too demonstrates that irregularities are unsafe for the buildings and also it's crucial that you have regular and simpler shapes of frames in addition to even load distribution within the construction. Thus, as much as potential irregularities in a construction should be avoided. But if irregularities need to be introduced without any reason, they should be designed effectively adhering to the circumstances of Is actually 13920: 1993. And now days, complex shaped buildings are becoming famous though they have a threat of sustaining damages during earthquakes. Therefore such structures must be created effectively taking care their dynamic behaviors.

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