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# SENSITIVITY ANALYSIS OF REINFORCED CONCRETE FRAMES FOR PARAMETRIC STUDY BY PUSHOVER CURVES

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Abstract:
To resist the lateral seismic load on buildings infill walls confined by reinforced concrete frame play a vital role. The sensitivity analysis is very useful for earthquake designing, that helps in selecting the parameters, which is more required to the building. The masonry infill panels in buildings generally are not considered for the design process and may be treated as nonstructural or architectural components. But, the presence of masonry infill panels has a great significant impact on the seismic response of the RC framed building. The presence of infill walls reduces lateral deflections and thereby reducing probability of the collapse. The lateral load transfer mechanism of the structure from predominant frame action to predominant truss action was changed by the introduction of infill wall in RC frame.

Keywords: Earthquake, Infill frame, Push over, RC frames, sensitivity analysis

## 1. INTRODUCTION

The fundamentals behind the damages caused by tremors of earthquake (EQs) due to structural weakness in lateral load resisting frames in multi storied building. Earthquake occur due to sudden release of energy as shocks that propagates as seismic waves on earth crust generated from the Earth's lithosphere. The earthquake is huge tremor events (whether natural or anthropogenic) that shake, and rupture or smash the structures. Ground rupture is the visible breaking and displacement of the Earth's surface for few meters along the trace of the fault. The EQ's originate at the epicenter located at or below the surface. About 90% of all EQs consequences from tectonic events primarily fault shifts. The seismic performance (SP) of building with irregular distribution of mass, strength and stiffness along the elevation are significantly different from the conventional building. For multi-storied buildings, construction, the reinforced concrete (RCC) frames are common structure universally in use, Aycardi et al., 1994, Ricci et al., 2011, Harms et al., 2015, Jiawei et al., 2020. Licciardi et al., 2022,

Present framework:

A four-storied four bays building frame considered for the study. Because the sensitivity analysis in a building are the approaches by taking many parameters. Present study adds an extra story height and taking live load to identify the parameter those are more sensitive by changing the value of live load. The effect of the changing load is observed happen in frame in 5%, mean and 95%. The height of the floor values also changed in the frame by taking the different values (for 5%, mean and 95%). Change in one parametric value alter the other parameter values. By maintaining the value of one parameter a change of 5%, keeping other parameter values constant, the resulting values will come in terms of pushover curve in the SAP-2000. Changing the values, the resulting final values compared with each other. By the Tornado Diagram Analysis (TDA) method, it can easily determine how changes in that variable will influence the structural response of building.

Past studies:

The RCC structures proved to accomplish better in past EQs. The seismic performance of buildings are functions of the variation in material, structural and geometrical properties of the building, (Sharma et al., 2016, Zhang et al., 2020, Wei et al., 2022, Pradhan et al. 2022). Two developed models to assess the SP are bare frame and infill frames. Bare frames constructed by column, beams. Infill wall is the supportive wall, which closes the perimeter of building Kim et al., 2022, The infill wall separates inner and outer space in the building structure (Pei et al., 2022). The external vertical opaque type of closure is the infill wall. Infill walls considered as nonstructural elements. Infill wall interact with the structural system during seismic actions and modify the behavior of the structure (Bhosale et al. 2013), Kareem et al., 2019, Bagnoli et al., 2021, Wei et al., 2022). Infill wall are non-load bearing function and their seismic response and their effect is accountable for the design. The equivalent diagonal strut methodology is used to represent the behavior of infill walls, Aslani et al., 2005, Abd-Elhamed et al., 2015, Gesualdi, et. al, 2020, Lee et al., 2021,

Infill walls confined by nonlinear reinforced concrete (RC) frames on all four sides, are resisting the lateral seismic loads on buildings with very high initial lateral stiffness and low deformability Abd-Elahmed et al. 2015. The mechanism of frame action to predominant truss action is responsiblefor reduction in bending moments and increase in axial forces in the frame members and parametric analysis. The low cost material, good, sound and heat insulation properties and local availability, the infill wall are in used for building construction but with uncertainty, Murty et al., 2000, Kominek et al., 2016, Wang et al., 2021, He et al., 2022. Xu et al., 2022.

Sensitivity analysis is a method (local or global) to test building performance by probing the extent to which degree of results affected by changes in methods, models, values of unmeasured variables focusing on the design and optimization of sustainable buildings on the building design process used for building performance analysis. Bhosale et al., 2012, Preti et al., 2015, Okoyo et al., 2022. The choice of sensitivity analysis depends on the purpose, the computational cost of energy models, the number of input variables, the analyst’s time for a project, the familiarity of sensitivity methods in structural engineering, Frey et al., 2002, Kim et al., 2021, Wankhade et al., 2014, Liedmann et al., 2022

SAP-2000, is the old structural analysis methodology has been synonymous with state- of-the-art analytical methods. ETABS and SAP2000 are the software is available for structural analysis whereas SAP-2000 is versatile, errorless and used for general purposes. The ETABS is the building system software that helps in while SAP2000 is also have applications for the Pushover analysis and design, Montereiro et al., 2018 Chen et al, 2019,

From the review of literature on sensitivity analysis of multistoried structures, the inferences are:

1. The sensitivity measures include the partial derivatives, variation of inputs by one Standard Deviation (SD) by 20%, sensitivity index, a relative deviation of the output distribution, a relative deviation ratio, partial rank correlation co- efficient standardized regression co-efficient, and squared-ranks test.
2. The four column specimens are studied (with and without lap splice), and two beam and column (exterior and interior) sub-assemblages to develop analytical models to predict the seismic response of the one-third scale model building.
3. Reported on sensitivity theory and techniques related to the environmental transport, reactor safety, chemical kinematic models, radiation dosimetry, multi-compartment ecological model and general mathematical.
4. The assessment of damage potential to eccentric multistory buildings used the two 3-D pushover analyses are used together with the dynamic response of a single degree of freedom system and it is used to estimate the seismic deformation and damages of elements located in the building parameter.
5. Optimizing building retrofit, Mixed Integer Linear Programming (MILP) models used. The change of input data in sensitivity analysis is not always affected the resulting of Life Cycle Cost (LCC). It screens Morris method from Local sensitivity analysis method and Global sensitivity analysis method and cost effect.
6. 3-D model push over analysis (MPA) developed to show the significant improvement over the push over analysis procedures. The MPA estimates seismic demand for torsionally - stiff and torsional-flexibility unsymmetrical systems.
7. The RC bare frame structure underestimate the base shear and consequently damage or even collapse, shrink the buildings

8. Previous studies utilized SRC (Standardized Regression coefficient), Morris design, extended FAST (Fourier Amplitude Sensitivity Test) and TGP (Treed Gaussian process) method were used for sensitivity analysis and found that TGP was useful among all.

9. The results show that concrete and masonary strength-related variation values have shown a significant effect on the building capacity. This effect increase with the progress of damage condition for the concrete also the effect of probability of exceedance of damage expressed in terms of reliability index.

The research gap:

The Infill walls provided in buildings for either façade or envelope. They compartmentalize the available floor space in various floors and resist the lateral deflection. Presently no provision in Indian standard codes (IS) are available for infill RC framed structures and considered during design of the multi storied buildings and considered as nonstructural component though they have significant impact on seismic tremor in high rise multistoried RC buildings.

2. Methodology:

Present work comprises of examining the most sensitivity random variable, pushover by the sensitivity analysis by use of SAP2000 software .Investigating the disparity in building structures at 5%, mean and considering 95% probability. Some parameters of the building structure are in use randomly, for determining few the sensitive parameter. They are concrete compressive strength (Fck) , Yield strength of steel (Fy) , Elasticity modulus of concrete (Ec) , Elasticity modulus of steel (Es), shear strength, live load, and floor height, of masonry infill (τcr) for bare frame and infill frame.The sensitive nature of the material, structural and geometrical properties affect the response of the building

.

Sensitivity analysis

The main objective of the sensitivity analysis is to find the most sensitive parameter and strength respondent of the building and to identify the most significant parameters, which are the models. They quantify as to how the parameter's uncertainty influence the outcomes. Amongst various sensitivity analysis method, such as Tornado plot, box plots, spider plot etc., the Scatter plots give promising relationship between inputs and outputs. The Tornado Diagram Analysis (TDA) method are fast, time saving and efficient that can easily determine how changes invariables that will affect the structural response of building. The Spider and box plots are not widely used for sensitivity analysis, Grubisic et al., 2015, Kim et al., 2020, Vreman et al., 2022.

Seismic evaluation

Seismic evaluation used to evaluate the possible seismic response of buildings that is earthquake damaged. Seismic evaluation divided into two categories. They are (1) Quantitative methods further subdivided as a) condition assessment, b) visual inspection and c) non-destructive. The second method is 2) Analytical methods and divided as a) C/D method, b) Pushover analysis and c) Inelastic time-history analysis. Out of the above popular analytical methods the practices are C/D method ar:

i. The C/D ratio less than one indicate member failure and thus needs retrofitting. The C/D procedures have been subjected to more detailed examination in the light of recent advances in earthquake response studies. The main difficulty is found in this methodis that there is no relationship between member and structure ductility factor because of non-linear behavior.

ii. The 3-D pushover analysis is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake-induced forces. The pushover analysis enables weakness of the structure identified.

iii. Inelastic time-history analysis- During the design of earthquake motion, a seismically deficient building will be subjected an inelastic action. Inelastic time- history analysis is the most rational method available for assessing building performance. For doing this analysis computer program are available. The methodology is used to ascertain deficiency and post-elastic response under strong shaking. Building under strong ground motionbrings out the regions of weakness and ductility demand on the structure.

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Bare Frame

It is the most frequent model of structural analysis where the masonry infill considered to contribute onlyto the mass of the structure and a nonstructural element. This bare frame method of beam and columns are treated and designed as a frame member where the strength and stiffness characteristic of the infill is not considered. The model is still in practice globally, even in seismic prone areas.

Building Geometry

The present study deals with the sensitivity analysis is done by taking bare frame for a four storey-four bays (4S2B) and infilled frame four storey four bays(4S4B-F) are considered. For thisanalysis zone-V has taken as per Indian standard IS 1893.Considring medium soil conditions. Several parameters are taken for this study like concrete compressive strength (fck), Yield strength of steel (fy), Live load, storey height, Elasticity modulus of concrete (Ec) and elasticity modulus of steel (Es). In this analysis the values of diffirent parameters are taken randomly for 5%and 95%. The analysis is done by comparing the parameter values in 5% and 95% with the mean values. To calculate mean the height of the building is taken as (3.2 × 3) m shown in table 1. The characteristic strength of steel and concrete were taken as 415mpa and 30mpa respectively. For 5% and 95% the characteristic strength of steel and concrete are calculated and same way considered for all other parameters.

Table 1 Dimension of frame structure

| Structural members | Dimension (mm) |
|---|---|
| Height | 3200 |
| Width | 3000 |
| Beam | 300 × 230 |
| Column | 300× 300 |

The detailing part of the beam and column give results of the reinforcement size of the column in SAP2000 (V19), but not for the beams. In sap model, the design of beam is automatically done. Only the spacing for top reinforcement and bottom reinforcement are given. The detailing of the beam and column are given below in table 2.

Table 2 Detailing of beam and columns

| | reinforcement | Spacing |
|---|---|---|
| Beam | 4@12∅ mm | 8∅ mm250mm c/c |
| Column | 4@ 16∅ mm | 8∅ mm 200mm c/c |

Modelling of Moment-Curvature in RC Sections

Using the Modified Mander model of stress-strain curves for concrete (Panagiotakos and Fardis, 2001) and Indian Standard IS 456 (2000) stress-strain curve for reinforcing steel, for a specific confining steel, moment curvature relations can be generated for beams and columns (for different axial load levels).

Scope of the present work

The scope of present study, considering the limitations and drawbacks in the present area as observed from literature to fulfill the objective stated is limited to

- Design the bare frame and infill frame to be used the sensitivity analysis.
- Select the parameters such as concrete compressive strength (fck), yield strength ofsteel (fy), elasticity modulus of concrete (Ec), elasticity modulus of concrete (Es), live load, storey height and shear strength of masonry infill for 5% and 95%.
- Carry out push over analysis of the two-dimensional building frames using SAP- 2000 (V19).
- Illustrate the variation of base shear with displacement and yield points are taken for sensitivity analysis.
- Determine the effective parameters using Tornado Diagram Analysis (TDA) methods.

Assumptions

1. The strain is linear across the depth of the section (‘plane sections remain plane’).

2. The tensile strength of the concrete ignored.
3. The concrete spalls off at a strain of 0.0035.
4. The initial tangent modulus of the concrete, Ec= $5000\sqrt{ffcc}$ (IS 456 (2000))
5. The neutral axis assumed to be within an acceptable tolerance of 1%.
6. Algorithm for Generating Moment-Curvature Relation
7. Assign a small value to the extreme concrete compressive fibre strain (normally)
8. Assume a value of neutral axis depth measured from extreme conc. compressive fiber.
9. Calculate the strain and the corresponding stress at the centroid of each longitudinal reinforcement bar.
10. Determine the stress distribution in the concrete compressive region based on the modified Mander stress-strain model for a given volumetric ratio of confining steel. The resultant concrete compressive force obtained by numerical integration of the stress over the entire compressive region.
11. Calculate the axial force from the equilibrium and compare with the applied axial load (for beam element both of these will be zero). If the difference lies within the specified tolerance, the assumed neutral axis depth adopted. The moment capacity and the corresponding curvature of the section are then calculated. Otherwise, a new neutral axis is determined from the iteration (using bisection method) and steps (iii) to (v) repeated until it converges.
12. Assign the next value, which is larger than the previous one, to the extreme concrete compressive strain and repeat steps (ii) to (v).
13. Repeat the whole procedure until the complete moment-curvature is obtained.

Moment-Rotation Parameters

For other inclination of cracking and stirrups, similar expression is available in Park and Paulay (1975). As per FEMA recommendations, for modelling of the shear hingesas shown in Figure 5.9 the ultimate shear strength (Vu) is taken as 5% more than yieldshear strength (Vy) and residual shear strength is taken as 20% of the yield shear strength. Similarly maximum shear deformation (Δm) is considered as 15 times the yield deformation (Δy). In this study, shear strength was calculated by using IS code 456: 2000 and shear displacement at yield and ultimate point were calculated by usingPriestley et al. (1996) and Park and Paulay (1975) model respectively.

Non-Linear Pushover Analysis

The pushover analysis is a common procedure that uses simplified nonlinear static analysis. The analysis is indicated for assessing the seismic vulnerability of existing structures. It is a nonlinear static analysis in which the structure is subjected to gravity loads increasing lateral load until the target displacement is reached or the collapse state of the structure is reached. The pushover analysis is used to obtain a pushover or so called capacity curve i.e. Base shear with displacement, from which we get the deformation capacity of the structure. It is also helps in understanding how a structure behaves after some damage on structural members.

The pushover analysis done to describe the sensitivity analysis. In sensitivity analysis, several parameters are taken for the building frame in the present study. Bare frame and Infill frame are taken for the analysis. The parameters are taken for mean, 5% and95%. The analysis can done by changing one factor at a time, that means at a time one parameter will change and other are constant. In other words when one parameter will be change for 5% and 95% at that time the other parameter values are in mean position. The parameters are given in table below

Table 3 Parameters considered for the sensitivity analysis

| Material property | Unit | Mean | Covariance (%) | Distribution | 5% | 95% |
|---|---|---|---|---|---|---|
| Concrete compressive strength (fck) | Mpa | 30.28 | 21.0 | Normal | 19.835 | 40.720 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Yield strength of steel (fy) | Mpa | 483.470 | 10.0 | Normal | 390.369 | 541.914 |
| Elasticity modulus of concrete (Ec) | Mpa | 29000 | 15.0 | Normal | 22446.612 | 36647.665 |
| Elasticity modulus of steel (Es) | Mpa | $2.1\times10^5$ | 5.0 | Lognormal | 193184.18 | 227703.734 |
| Live Load | $Kn/m^2$ | 1.5 | 10.0 | Normal | 1.35 | 1.65 |
| Storey height | M | 3 | 8.0 | Lognormal | 2.76 | 3.24 |
| Shear strength of RC infill ($\tau\tau cr$) | $N/m^2$ | 0.2041 | 12.0 | Normal | 0.163 | 0.2444 |

The sensitivity analysis is done for bare frame and infill frames. For the bare frame and infill frame the pushover analysis is done by considering the dead load and pushover load as nonlinear in SAP2000. In SAP2000 the push load will taken as displacement control. Same procedure will follow for the infill frame, but for this frame the hinge properties are given. After this pushover curve found between base shear and displacement. The maximum values are taken from the base shear and displacement value, which are used to calculate the most sensitive parameter. To calculate the sensitivity $\Delta yy$ is defined as $\Delta y = [y(Pn)-y(Pmean)]/y(Pmean)$ (3.28) Where, y (Pn) is response at nth percentile value of variable (5th and 95th percentile) y(Pmean) response considering mean value of variable.

3. RESULTS AND DISCUSIONS Results for Bare frame

Fig. 1 shows the pushover curves of bare frames for elasticity modulus of concrete. In this graph, the values of Elasticity modulus of concrete for 5%, mean and 95% are calculated.

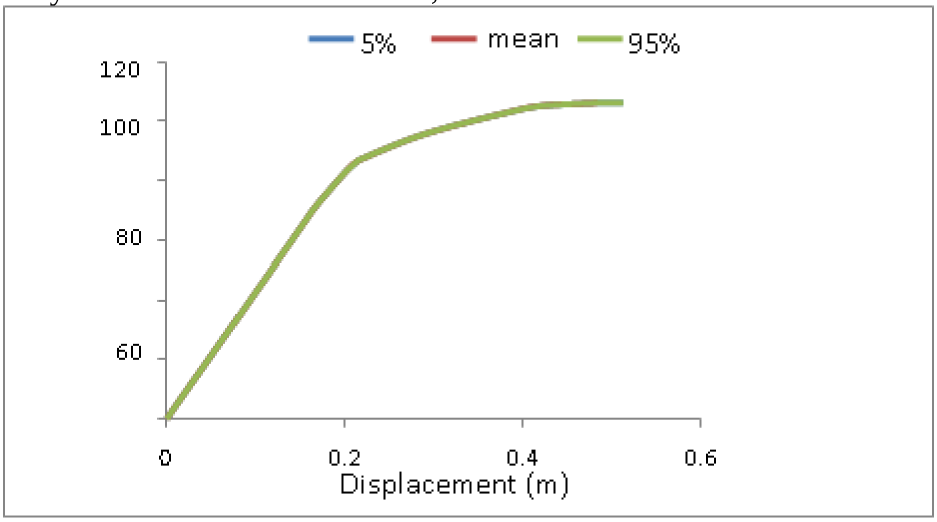


Fig. 1: Pushover curve of bare frame for Ec

However, there are no variations shown in the calculated values of elasticity modulus of concrete for 5% and 95%.

Fig. 2 shows the pushover curve of bare frames for Elasticity modulus of steel (Es) of a bare frame. The graph plotted by considering values for Es in 5% and 95%. Thereare no many variations shown in this graph for elasticity modulus of steel. For the sensitivity analysis the yield point values were taken from the pushover curve.

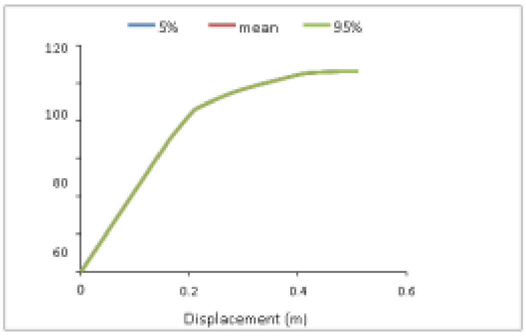


Fig. 2: Pushover curve of bare frame for Es

Fig.3 the graph plotted for concrete compressive strength (fck) of a bare frame.
The curve shows that 95% value for fck is more, less value for 5% and the mean values come between 5% and 95%. Here also yield point values are taken for the sensitivity analysis. That means the value of M40 grade concrete gives more strength then M30 and M20.

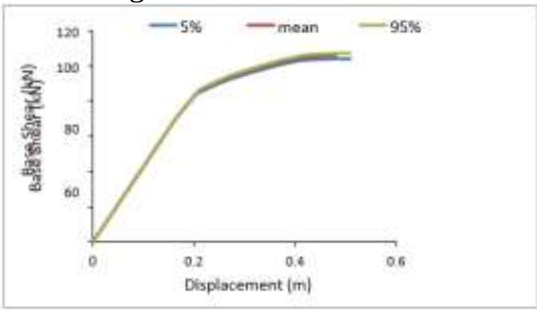


Fig.3: Pushover curve of bare frame for fck

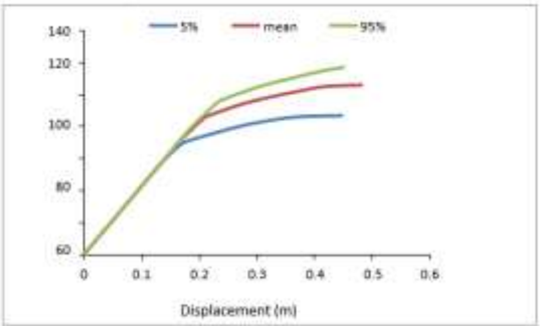


Fig.4: Pushover curve of bare frame for fck

Fig.4 plotted for yield strength of steel (fy) of a bare frame. The graph shows variation in results. In the analysis is 95% values higher than mean and 5% which are shown in the graph. That means the yield strength of steel fe550 gives more strength than fe415 and fe 500for building structures.Fig.4.4: Pushover curve of bare frame for fy.
Fig.5 the graph shows live load for the bare frame. The graph plotted by considering the values of live load for 5%, mean and 95%, these values are calculated. The graph shows there are no variations in the result. So, the graph was plotted in one line.

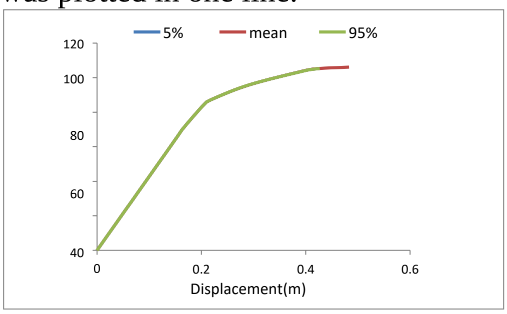


Fig.5: Pushover curve of bare frame for Live Load

Fig.6 the graph has plotted for storey height. Different store height values are taken for pushover analysis in 5%, mean and 95%. In the results, the values of 5% are more as compare to mean and 95%. That means the yield point in 5% is more than mean and 95%. For 5% the stiffness is less than mean and 95%.

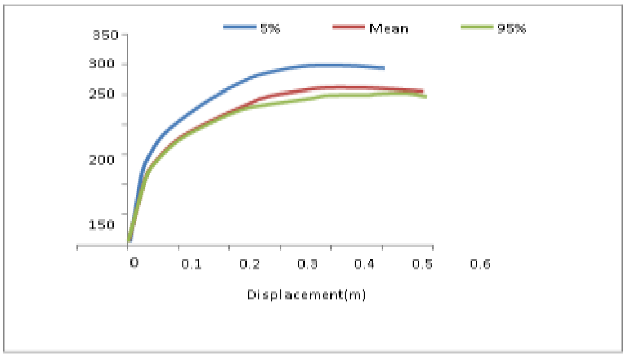


Fig.6: Pushover curve of bare frame for storey height

Fig. 7 shows the Tornado diagram analysis for the bare frame by considering all the parameters. The Tornado Diagram analysis (TDA) method is more useful for the sensitivity analysis. The graph is plotted by taking the yield point from pushover curve. The yield points are used for choosing the sensitivity parameters by the help of sensitivity equation. The graph shows that the comparison of the parameters for 5%, mean and 95%. By taking the yield point from the pushover curve the Tornado diagram are plotted after the analysis. The graph shows that yield strength of steel (fy) and storey height are higher values than other parameters. The yield strength of steel (fy) and storey height are more effective for the bare frame structure.

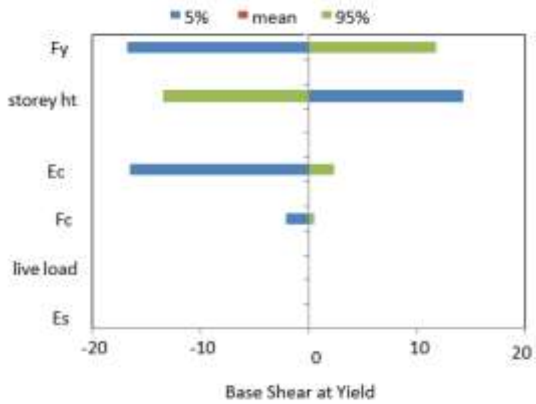


Fig.7 Tornado Diagram for 4S4B bare frame

Results for Infill Frame

Fig. 8 shows the pushover curves of infill frames for elasticity modulus of concrete. The pushover curve is plotted between base shear with Displacement. Graph are plotted for 5%, mean and 95%. In this graph the values of Elasticity modulus of concrete for 5%, mean and 95% are calculated. However, the variations are shown in the graph that 95% has more value than mean and 5%.

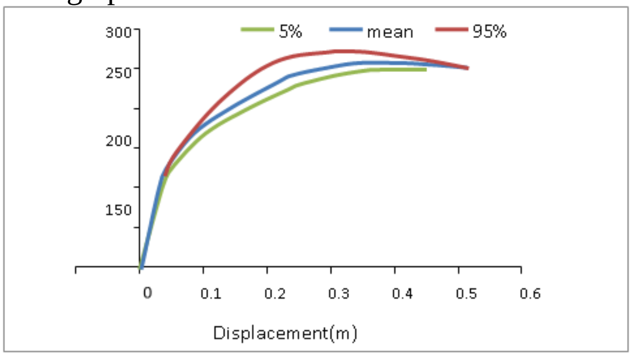


Fig.8: Pushover curve of infill frame for Ec

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Fig. 9 shows the pushover curve of infill frames for Elasticity modulus of steel (Es) of a bare frame. The graph plotted by considering values for Es in 5% and 95%. Thereare many variations shown in this graph for elasticity modulus of steel. In this graph 95%, mean and 5% come same values after analysis. For the sensitivity analysis the yield point values were taken from the pushover curve.

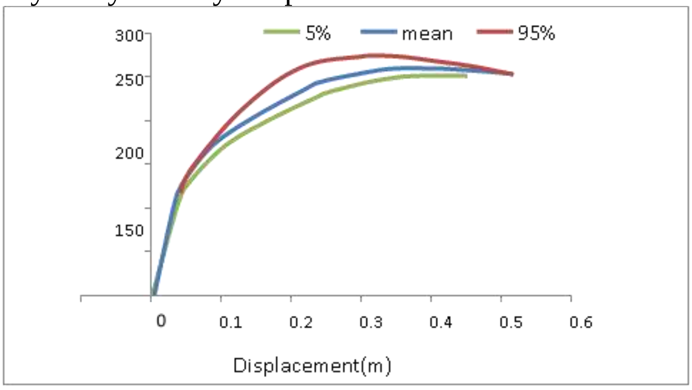


Fig. 9: Pushover curve of infill frame for Es

Fig. 10 the graph plotted for concrete compressive strength (fck) of an infill frame. In the graphs the curves for 5%, mean and 95% come approximately close to each other. The curve shows that 95% value for fck is more, less value for 5% and the mean and the mean values comes between 5% and 95%. Here also yield point values are taken for the sensitivity analysis. That means when the vale is M40 grade concrete gives more strength then M30 and M20.

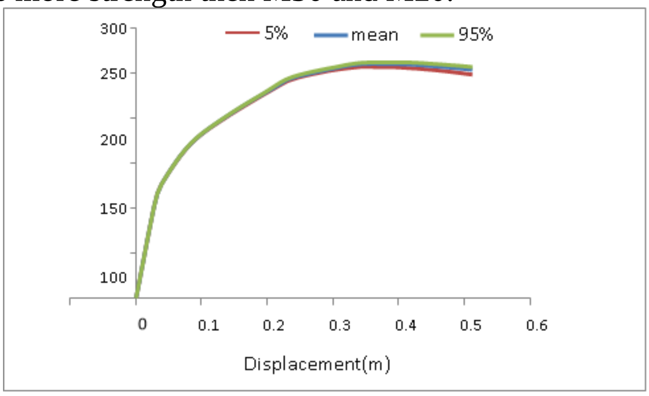


Fig. 10: Pushover curve of infill frame for fck

Fig.11 plotted for yield strength of steel (fy) of infill frame. The graph shows many variations in results. The graph for mean and 5% are slightly close to each other. The 95% values for the analysis are much higher than mean and 5% which areshown in the graph. That means the yield strength of steel fe550 gives more strength than fe415 for building structures.

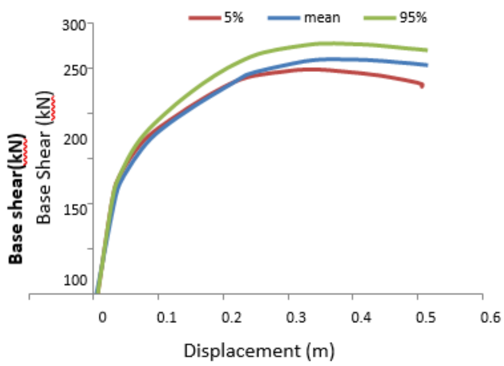


Fig. 11: Pushover curve of infill frame for fy

Fig. 12 the graph shows live load for the infill frame. The graph plotted by considering the values live load for 5%, mean and 95%, these values are calculated by using distribution and covariance. The graph shows there are insignificant variationsin the result. So the graph was plotted in one line.

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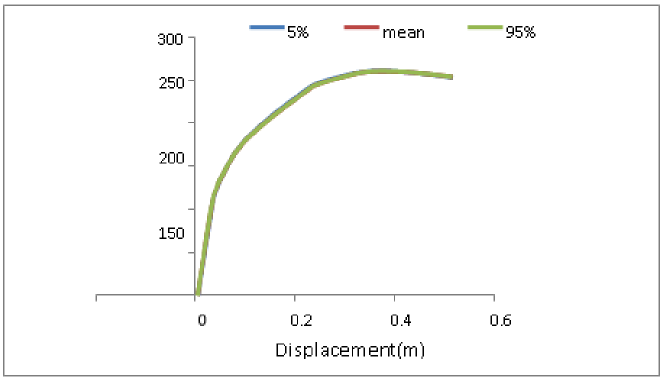


Fig.12: Pushover curve of infill frame for Live load

Fig. 13 shows the building story height for 5%, mean and 95%. Here the 5% curve shows more values then mean and 95%. The mean curve comes approximately closeto the 95% curve. 5% curve values are high because the less height of the building have less stiff than the more height buildings.

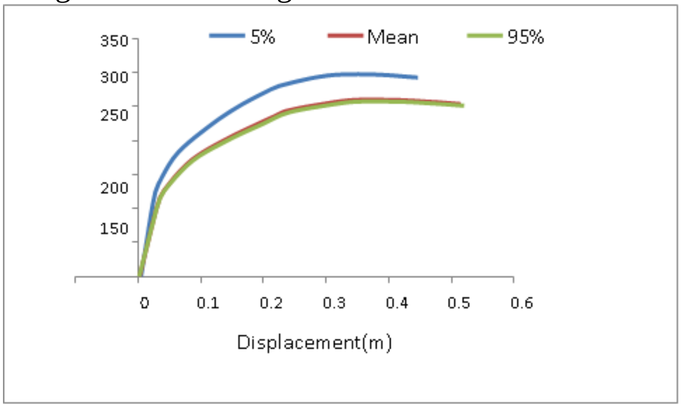


Fig. 13: Pushover curve of infill frame for Storey height

Fig. 14 plotted for shear strength of masonry infill ($\tau\tau$cr) of a infill frame. The graph shows many variations in result. The 95% values for the analysis are much higher than mean and 5% which are shown in the graph. That means more shear strength of masonry infill, less collapse.

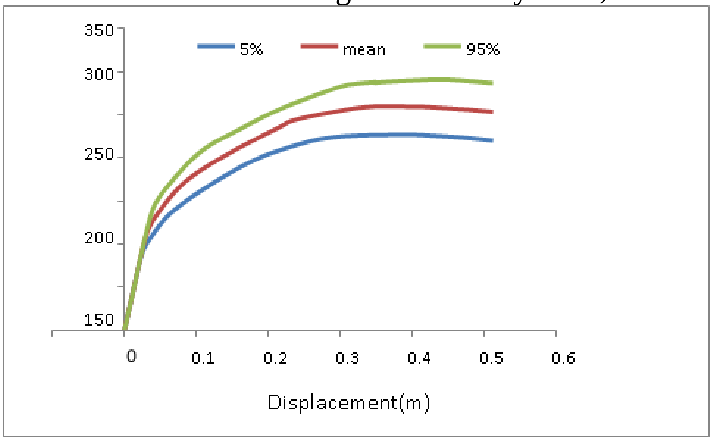


Fig. 14: Pushover curve for infill frame for $\boldsymbol{\tau\tau}$cr

Fig. 15: shows the Tornado diagram analysis for the infill frame by considering all the parameters. The Tornado Diagram analysis (TDA) method is more useful for the sensitivity analysis. This method is used for comparing the parameters, and determines the highest values of the input parameters. The graph is plotted by taking the yield point from pushover curve. The yield points are used for choosing the sensitivity parameters by the help of sensitivity equation. The graph shows that the comparison of the parameters for 5%, mean and 95%. By taking the yield point from the pushover curve the Tornado diagram are plotted after the analysis. The graph shows that the Shear strength of masonry infill ($\tau\tau$cr)

is higher values than other parameters. The Shear strength of masonry infill ($\tau\tau$cr) and yield strength of steel (fy) are more effective for the infill frame structure.

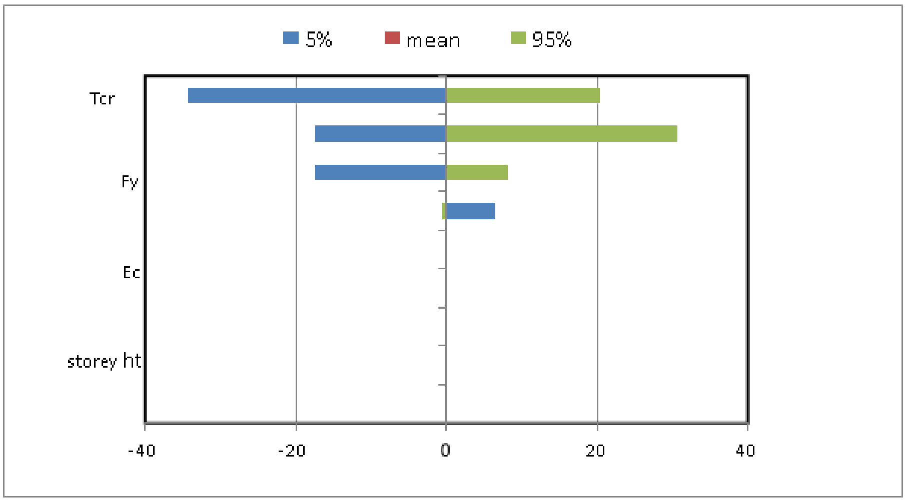


Fig. 15: Tornado Diagram for 4S4B infill frame

The analysis is easy to do by using the software; it gives direct the pushovergraph. The chapter shows the non-linear pushover analysis for several parameters. In this the comparison results are shown for bare frames and infill frames.

## 4. CONCLUSIONS

The present study is undertaken to carry out the sensitivity analysis of the RC building. The analysis is conducted for the bare frame and infill frame structures. For this analysis, several parameters (compressive strength of concrete (fck), yield strengthof steel (fy), elasticity modulus of concrete (Ec), elasticity modulus of steel (Es), live load, storey height and shear strength of masonry infill ($\tau\tau$cr) are taken. The pushover analysis is performed for this structure done by using the software SAP 2000(V19). The Tornado Diagram Analysis (TDA) analysis is done to compare the parameters which are taken for this study. Based on the work presented in this thesis following point-wise conclusions can be drawn:

- For bare frames
- No significant variations in the calculated values of elasticity modulus of concrete (Ec) is detected for 5%, mean and 95%. Similarly, no substantial variations shownin this graph for elasticity modulus of steel (Es).
- The pushover curve for concrete compressive strength (fck) shows that curve for 95% has greater values than mean and 5%. That means the concrete compressive strength is more for M40 than M20 and M30.
- Yield strength of steel for 5%, mean and 95% are compared. It is found that 95% curves are much higher than mean and 5%. That means fe 550 are more than fe 450.
- For the live load there are significant variations in push over curve for 5%, mean and 95%.
- Less storey height more stiffness and more storey height less stiffness. That meansthe curve shows that 5% are stiffer than mean and 95%.
- For Infill frames
- The elasticity modulus of concrete (Ec) shows the curve for 95% shows higher values then mean and 5% in the pushover curve.
- The curve shows no significant variations shown in this graph for elasticitymodulus of steel (Es) in 5%, mean and 95%.

• The pushover curve for concrete compressive strength (fck) shows that curve for 95% has approximate values with mean and 5%. That means the concrete compressive strength is more for M40 than M20 and M30.
• Yield strength of steel for 5%, mean and 95% are compared for the infill frame. From the graph 95% curve are much higher than mean and 5%. That means fe 550 are more than fe 450.
• For the live load there are also no significant variations shown in the graph for 5%, mean and 95% for infill frames.
• Less storey height more stiffness and more storey height less stiffness. That meansthe curve shows that 5% are stiffer than mean and 95% for bare frames.
• The pushover graph shows many variations in results. The 95% values for the analysis are much higher than mean and 5% which are shown in the graph.
• After the analysis the results obtained that in the bare frame among those parameters the yield strength of steel (fy) and storey height are more effective and for the infill frame the shear strength of masonry infill ($\tau\tau$cr) and yield strength of steel (fy) are more effectible for the building structure.
• Concrete and masonry strength-related variation values have shown a significant effect on the building capacity and this effect increase with the progress of damage condition for the concrete.

5. Future scope

1. The present study is limited to two-dimensional (2D) reinforced concrete (RC) four storied building frame of sensitivity analysis. There is a future scope of study on three- dimensional building models for the sensitivity analysis.
2. In the study the nonlinear analysis was taken for the sensitivity analysis, it can be extended to linear analysis in future.
3. For the sensitivity analysis the pushover analysis was carried out, other methods can be also useful like inelastic time history analysis, capacity demand (C/D) analysis and modal pushover analysis also.
4. Among the SAP2000 other software can also be used for the analysis like Etabs, OpenSees and Ansys.

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