Comparative Analysis of Vertical Geometric Irregular Buildings by Fragility Curve Using Pushover Analysis

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***Abstract*— The present work deals with analysis of vertical geometric irregular stricture like step building and setback building having stiffness irregularity at different locations. These are analyzed by Pushover analysis. Further from the data obtained from pushover analysis fragility curves are plotted for different damage states for the structure. comparative analysis is carried out. It is found that step building having stiffness irregularity at middle can transfer loads relevantly than when compared to irregularity at bottom. Setback and step building having stiffness irregularity at top may less damaged at initial stage of damages but later gets affected when reaching to extensive or complete damage state concludes they becomes venerable as they get displaced largely.**

***Index Terms*—Pushover analysis, fragility curve, stiffness irregularity, geometric irregularity.**

I. INTRODUCTION

India recently became the most populated country in the world, as the population is increasing day by day there is a huge demand for accommodation. Use of irregularities such as planar irregularity and vertical irregularities are key factors practices for recent projects. The effect of seismic ground motion on these structures needs to be inspected. Thus there is need of understanding the behavior of the structure fragility curves parameter can be a game changing. Many previous researchers had worked on vertical geometric irregularities but without introducing any type of irregularity hence need to inspect the behavior of damage states of those structures is done in this present work

This thesis is related to the study of the probabilistic damage behavior of regular and vertical geometrically irregular buildings with varying stiffness of buildings at particular stories using the pushover method to form fragility curves. By performing pushover analysis, Fragility curves are plotted and used for the predictions of disaster models to define probabilistic damage to the structure. These fragility curves can determined probability of damage state to seismic intensity. These seismic intensities are of three different types; they are spectral displacement, spectral acceleration, and peak ground displacement. For the study, the parameter considered is spectral displacement.

In Pushover analysis, a series of static lateral forces are applied to the structure, basically in proportion to the design force profiles outlined in relevant codes. These forces are gradually increased until it achieve the desired displacement, with the structure analyzed at each stage. As the loads escalate, the building may undergo yielding and deformation at specific locations. During yielding, the structural properties are adjusted approximately to interpret this yielding. The analysis continues until the structure collapses or reaches a desired level of lateral displacement. Here for the present work displacement controlled pushover analysis is used.

According to FEMA HAZUS Section 5, The fragility curve is the function that describes probability of structural damage state or performance level of building's that certain ground motion. Typically, fragility curve plots probability of exceeding damage threshold against intensity measures such as spectral acceleration, spectral displacement and peak ground acceleration. These fragility curves obtained by pushover analysis can provide information about vulnerability of structure under seismic loading. Predicting the damage offered by a certain seismic activity to the structure helps designer to provide solution over the damaged element to the stake holders which won't get affect their properties which they are investing upon along with the public who would use that property. These curves are used to describe the probability of reaching different damage states given by permanent ground deformation. It also helps to find out the behavior of building beyond the linear state of analysis.

II. LITERATURE REVIEW

Many previous researchers had worked on vertical geometric irregularities but without introducing any type of irregularity hence need to inspect the behavior of damage states of those structures isdone in this present work. Alex barbet[1] had worked on damage scenarios of urban areas of Barcelona and Spain with capacity spectrum. He formed an equation to plot probability of damage states at different levels. Anil Chopra[2] worked on six different height frames with nonlinearity methods like pushover analysis and nonlinear time history analysis. His research estimates that pushover analysis helps to investigate soft or weak story in the structure. Haider & Paul [3] researched about vulnerability of low rise structures with the help of DBE and MCE levels. Patel & Vasanwala[4] studied analytical method from HAZUS and pushover analysis concluding low stories building are higher susceptible to damages. Pijush Shil [5] investigates damage states with and without precast shear wall subjected to nonlinear pushover analysis and incremental dynamic analysis. They found that slight and moderate state was had damage provability up to 90% of the structure but for extensive damage its more than 80% for structure without precast shear wall . Paul along with Debnath [6] further continued their research with DBE and MCE levels by consideration of low rose and mid rise structures. Ravikumar [7] investigated sloping ground buildings with pushover analysis method. They concluded that sloping ground is the most vulnerable type of building.

III. SYSTEM DEVELOPMENT

In the present work, vertical geometric irregular buildings like open ground story buildings, setback buildings, and step buildings are considered. These buildings are assigned with stiffness irregularity at different portions such as at base, at middle and at the top stories of the structure. After assigning these irregularities, pushover analysis is carried out. After performing the pushover analysis , fragility curves are plotted. Following are the parameters considered for present work. Following are the dissimilar geometric parameters for various models below.

PARAMETERS	DATA
Number of stories	G+12
Bays in x direction	5
Bays in y direction	5
Length of each bay in x-direction	3m
Length of each bay in x-direction	3m
Grade of steel	Fe500
Grade of concrete	M25
Column dimension	400 X 400
Beam dimension	300 X 400
Slab thickness	150mm
External wall thickness	230mm
Internal wall thickness	115mm
Height form base to I st story	1.5m
Height of typical story	3m

Types of Models
Set Back Building (SB)
Set Back Building with stiffness irregularity at bottom (SB-IR-B)
Set Back Building with stiffness irregularity at middle (SB-IR-M)
Set Back Building with stiffness irregularity at middle (SB-IR-M)
Step Building (ST)
Step Building with stiffness irregularity at bottom (ST-IR-B)
Step Building with stiffness irregularity at middle (ST-IR-M)
Step Building with stiffness irregularity at middle (ST-IR-T)

A] Following are G+12 setback building (SB) model along with setback building having stiffness irregularity at locations: bottom (SB-IR-B), middle (SB-IR-M) and top (SB-IR-T) of the building.

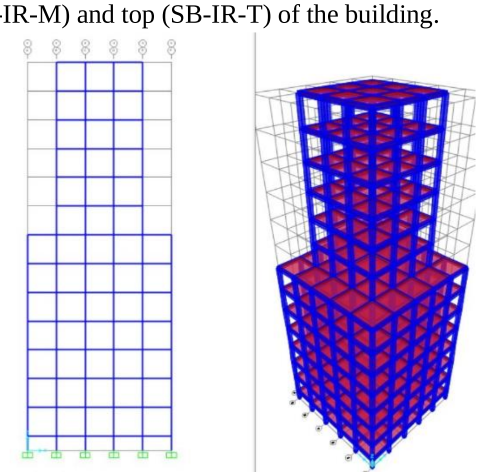

Fig.1 Setback Building (SB)

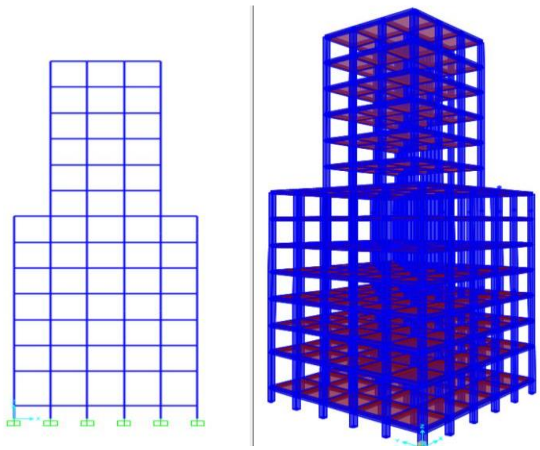

Fig.2 Setback building with stiffness irregularity at base (SB-I-B)

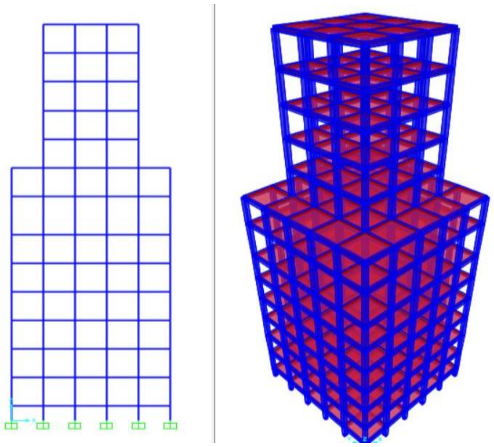

Fig.3 Setback building with stiffness irregularity at middle (SB-IR-M)

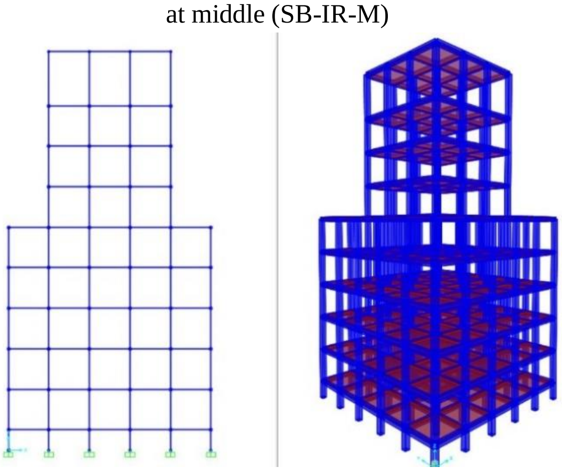

Fig.4 Setback building with stiffness irregularity at top (SB-IR-T)

B] Following are G+12 setback building (SB) model along with setback building having stiffness irregularity at locations: bottom (SB-IR-B), middle (SB-IR-M) and top (SB-IR-T) of the building.

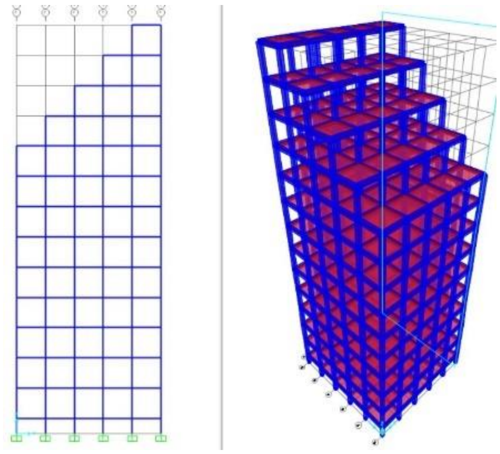

Fig.5 Step Building (ST)

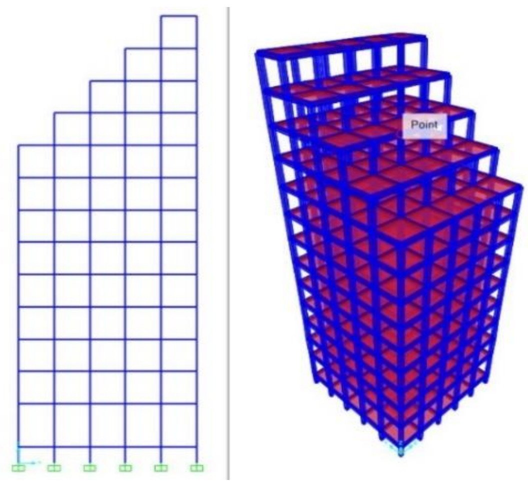

Fig.6 Step Building with stiffness irregularity at bottom(ST-IR-B)

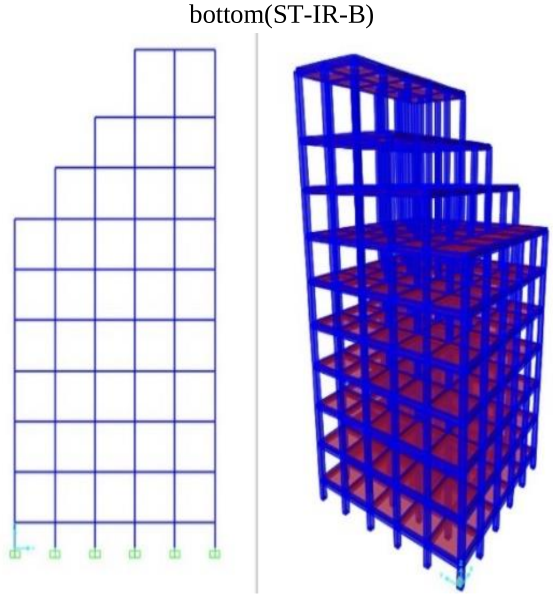

Fig.7 Step Building with stiffness irregularity at middle (ST-IR-M)

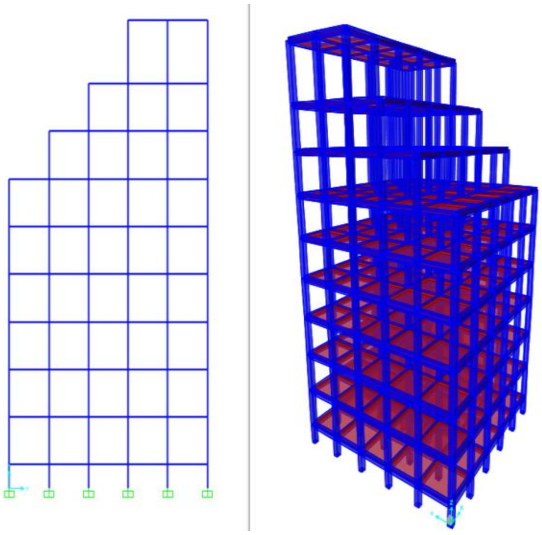

Fig.8 Step Building with stiffness irregularity at middle (ST-IR-M)

IV. RESULT AND DISCUSSION

In this paper, nonlinear static pushover analysis is used to plot seismic fragility curves. The models considered for present work are set back and step building without stiffness irregularity and along stiffness irregularity at bottom, middle and top. Following are the fragility curves obtained for different structures. Here all the graphs has displacement in cm on X-axis and y-axis represents the probability of respected damaged state.

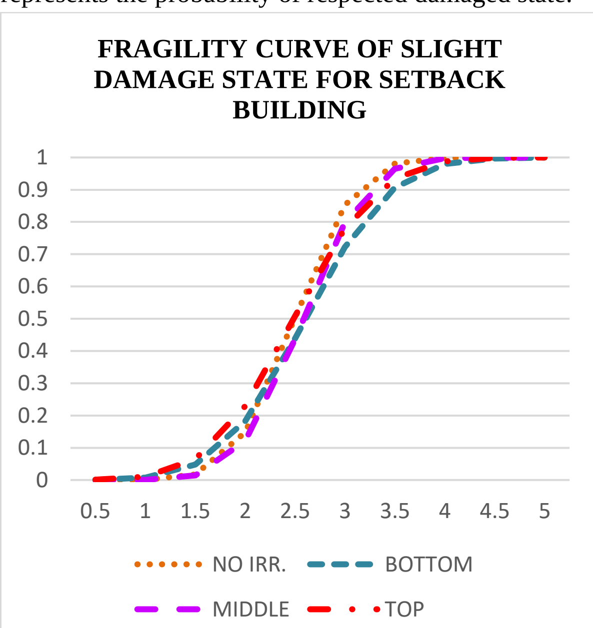

Fig.9 fragility curve for slight damage for Setback building

Discussion:- Above fig.9 denotes slight damage state of the SB building having stiffness irregularity at different locations. Probability of damage state at 2.5cm i.e. 25mm shows SB has and SB-IR-T has close percentage of probability of damage state of about 50% of total slight damage state. Similarly, SB-IR-B and SB-IR-M shows percentage of probability of damage about 43.9 % of total slight damage state.

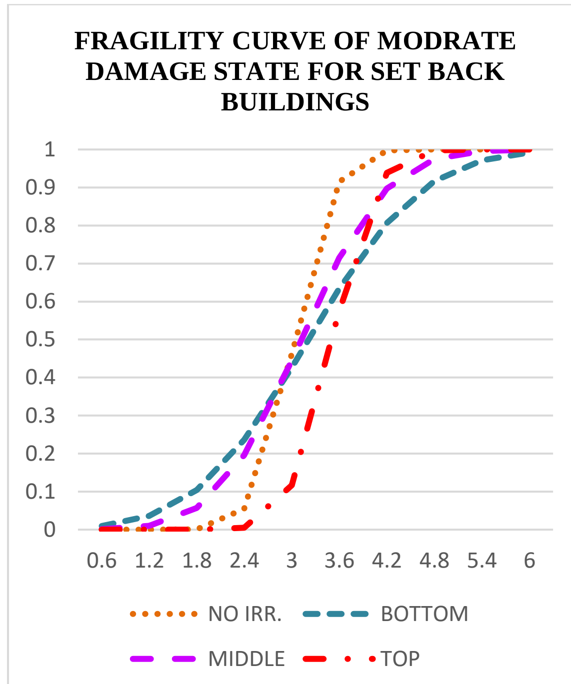

Fig.10 fragility curve for extensive damage for Setback building

Discussion:- Fig.10, reports represent Moderate damage state of SB at different locations. It is observed that at displacement 3cm i.e. 30mm SB with no irregularity has probability of damage state of about 46.23% which is observed large compared to other irregularities. SB-IR-B shows comparatively less damage state of about 42.64%. For SB-IR-M, percentage of damage is observed 44.46% which is second most damaged structure observed at moderate damage state. Compared to SB-IR-T, has least damage observed of only about 11.64%. Thus concluding that at moderate state it is most stable structure.

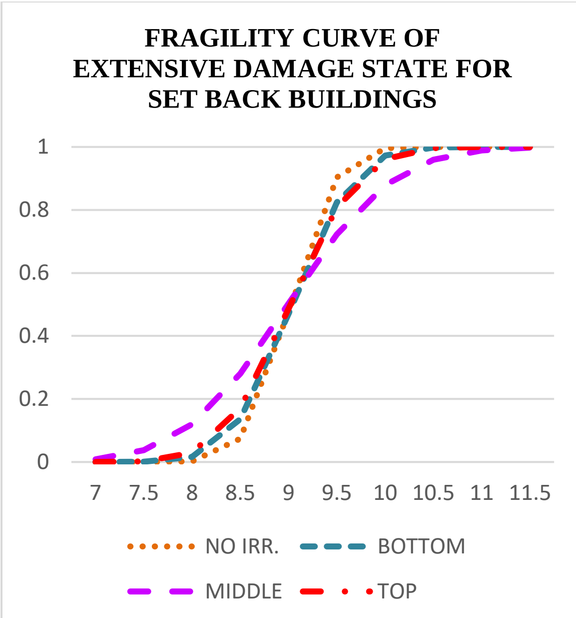

Fig.11 fragility curve for extensive damage for Setback building

Discussion:- Above fig.11, denotes extensive damage state of SB, from this graph it is observed that at displacement of 9cm that is 90mm, percentage of damage observed for SB with no irregularity is about 47.67% which is observed more than that of SB-IR-B of about 47.01%,for SB-IR-M and SB-IR-T probability of damage state is about 50.3% and 48.71%respectively of total extensive damage state .

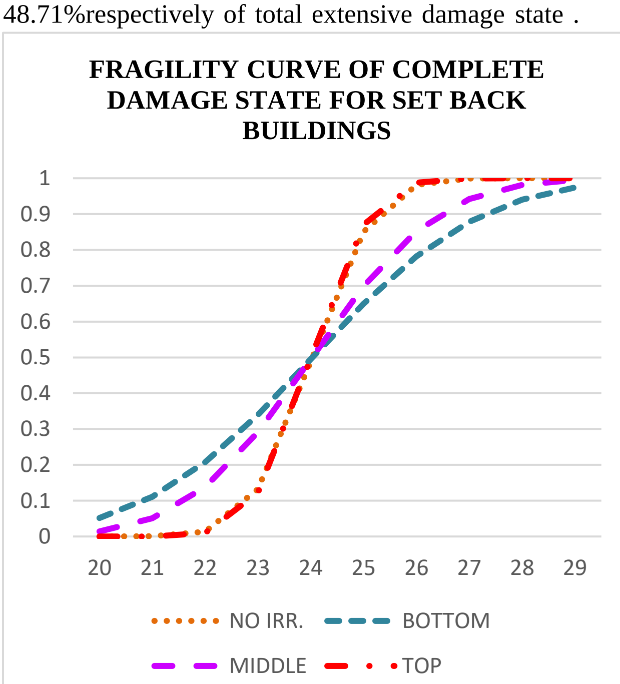

Fig.12 fragility curve for complete damage for Setback building

Discussion:- Fig.12,It presents the relationship between displacement and the probability of complete damage in setback buildings. At displacement of 25cm, probability of damage to the structure with stiffness irregularity at top SB-IR-T shows huge percentage of damage state of 87.065. Though SB-IR-B and SB-IR-M shows less probability of damage state is due to presence of fractures at the joints is about 64.94% and 69.88%respectively.

Results for Step building, are below,

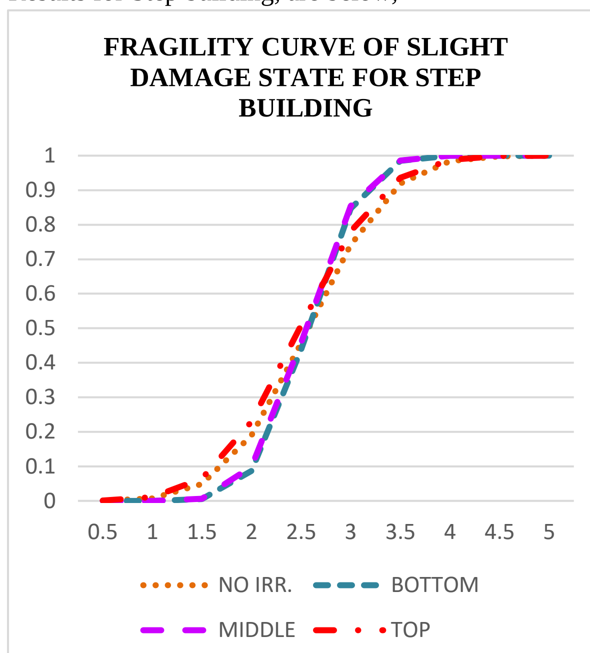

Fig.13 fragility curve for slight damage for Step building

Discussion:- Above graph fig.5.5, is of the fragility curve of step building. The damage probability of step building ST at 2.5cm is about 45.66% of entire damage state. Compared to bottom stiffness irregularity (ST-IR-B) structure damage probability is of 43.85% which shows building significantly distributes loads at this stage. Sillier is for ST-IR-M; more affected structure in slight damage state is of ST-IR-T which shows nearly 50% of entire slight damage probability.

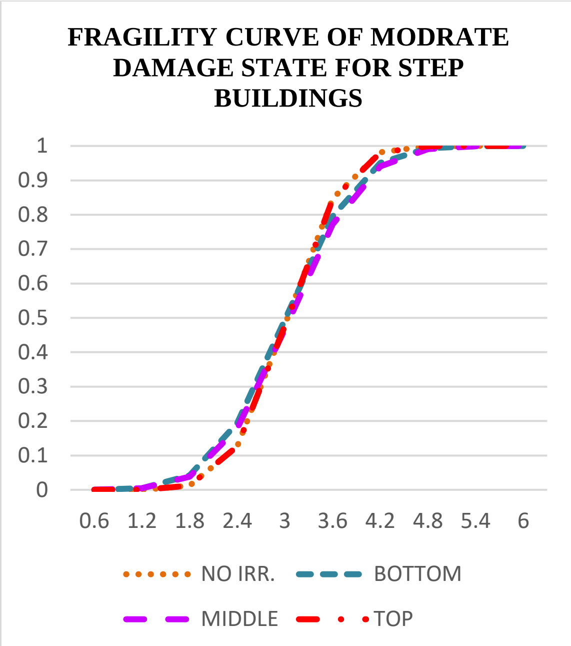

Fig.14 fragility curve for moderate damage for Step building

Discussion:- At displacement 3 cm percentage of moderate damage state for ST-I-B has high damage percentage of about 49.52%. and lowest is for ST-IR-M which is about 46.73%. compared to SB-IR-T has less percentage of damage state of 47.81% than that of SB with 48.06%.

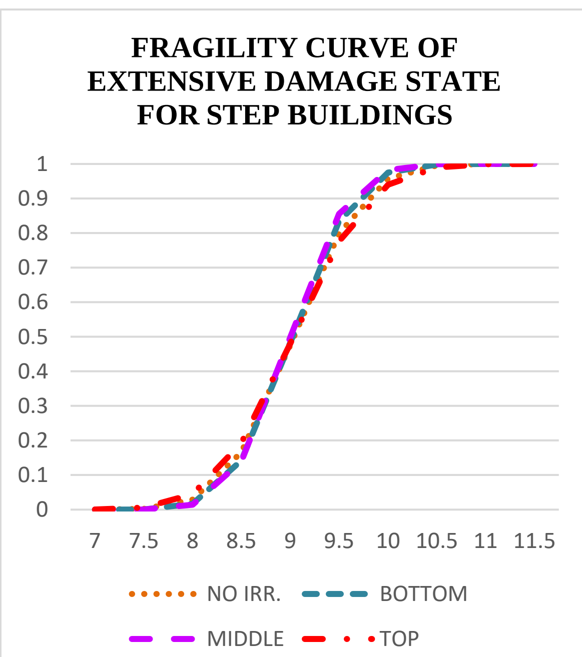

Fig.15 fragility curve for extensive damage for Step building

Discussion:-Fig.15,At displacement of 9cm Setback building having no stiffness irregularity has probability of extensive damage state of about 47.62% which is less compared to other damage state thus less affected in this state.49.94% of damage state is obtained for ST-IR-M where as ST-IR-B & ST-IR-T shows close that is 48.34% and 48.08% of damage for extensive damage state.

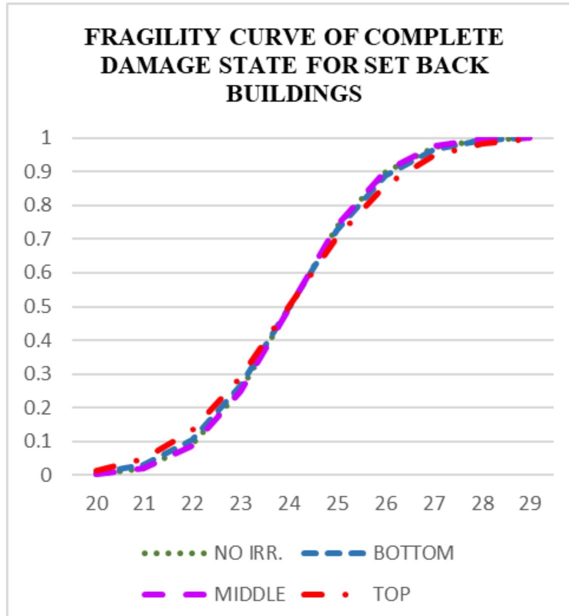

Fig.16 fragility curve for complete damage for Step building.

Discussion:- At the complete damage state for step building probability of exceedance at a displacement of 25cm for SB is 73.67% which is the second-highest damage .The ST-IR-M has 74.025% of damage. ST-IR-B and ST-IR-T shows 72.7% and 70.7% of damage complete damage state.

V. CONCLUSION

This chapter shows the summery of the present work. Structures like setback building and step building are introduced with stiffness irregularity at base, middle and top. These structures are analysed by pushover analysis and fragility curves are plotted from the data obtained. Following conclusions are made from the fragility curves of each building.

1. Buildings with setback designs, characterized by stiffness irregularities at the base and lower levels, exhibit lower probabilities of damage at slight damage states that shows some hairline cracks at

some beams and columns is observed at 20 mm displacement compared to other structures. This suggests that such buildings demonstrate better resilience during the initial stages of damage.

2. At moderate damage state, least damage is observed in setback building having stiffness irregularity at top and step building having stiffness irregularity at middle than any other types of structures denotes few members of structure have reached their yield capacity.
3. At the state of extensive damage all the structures get affected by almost 50% of damage which shows but low damage is observed in the SB and ST having no stiffness irregularities. Large flexural cracks and buckled main reinforcement is observed in beams. While main reinforcement in column is slightly buckled which is partial collapse due to broken ties.
4. Set back buildings have the highest probability of damage at a complete collapse state which denotes but is better than others because of stiffness irregularity
5. Irregularities at the top level of structure represent high risk in completely damaged state because when structure is subjected to ground motion large displacement may occur at top of the building.
6. At initial stage structures having stiffness irregularity at bottom show large displacement at initial stage which is due to soft story effect hence needed to be strengthen when used.
7. When irregularity is added to middle of the structure , can distribute load equivalently up to moderate damage state.

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