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RISK ASSESSMENT OF SEISMICALLY EXCITED STRUCTURES USING FRAGILITY CURVE

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ABSTRACT

This paper presents the performance of an open ground storey is a typical feature in the modern multistorey constructions in urban India. Such features are highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes. This paper highlights the importance of explicitly recognizing the presence of the open ground storey in the analysis of the building using SAP 2000. The error involved in modeling such buildings as complete bare frames, neglecting the presence of infills in the upper storeys, is brought out through the study of an example building with different analytical models of with and without bracings in open ground storey in inplane direction. This paper argues for immediate measures to prevent the indiscriminate use of soft ground storeys in buildings, which are designed without regard to the increased displacement, ductility and force demands in the ground storey columns. Alternate measures, involving stiffness balance of the open ground storey and the storey above, are proposed to reduce the irregularity introduced by the open ground storey.

Keywords: Fragility, Risk, Seismic, Soft Storey,Vulnerability

I. INTRODUCTION

The international fact finding expert mission on the Fukushima nuclear power plant (NPP) related disaster, following the great east Japan earthquake and tsunami (March, 2011), categorically concluded, ‘‘There is a need for the nuclear community to increase effort in developing probabilistic safety assessments (PSA) for external events”. This mission also emphasized on a rigorous PSA treatment avoiding the screening of extreme events based on approximate criteria. The objective of a seismic PSA of a NPP is to examine the existence of vulnerabilities against postulated earthquake hazards. It involves assessing the plant’s (or, its components’) safety numerically, in a probabilistic framework, so that appropriate measures can be taken to enhance the plant’s safety level, if required. One of the major components of this PSA, is the seismic fragility evaluation. Seismic fragility is defined as the conditional probability of failure of a structure for a given seismic intensity level. These fragilities are typically expressed using conditional probability versus seismic intensity ‘fragility’ plots. The present work focuses on the seismic fragility analysis of the primary structure in Andaman and Nicobar Islands, which is considered to be in Zone V earthquake region. Fragility definitions also change on the basis of how failure of a structure or a component is defined.The “soft ground storey” at the stilt level is clearly the primary reason for a severe damage during earthquake shaking. A simple example building is analyzed with different models and the stiffness effect is demonstrated.

II. STRUCTURE FINDING FROM PREVIOUS RESEARCH

Relationship between peak ground acceleration (PGA) and structural damage is frequently used to estimate the distribution of structural damages in buildings over certain seismic regions. Giuseppe Carlo Maranoet. al. focused on obtaining the fragility curves in terms of the probability of exceeding a given damage level, by using an approximate theory of stochastic processes. Miroslav Nastevet. al. comparison of analysis in ELER and Hazus shows the importance of the development of fragility curves specific to the generic construction characteristics in the study area and emphasizes the need for critical results. D. J. Chaudhariet. al. uses probabilistic seismic demand models by using power law model, results show that performance of upper storeys while applying multiplication factor only to the ground storey needs to be checked. Marco Vona highlights different thresholds of IDR have been associated with different typologies, considering their different ductility member levels after their different structural responses. Bakhshi, M. Ansari found an increase in the probability of exceedance of different damage states is observed in the cases of considering SSI effects, type D soils and near-source accelerograms. John Wilson developed fragility curves to provide a more realistic representation of the seismic vulnerability of the building than the conventional approach based simply on the degradation in the horizontal resistance of the column.Nor MayuzeMohamadaet. al. developed the Fragility curve based on the probabilistic hazard level, cumulative probability function and classification damage-states. Level Confident Interval safety of double-storey house is assessed based on the plotted fragility curve and experimental work. Prediction damage states of this house at Design Basis Earthquake (DBE) and Maximum Considered Earthquake (MCE) can obtain from fragility curve analysis.

The objective of this study is to analyse various building configurations in Andaman, develop and compare fragility curve with bracings for each type.

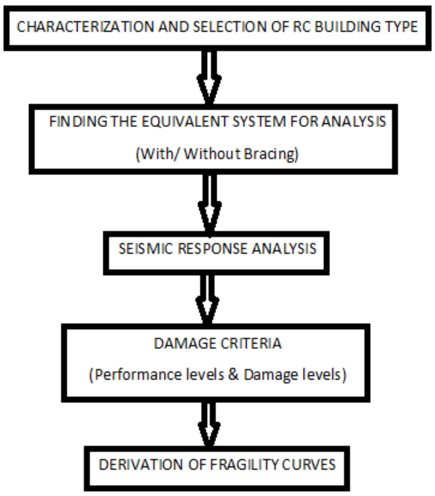


Fig. 1 Flow chart of methodology

III. ANALYTICAL MODELLING OF BUILDING

Case 1:

The building is considered to be located in seismic zone V and intended for residential use. The building is founded on medium strength soil through isolated footings (of size 2m×2m) under the columns. When a central concrete service core is used, a 2m wide footing is taken to go all around under the wall in the core. Elastic moduli of concrete and masonry are 28,500 MPa and 3,500 MPa,respectively, and their Poison's ratio is 0.2. Performance factor (K) has been taken as 1.0 (assuming ductile detailing). The unit weights of concrete and masonry are taken as 25 kN/m^{3}and 20 kN/m^3. The floor finish on the floors is 1 kN/m^2.The weathering course on roof is taken as 2.25 kN/m^2. The live load on floor is taken as 2 kN/m^2 and that on roof as 0.8 kN/m^2. In the seismic weight calculations, only 25% of the floor live load is considered.

The structure used for analysis is a reinforced concrete frame structure. The details of the building are given below:

For 2 Storey, number of bays in x and y: 2 nos.

Bay length in x.direction : 4m

Bay length in y.direction : 4m

Bay length in z.direction : 4m

Size of the beam : 0.23 m x 0.3m

Size of the column : 0.23 m x 0.23 m

Depth of slab : 0.12 m

Angle section : 45 x 45 x 6 mm

Case 2:

For 8 Storey, number of bays in x and y: 6 nos. and 8nos.

Bay length in x.direction : 4m

Bay length in y.direction : 4m

Bay length in z.direction : 4m

Size of the beam : 0.23 m x 0.6m

Size of the column : 0.4 m x 0.5 m

Depth of slab : 0.12 m

Angle section : 45 x 45 x 6 mm

Case 3:

For 4 Storey, number of bays in x and y: 4 nos.

Bay length in x.direction : 4m

Bay length in y.direction : 4m

Bay length in z.direction : 4m

Size of the beam : 0.23 m x 0.3m

Size of the column : 0.3 m x 0.4 m

Depth of slab : 0.12 m

Angle section : 45 x 45 x 6 mm

Fragility Function Used:

P(C|IM=x) Ø{ln(x/ Θ)/ β}……………………(1)

C: Collapse

IM: Intensity measure

Ø : Normal cumulative distribution function

Θ ,β : constants

P(C|IM=x) $= \frac{no.\ of\ collapse\ when\ IM = xj}{no.\ of\ ground\ motions}$ ……………………(2)

IV. RESULTS AND DISCUSSION

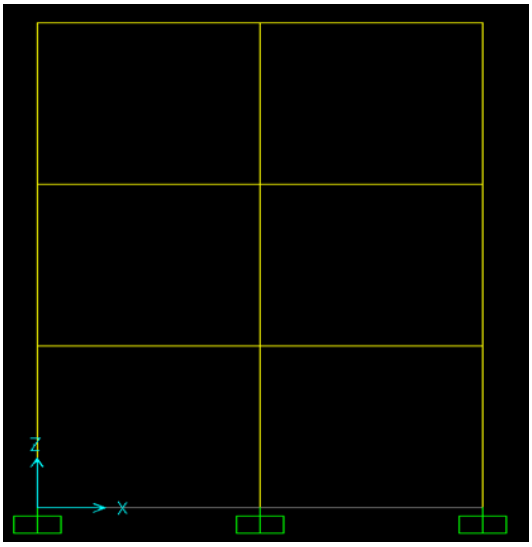


Fig. 2 Elevation of G+2 building frame without bracing

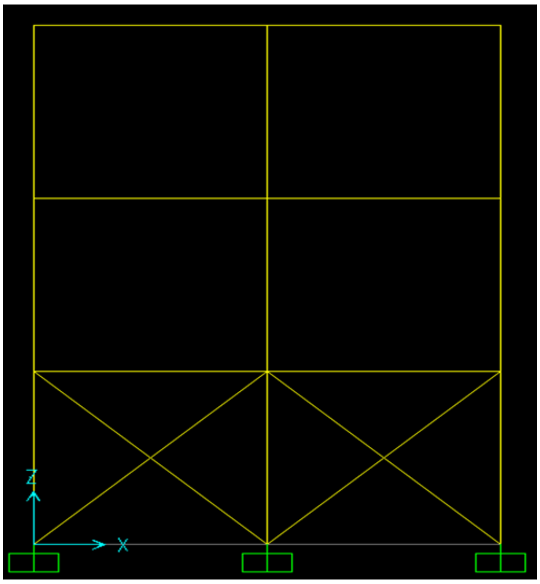
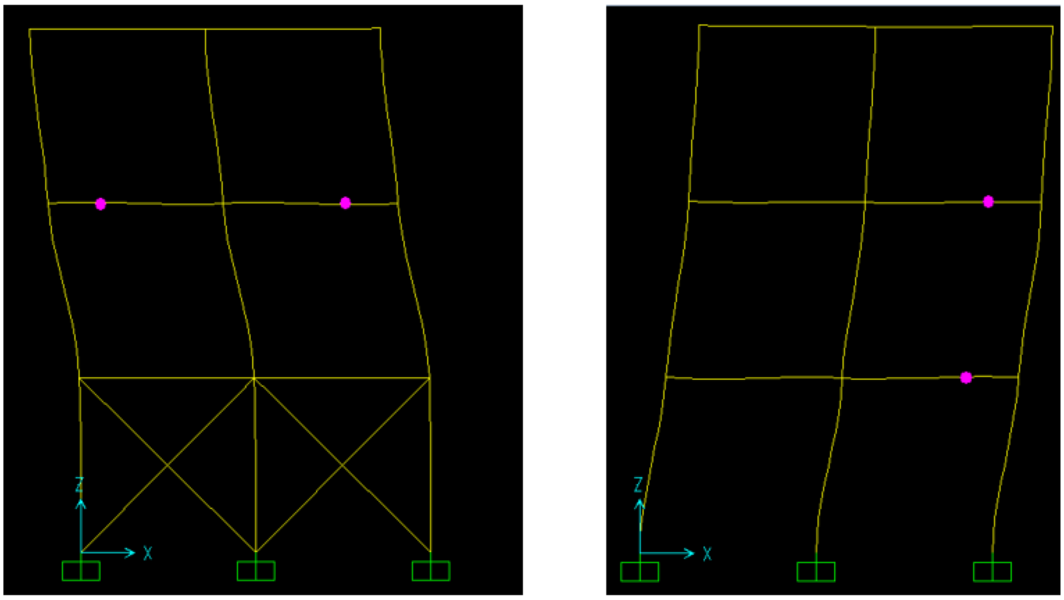


Fig.3 Elevation of G+2 building frame with bracing



Hinge formation at step 12 | Hinge formation at step 6

Fig.4 Hinge formation of G+2 building frame with and without bracing

Table 1.Damage state of 2 Storey building

Without bracing					With bracing			
Grades	**Steps**	**Disp (mm)**	**Base shear**		**Grades**	**Steps**	**Disp (mm)**	**Base shear**
IO	14	0.073	339.005		IO	18	0.049	701.371
LS	24	0.108	371.596		LS	30	0.072	718.739
CP	32	0.153	396.729		CP	35	0.113	745.477
Performance pt		0.112	380.068		Performance pt		0.068	711.470

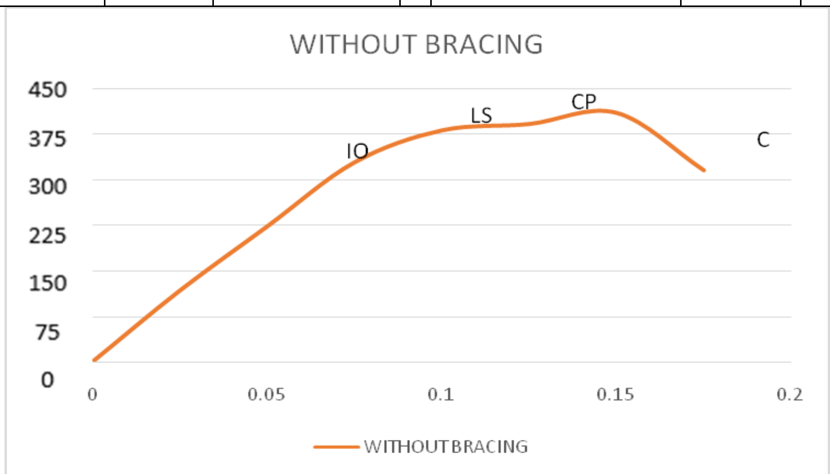


Fig.5Capacity curves for the two storey model without bracing

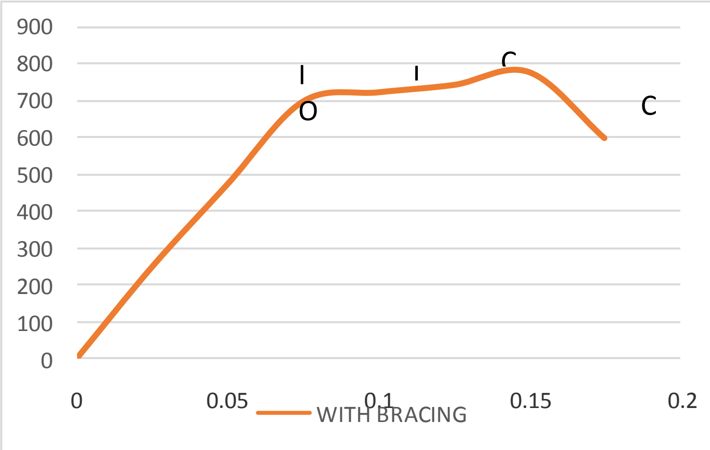


Fig.6Capacity curves for the two storey model with bracing

Drift	Storey Height	Drift	Storey Height
6.89e-20	12	2.43e-20	12
6.47e-20	8	3.56e-20	8
3.90e-20	4	3.17e-20	4
0	0	0	0

(a) (b)

Table 2.Interstorey drift for the two strorey model (a)without and (b)with bracing

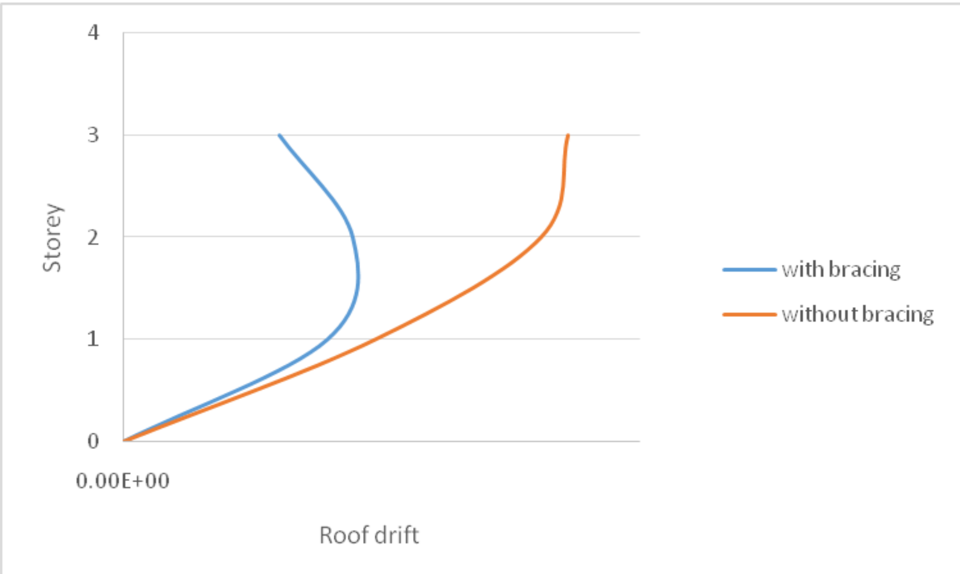
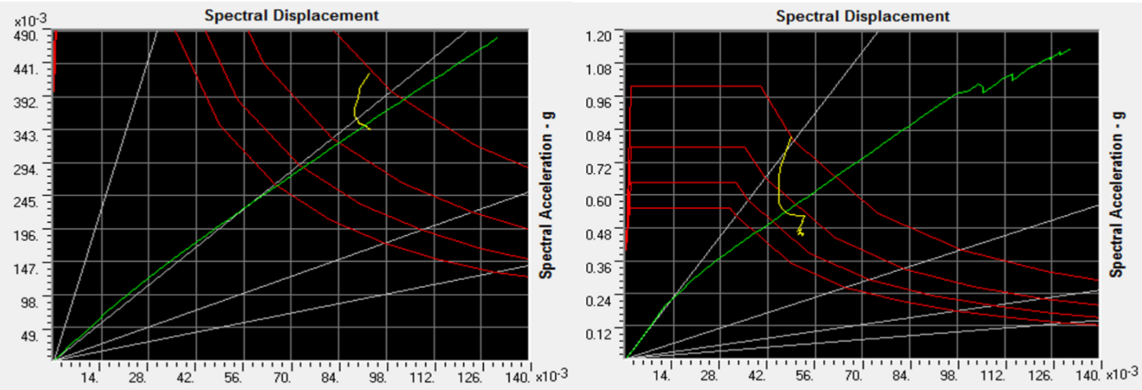


Fig. 7 Inter-storey drift curves for the two storey model



(a) **(b)**

Fig. 8 Response spectrum for two storey model (a)without and (b) with bracing

Without bracing		With bracing	
Spectral Accelration	Probability of collapse	Spectral Acceleration	Probability of collapse
0.049	0	0.12	0
0.098	0.06	0.24	0.01
0.147	0.08	0.36	0.02
0.196	0.19	0.48	0.12
0.245	0.22	0.6	0.17
0.294	0.25	0.72	0.2
0.343	0.31	0.84	0.29
0.392	0.94	0.96	0.83
0.441	0.95	1.08	0.91
0.49	0.98	1.2	0.96

Table 3. Probability of collapse for the various intensity measure

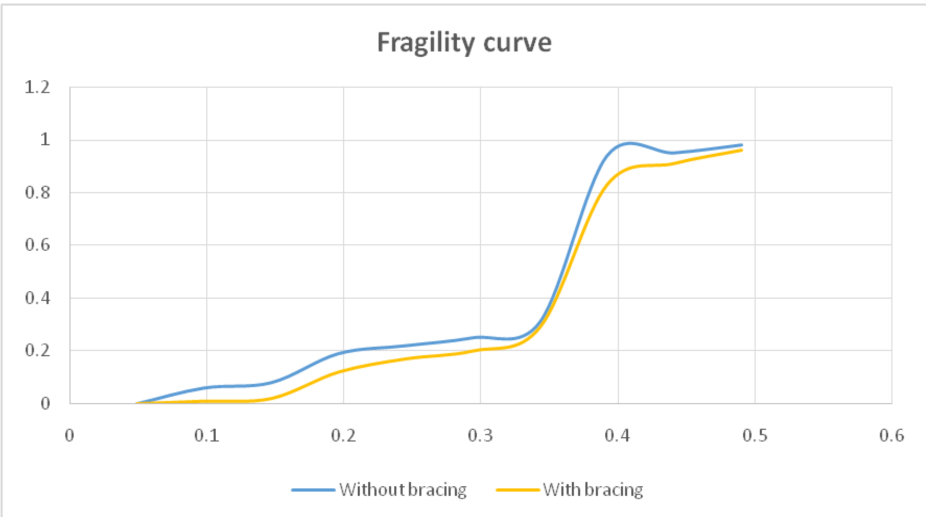


Fig. 9 Comparison of Fragility curve for two storey model without and with bracing in OGS

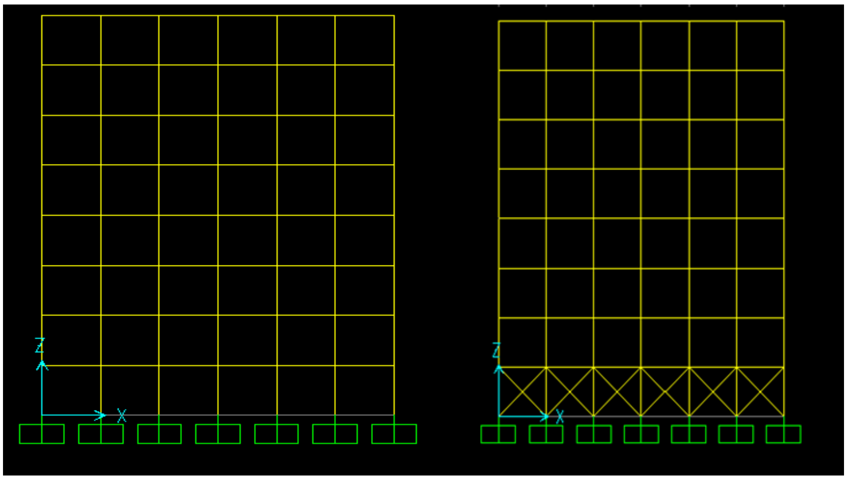


Fig.10 Elevation of G+7 building frame without and with bracing

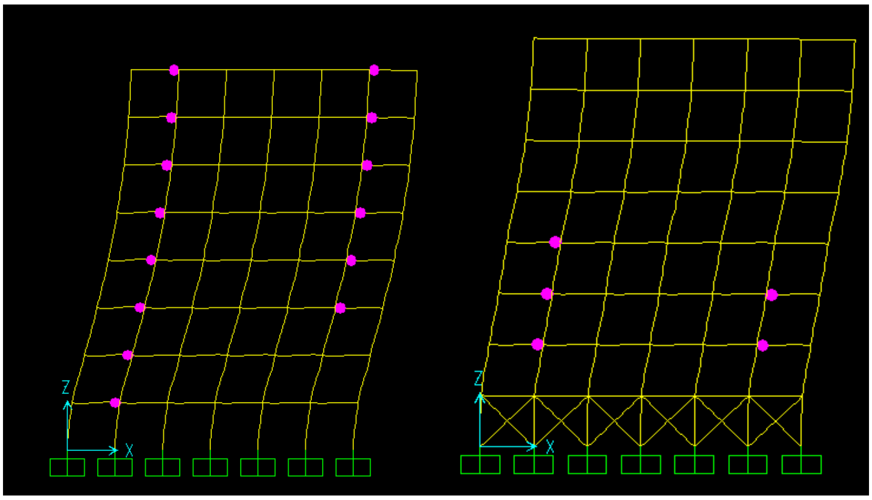


Fig.11 Hinge formation of G+7 building frame without and with bracing

Without bracing			With bracing	
Spectral Accelration	Probability of collapse		Spectral Acceleration	Probability of collapse
0	0		0	0
0.052	0.05		0.043	0.01
0.104	0.06		0.111	0.02
0.156	0.12		0.145	0.04
0.208	0.23		0.214	0.12
0.26	0.25		0.23	0.17
0.312	0.31		0.31	0.21
0.364	0.55		0.346	0.29
0.416	0.85		0.412	0.37
0.468	0.91		0.414	0.81
0.52	0.96		0.443	0.88

Table 4. Probability of collapse for the various intensity measure

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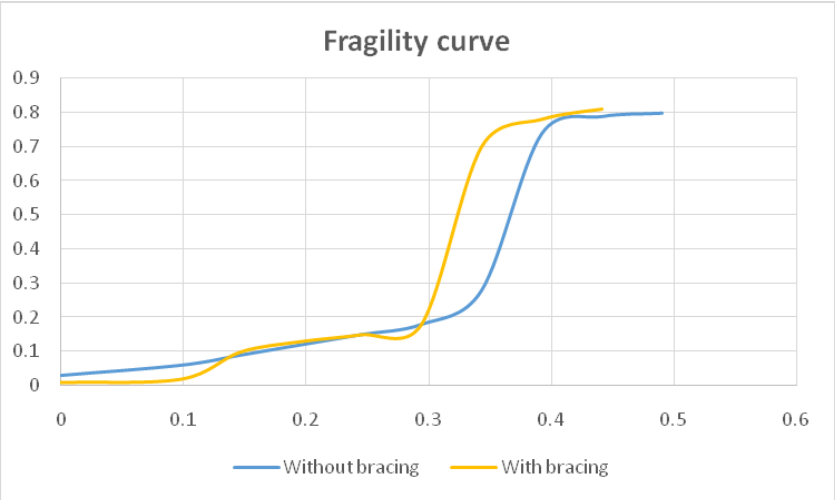

Fig. 12 Comparison of Fragility curve for 7storey model without and with bracing in OGS

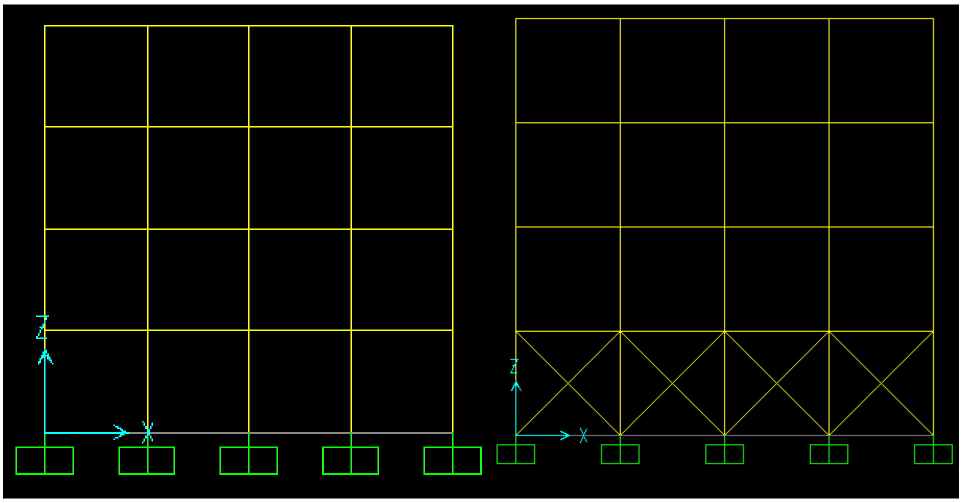

Fig.13 Elevation of G+3 building frame without and with bracing

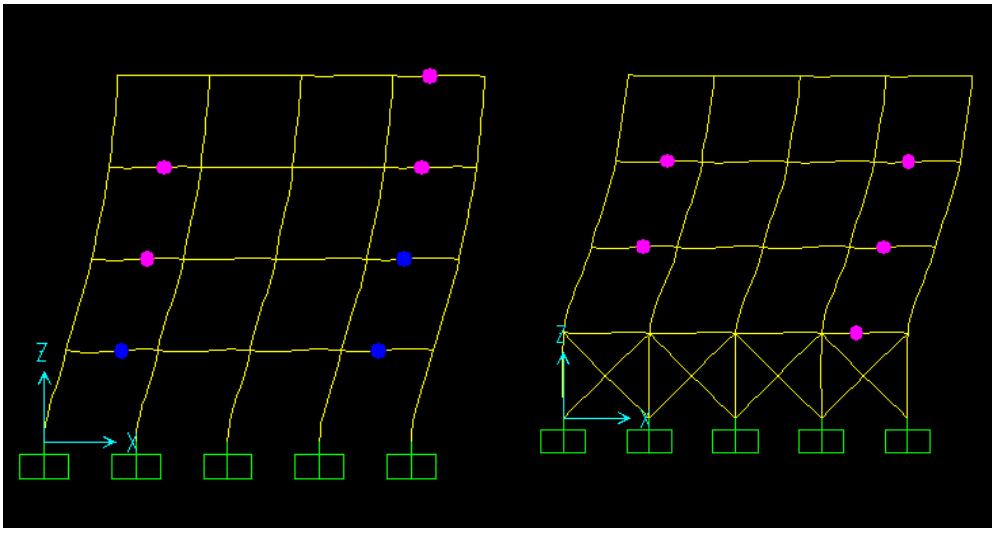

Fig.14 Hinge formation of G+3 building frame without and with bracing

Without bracing			With bracing	
Spectral Accelration	Probability of collapse		Spectral Acceleration	Probability of collapse
0	0.03		0	0
0.098	0.06		0.048	0.01
0.147	0.09		0.096	0.02
0.196	0.12		0.144	0.1
0.245	0.15		0.192	0.13
0.294	0.18		0.24	0.15
0.343	0.28		0.288	0.18
0.392	0.74		0.336	0.7
0.441	0.79		0.432	0.78
0.49	0.8		0.48	0.81

Table 5. Probability of collapse for the various intensity measure

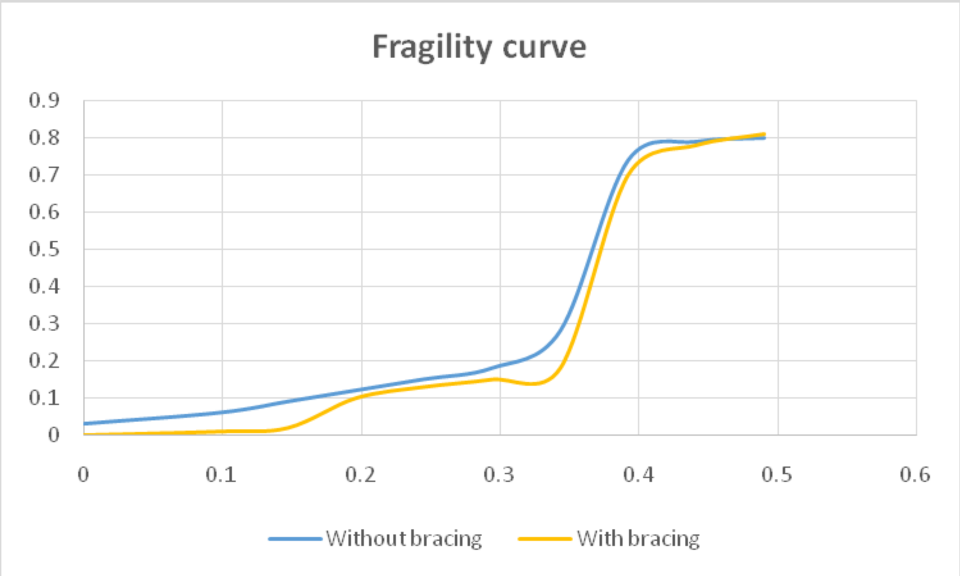

Fig. 15 Comparison of Fragility curve for 3storey model without and with bracing in OGS

V. CONCLUSIONS

RC frame buildings with open ground storeys are known to perform poorly during in strong earthquake shaking. In this paper, the seismic vulnerability of buildings with soft ground storey is shown through an example building. The drift and the strength demands in the ground storey columns are very large for buildings with soft ground storeys. It is notvery easy to provide such capacities in the columns of the ground storey. Thus, it is clear that such buildings will exhibit poor performance during a strong shaking. This hazardous feature of Indian RC frame buildings needs to be recognized immediately, and necessary measures taken to improve the performance of the buildings. The open ground storey is an important functional requirement of almost all the urban multi-storey buildings, and hence, cannot be eliminated. Alternative measures need to be adopted for this specific situation. The under-lying principle of any solution to this problem is in (a) increasing the stiffnesses of the ground storey such that the ground storey is at least 50%as stiff as the first storey, i.e., soft ground storeys are to be avoided, and (b) providing adequate lateral strength in the ground storey. The possible schemes to achieve the above are (i) provision of stiffer columns in the ground storey, (ii) provision of a concrete service core in the building, (iii) provision of bracing in inplane direction in the ground storey. The former is effective only in reducing the lateral drift demand on the ground storey columns. However the latter is effective in reducing the drift as well as the strength demands on the ground storeycolumns.It has been seen that the interstorey drift was reduced by 49.2% in structures with bracing. The soil flexibility needs to be examined carefully before finalizing the analytical model of a building. Flexible soil conditions may require alternate solutions than those described in this paper, to reduce seismic drift and strength demands on the columns in the ground storey.

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