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Effect of Shear Wall on Seismic Fragility of RC Frame Structures

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***Abstract*—Information on structural damage is of critical importance for reliable economic loss evaluation for a structure or a region that has been or that might be affected by an earthquake. The extent of structural damage is also important in determining expected casualties from collapsed buildings or from falling debris.A fragility function gives the probability that an undesirable event occurs (probability of exceeding certain damage state) as a function of environmental excitation (PGA).Interstorey drift percentage is selected as damage criteria.Seven number of PGA values has been considered in this study .Spectrum compatible ground motion are synthesized using MATLAB(30 nos of ground motion of each PGA).Target spectrum selected is according to IS 1893 : 2002 medium type soil.10 numbers of 2D RC frames has been considered(both regular as well as irregular frame) with varying Shear wall locations.Time history analysis of each frame is done using SAP 2000.Each of the frame is subjected to 210 ground motions. Fragility curves are developed and effect of shear wall in the fragility is studied.**

Keywords—Time-history analysis,Shear wall, Interstorey drift,Seismic fraglity

I. INTRODUCTION

The extent of structural damage is also important in determining expected casualties from collapsed buildings or from falling debris. These motion- damage relationships are in the form of probability distributions of damage at specified ground motion intensities and are usually expressed by means of fragility curves. In structural engineering, a fragility function expresses damageability of an asset as a function of environmental excitation. A fragility function gives the probability that an undesirable event occurs (probability of exceeding certain damage state) as a function of environmental excitation (usually PGA). Fragility curves are important for estimating the risk from potential earthquakes and for predicting the economical impact for future earthquakes.

A damage index is usually defined as the damage value normalized with respect to failure level so that a damage index value of unity corresponds to the (arbitarily defined) failure. Interstorey drift ratio is good measure of damage of RC frame structures. According to FEMA [1] , inter-storey drift ratio is determined as the difference between the deflections of two adjacent floors which can be expressed as a percentage of the storey height. According to Sozen [2] the percentage of damage to the structure is given by 50 times the maximum interstorey drift percentage minus 25.

Gulec et al.[3] proposed the fragility functions for shear walls in terms of demand parameters related to damage. Excessive inter-storey drift could cause damage to both the structural and nonstructural components. Rossetto and Elnashai [4] studied 99 post-earthquake damage datasets from 19 earthquakes and comprising 3,40,000 RC buildings. The limit states are defined in terms of damage index, the HRC-damage index (DI_{HRC}), which is based on experimental calibration with structural response parameter of maximum inter story drift ratio (ISD_{max}%). As per IS: 1893 2002 Storey Drift limitation with partial safety factor of 1.00 shall not exceed 0.004 times the storey height or H/250 SEAOC(1995) recommended Interstorey drift percentage values for different damage states of RC frame structures and same has been used in this study shown in Table I.

TABLE I. SEAOC(1995)

Interstorey drift percentage	**Damage states**
ISD > 0.2%	Light damage
ISD > 0.5%	Moderate Damage
ISD > 1.5%	Severe damage
ISD > 2.5%	Complete damage

Shear wall has high in plane stiffness and strength which can be used to simultaneously resist large horizontal loads and support gravity loads, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Bozdogan K.B.,Deierlein [5], discussed in detail the modeling issues, nonlinear behavior and analysis of the frame – shear wall structural system.

II. CASE STUDY DETAILS

A. *Modelling*

For the present study,two-dimensional RC frames of 6-storey and 8-storey are considered and in each case vertical irregularity is taken into account.Grade of concrete is M25 and grade of reinforcement used is Fe500.The frames are designed according to IS 456:2000. Frames are modelled in SAP 2000.Shear walls are deigned according to IS 13920 : 1993 and modelled as layered shell elements in SAP 2000.

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The shear wall beams are modelled as rigid beams.A total of 10 models are analysed.Ground storey height in 6 storey frame is 3.8 m and regular storey height is 3.3 m. In 8 storey frame storey height is 3.3 m uniform throughout its height. Number of bays is 3 in each frame in both the cases.Few typical bare and shear frame models are shown in Fig 1 –Fig 4.Depth of slab is 0.150 m and Live load = 4 KN/m^2 and Floor finish =0.5 KN/m^2.

TABLE II. DIMENSIONS AND REINFORCEMENT DETAILS OF VARIOUS ELEMENTS

6 storey RC frame(both regular and irregular frames)	
Beam size	0.300 m x 0.400 m
Column size	0.450 m x 0.450 m
Column reinforcemnt details	10 nos of 20 dia bars as longitudinal reinforcement 8 dia bars @ 0.150 m spacing as lateral ties
8 storey RC frame(both regular and irregular frames)	
Beam size	0.300 m x 0.450 m
Column size	0.500 m x 0.500 m
Column reinforcemnt details	10 nos of 20 dia bars as longitudinal reinforcement 8 dia bars @ 0.150 m spacing as lateral ties
Shear wall	
Thickness	0.160 m
Reinforcement	8 dia bars @ 0.120 m c/c spacing

The details of various models selected are summarized in the Table III below.

TABLE III. MODELS DETAILS

Model number	Model details
Model 1	6 storey regular bare frame
Model 2	6 storey irregular bare frame
Model 3	8 storey regular bare frame
Model 4	8 storey irregular bare frame
Model 5	6 storey regular , shear wall on the middle bay
Model 6	6 storey irregular, shear wall on the end bay
Model 7	8 storey regular shear wall on the middle bay
Model 8	8 storey irregular, shear wall on the end bay
Model 9	8 storey regular, shear wall on one end bay
Model 10	6 storey regular,shear wall on one end bay

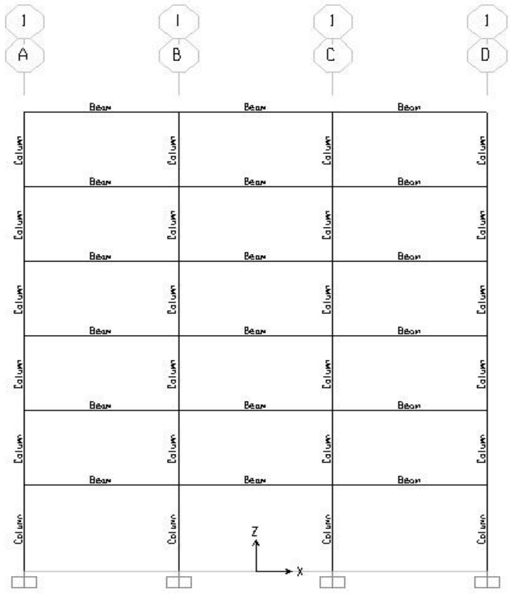

Fig 1: 6-Storey regular bare frame

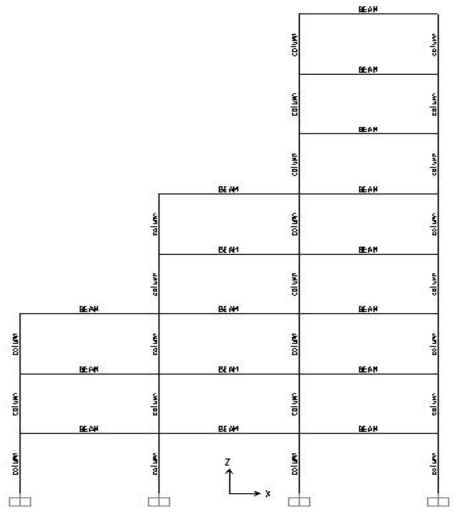

Fig 2: 8-Storey irregular bare frame

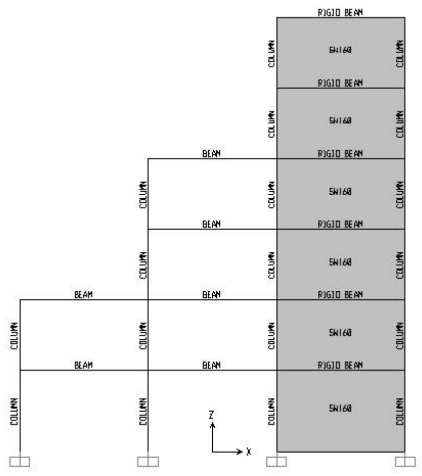

Fig 3: 6-Storey irregular frame with shear wall on end bay

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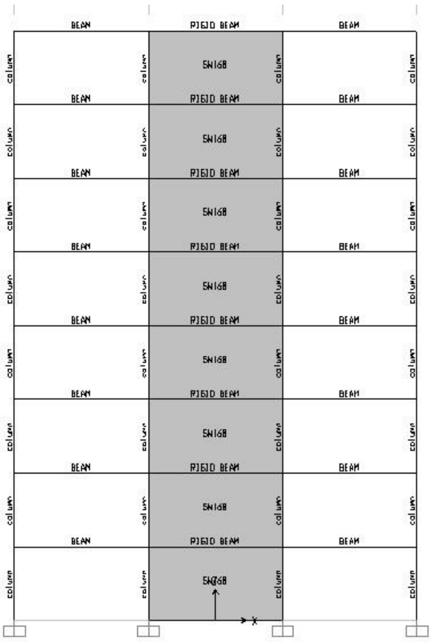

Fig 4: 8-Storey regular frame with shear wall on middle bay

B. Ground motion synthesis

For time-history analysis, seven number of PGA values are considered such as 0.05g, 0.5g, 1.0g, 1.5g, 2.0g ,2.5g, 3.0g. For each PGA 30 nos of ground motion data are synthesized in compatible with the response spectrum of medium soil of IS 1893 :2002.Frequency band considered is 0 to 15 Hz.It is done using MATLAB 2009.

III. METHODOLOGY

A. Time history Analysis

Nonlinear direct integration timehistory analysis of all the models are done in SAP 2000(each model subjected to 210 ground motion).Interstorey drift percentage of each floor at different PGAs are calculated.These interstorey drift percentage are selected as damage criteria and different damage states are selected according to SEAOC defined above.

B. Fraglity curve development

On the basis of EDP percentage and damage states data, the families of empirical cumulative distribution functions (CDF) can be created which can define the probability of exceeding each damage state for a specific magnitude of drift value.The lognormal probability functions at each level of ground motion are then used to obtain the probabilities of reaching or exceeding a damage state.Then smooth fragility curves are derived between probability of exceeding particular damage state and peak ground acceleration. The lognormal CDF has often been used to model earthquake damage fragility. it is bounded between 0 and 1 on the y-axis, satisfying the constraint that the probability of collapse (or any other damage state) is likewise bounded between 0 and 1.

The conditional probability of exceeding a particular damage state for a certain peak ground acceleration (PGA) is defined by the following relationship

$$P[D>= d;X=x] = F_d(x)=\Phi((ln_x-ln\theta_d)/\beta) \qquad (1)$$

The parameters θ_d is the median value of peak ground acceleration at which the structure reaches the threshold levels of each damage state. β is the standard deviation of the natural logarithm of peak ground acceleration each damage state, d = a particular value of D(damage state value), x = a particular value of X(PGA), $F_d(x)$ = a fragility function for damage state d evaluated at x, Φ(s)= standard normal cumulative distribution function.

IV. RESULTS AND DISCUSSIONS

After the analysis interstorey drift percentage is calculated at different floors and maximum is taken. Fraglity curves are then developed at for each damage state for each model and comparison is done.The fragility curves of different models at different damage states are shown in Fig 5 –Fig 15.

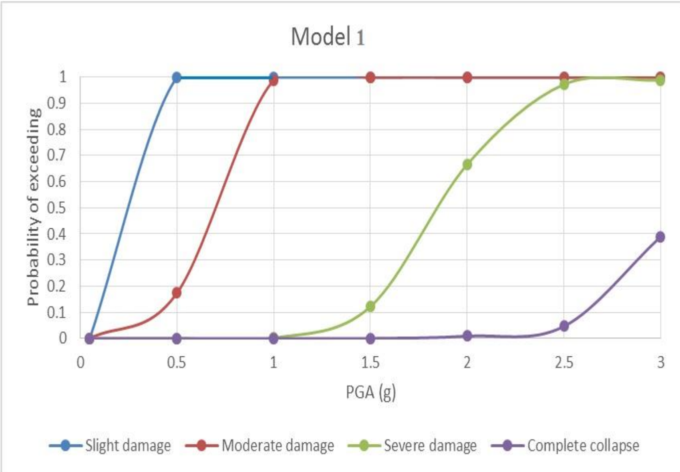

Fig 5: Fragility curves of various damage states

Fig 6: Fragility curves of various damage states

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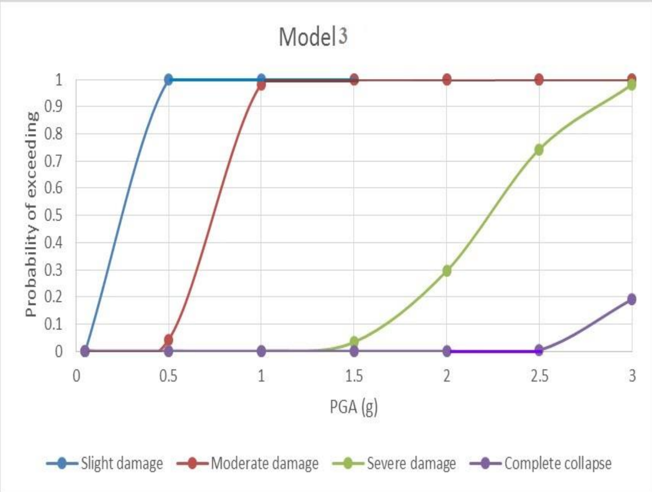

Fig 7: Fragility curves of various damage states

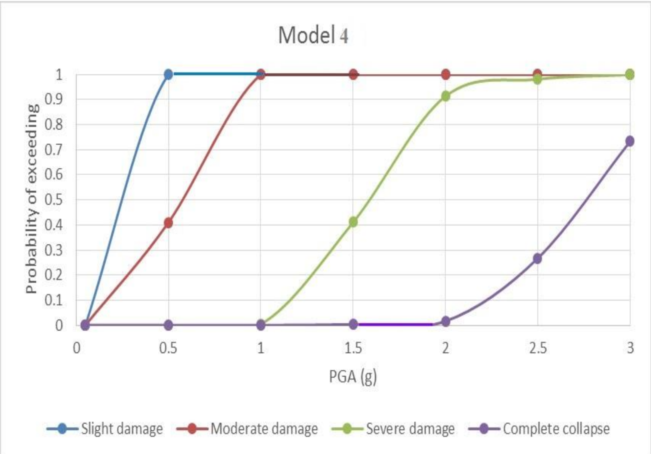

Fig 8: Fragility curves of various damage states

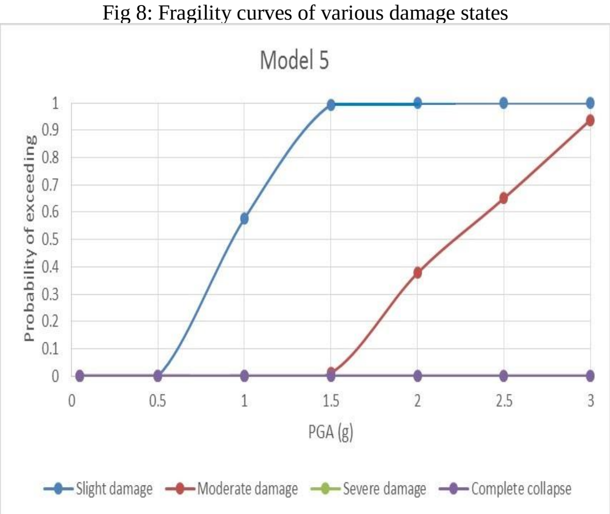

Fig 9: Fragility curves of various damage states

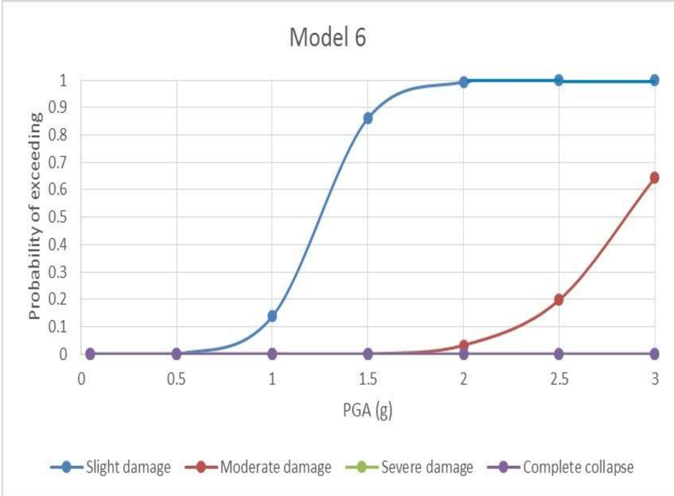

Fig 10: Fragility curves of various damage states

Fig 11: Fragility curves of various damage states

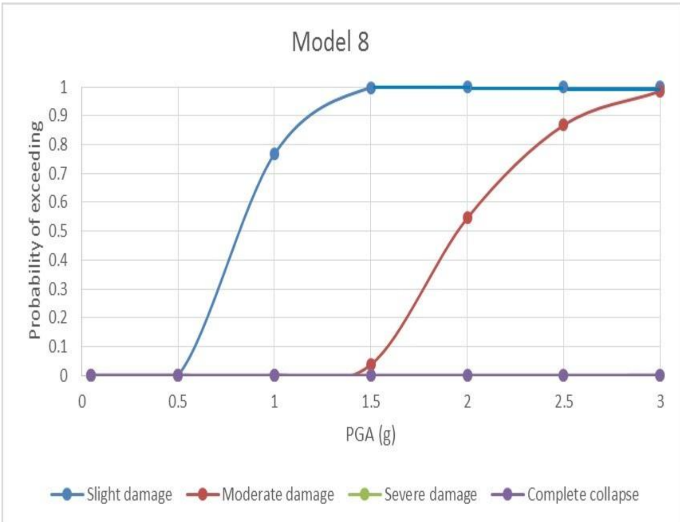

Fig 12: Fragility curves of various damage states

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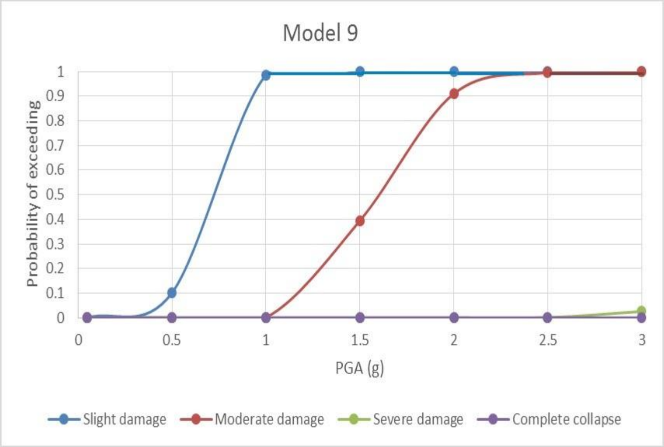

Fig 13: Fragility curves of various damage states

Fig 14: Fragility curves of various damage states

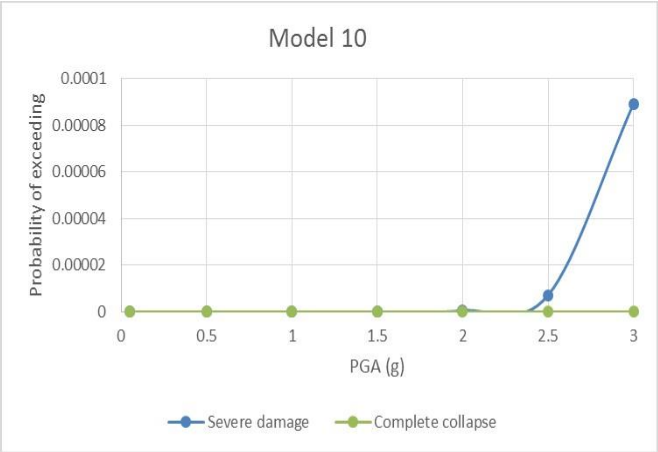

Fig 15: Fragility curves of severe damage and complete collapse states showing negligible value

We observe that in Model 5 to Model 10 the probability of exceeding severe damage and complete collapse is much much lower then the probability of exceeding those particular states in bare frames(Model 1 to Model 4).This is due to the presence of shear wall in these frames. Also the shearwall in middle bay is more effective then shear wall in end bay. Shear wall highly increases the lateral stiffness and simultaneously resist large horizontal loads and support gravity loads, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its elements. The interstorey drift percentage in the Model 5 to Model 10 ranges from 0.5 % - 0.8% much lower than that of bare frame, Model 1 to Model 4 (more than 2.2 %).

The probability of damage is higher in Irregular frames as compared to regular frames (Model 1 and Model 2 and Model 3 and Model 4). Hence we conclude that presence of shear wall significantly reduces the probability of severe damage and prevents complete collapse of framed buildings.

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