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Anartificial Neural Network for Prediction of Seismic Behavior in RC Buildings with and Without Infill Walls

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ABSTRAC:*In this study the influence of masonry infill walls on the seismicbehavior of RC frames with help of ETABS software were studied.Pushover analysis on buildings with five, seven, nine and eleven storey with symmetrical in the plan was carried out.And trial model with thirteenstorey was created for testing in ArtificialNeural Network (ANN).Each structure was modeled in two different types, such as RC bare frame and RC frame with masonry infill walls.In the present paper infill walls are modeled as equivalent diagonal strut. In this type of molding infill wall behaves like compression strut, as suggested in FEMA 365, 2000.*

Nonlinear analysis in according with IS1893, 2002 code is realized to sketch pushover curves and results at Immediate Occupancy, Life Safety and Collapse Prevention onperformances level were determined.

Thisstudy reports seismic behavior of RC building due to increase height of the buildings.For this purpose, one of the significantly techniques, Artificial Neural Network(ANN), was used.Result of this study using ANNis used for prediction of seismicbehavior of structures.The trial model with thirteen storey was modeled by ETABS to compare with result of ANN.

KEY WORRDS:*Nonlinear analysis, Masonry infill, Equivalent diagonal strut, ArtificialNeural Networks.*

I. INTRODUCTION

Motivation of this study is assessment of vulnerability of the building with and without unreinforcedmasonry infill walls. And behavior of a thirteen storey building is predicted by Artificial Neural Network (ANN) technique.

ANN is a branch of artificial intelligence which attempt to mimic the behavior of the human brain and nerves system. A neural network can be considered as a black box that is able to predict an output pattern when it recognizes a given input pattern. Neural networks are able to detect similarities in input, even though a particular input may never have been seen previously. This property allows for excellent interpolation capabilities, especially when the input data is noisy[1].

It is estimate that, effect of infill walls is important on the building performance, but structural engineers, during the design process, ignore the effect of infill wall in the structural analysis. According to the FEMA guideline the masonry unreinforced infill walls have a significant effect on the stiffness of building [2].In this study advantages and disadvantages of infill walls will be investigated.

Masonry infill walls are frequently used as interior partitions and architectural elements.In the design and assessment of the building infill walls are usuallytreated as non-structural elements and the presence of infill walls are usually neglected in conventional design because they are assumed to be beneficial to the structural responses. Therefore, their influences on the structural response are generally ignored. However, their stiffness and strength are not negligible, and they will interact with the boundary frame when the structure is subjected to ground motion. This interaction may or may not be beneficial to the performance of the structure and it has been a topic of much debate in the last few decades. [3].

II. DESCRIPTION OF STRUCTURAL MODEL

2-1 Building Models

In this studysymmetrical floor plans layout of 3D reinforced concrete residential building with moment resisting RC frames was selected as shown in fig 1. Thebuildings consist of five, seven, nine and eleven, but the plan was unaltered to avoid any irregularity effects. Buildingsare located inseismic zone IV, and soil profile type was assumed to be medium.

Response reduction factor for the special moment resisting frame has taken as 5.All the four models are designed and analyzed as per IS456, 2000. Further inputs include unit weight of the concrete is 25 KN/m^3, elastic modulus of concrete is $25*10^6$ KN/m^2, compressive strength of concrete is 25 N/mm^2 (M25), yield strength of steel is 415 N/mm^2 (Fe 415),elastic modulus of steel is $2*10^8 KN/mm^2$. The loading of building was assumed to be dead load 5.5 KN/m^2, live load 2.0 KN/m^2, and weight of floor finishes is 1 KN/m^2. Percentage of imposed load to be considered in seismic weight calculation 25.The support condition of columns was assumed to be fixed at ground level. All columns and beams had different dimensions in height, dimension of columns vary between 0.40*0.40 m and 0.50*0.50 m , dimension of beam vary between 0.40*0.30 m and 0.30*0.30 m and thickness of slab is 0.15m. finally the example structure used in this study are following as shown in fig1 to 9.

1. Fivestorey with two models: - Model 1-0: Bare frame.
 - Model 1-1: RC frame with brick masonry infill.
2. Sevenstorey with two models: - Model 2-0: Bare frame.
 - Model 2-1: RC frame with brick masonry infill.

3. Ninestorey with two models:- Model 3-0: Bare frame.
 - Model 3-1: RC frame with brick masonry infill.
4. elevenstorey with two models: - Model 4-0: Bare frame.
- Model 4-1: RC frame with brick masonry infill.

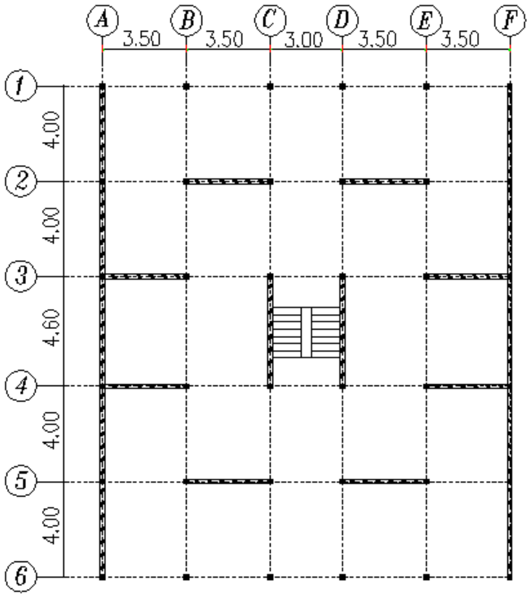
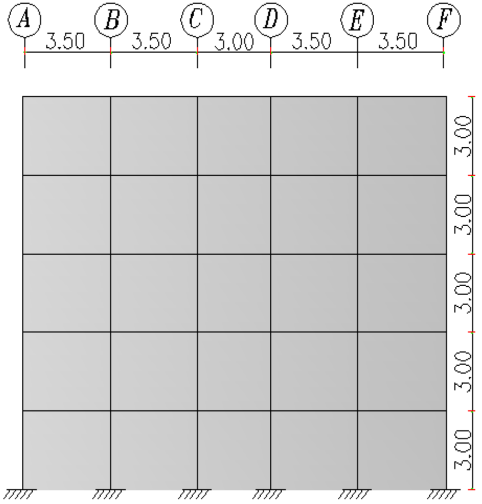


Fig 1: Typical plan of Buildings



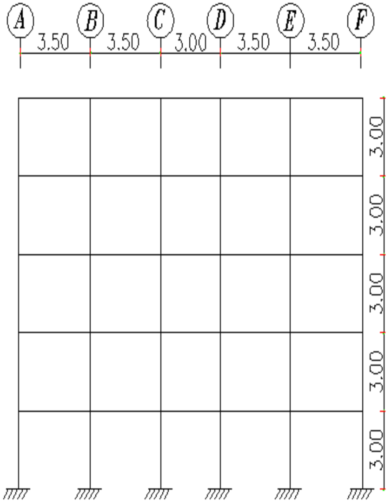
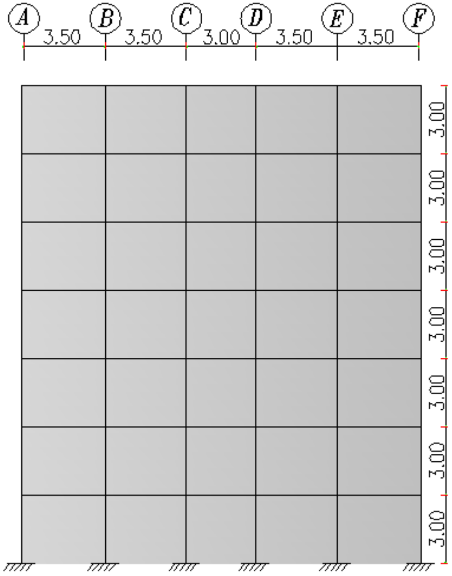


Fig2: Model 1-1Fig 3: Model 1-0



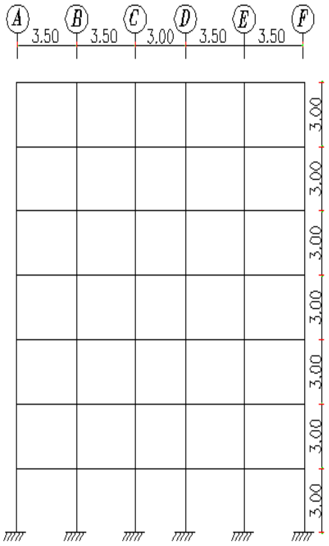
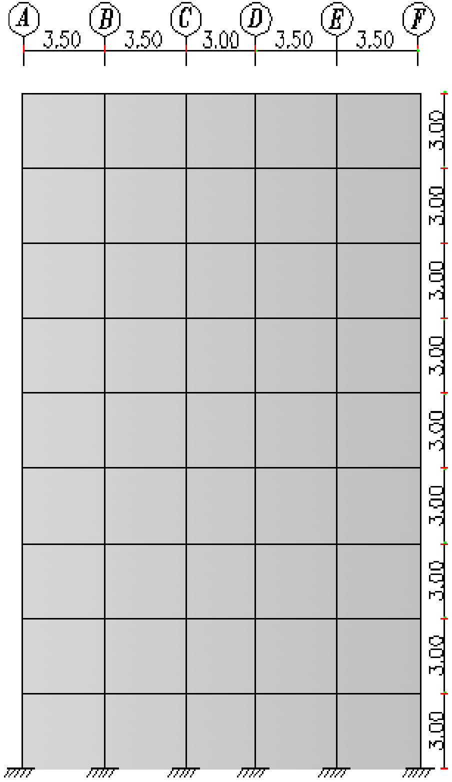


Fig 4: Model 2-1Fig5: Model 2-0



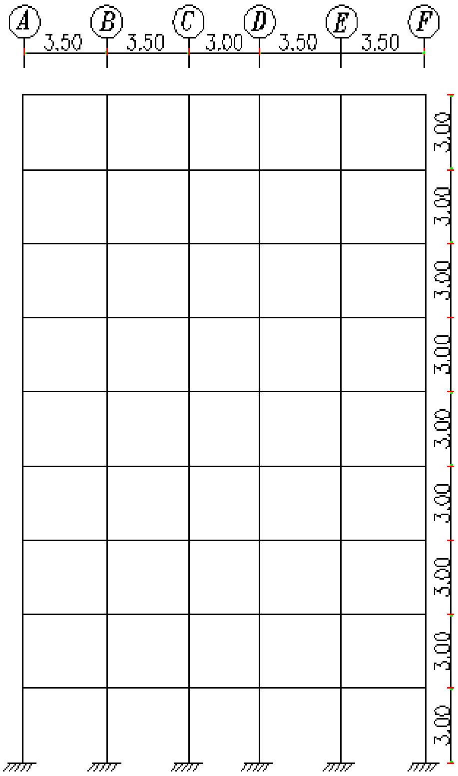
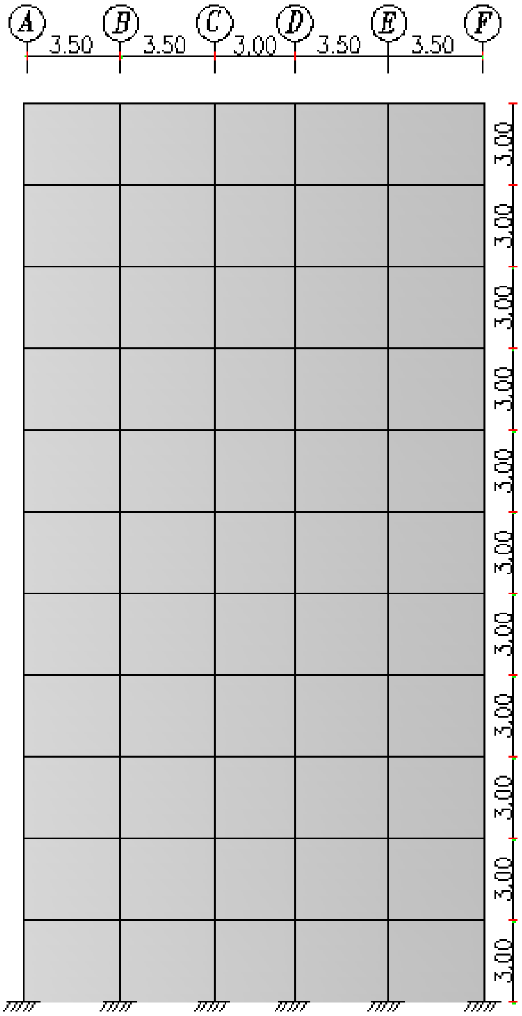


Fig 6: Model 3-1Fig 7: Model 3-0



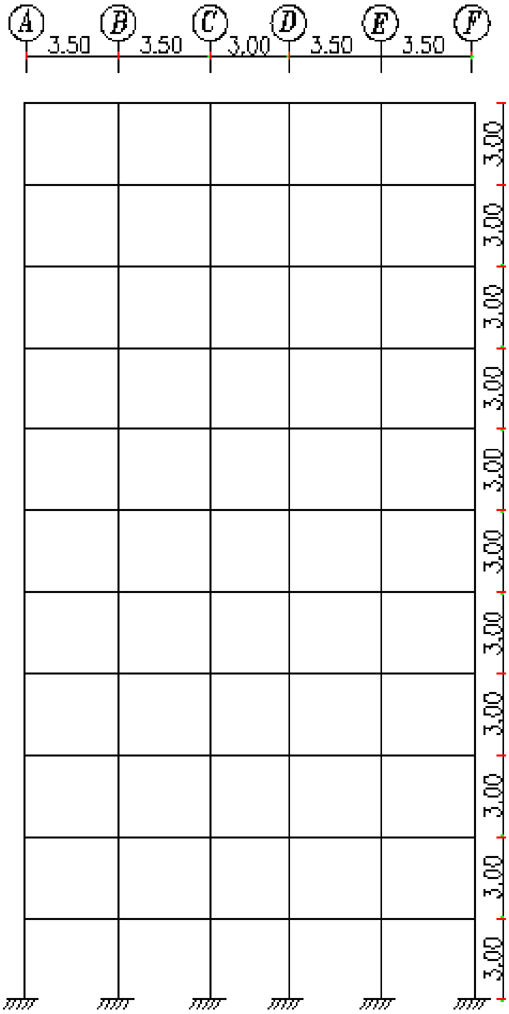


Fig8: Model 4-1Fig9: Model 4-0

2-2 modeling of infill masonry infill walls

Infill walls in this study can be generally categorized in to two types, masonry infill walls with and without opening. Only masonry infill walls without opening were considered as lateral load resistant element with shaded areas as shown in fig1. Infill walls with opening that prevent diagonal strut [2] formation are considered as dead loads only [4]. Window opening are assumed tiny relative to the overall wall area, thus not included in the as they have no appreciable bearing on the general behavior of the structure[5]. Usually in a building of the structure 40% to 60% presence of masonry infillsare effective as the remaining portion of the masonry infills are meant for functional purpose such as doors and window openings [6].In this study, buildings were modeled using 40% masonry infill.

The model for masonry infill walls can be classified as finite element method (micro) and static equivalent strut (macro).in this study equivalent compression strut used instead of masonry infill walls, this strut is a compression diagonal. The single strut model is the most widely used as it is simple and evidently most suitable for large structure [7]. Thus RC frames with unreinforced masonry walls can be modeled as equivalent braced frames with infill walls replaced by equivalent diagonal strut which can be used in rigorousnonlinearpushover analysis using the theory of beams on elastic foundations [8]suggested a non-dimensional parameter to determine the width and relative stiffness of diagonal strut according to FEMA306, 1997 the strut area A_e is given by following expression as shown in fig10.

$$A_e = W_e\, t$$

$$W_e = 0.175(\lambda h)^{-0.4} w$$

$$\lambda = \sqrt[4]{\frac{E_m t \sin(2\theta)}{4E_f I_c h'}}$$

E_m =The modulus of elasticity of the infill material
E_f =The modulus of elasticity of the frame material
I_c =The moment of inertia of column
t =The thickness of infill
h =The center line height of frame
h' =The height of infill
w =The diagonal length of infill panel
θ =The slope of infill diagonal to the horizontal.

In this study, the following material properties were used for solid brick masonry infill walls. Unit weight of masonry is 20 KN/m3, elastic modulus of masonry infill is E_m =550f_m =2275 KN/mm2.

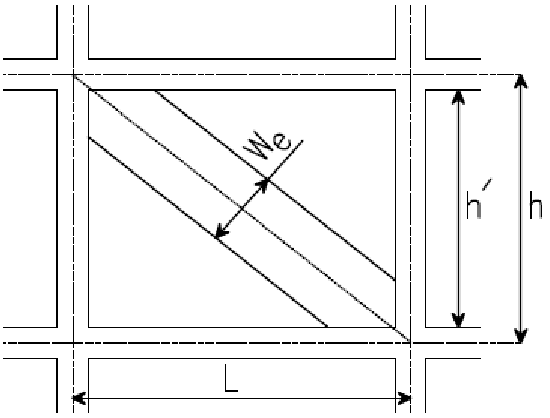


Fig10: Equivalent diagonal strut model [9].

III. ARTIFICIAL NEURAL NETWORKS

One efficient way of solving complex problems is following the lemma “divides and conquers”. A complex system may be decomposed into simpler elements, in order to be able to understand it. Alsosimple elements may be gathered to produce a complex system [10]. Artificial Neural Networks (ANNs) are one approach for achieving this. The scope of this study is to create a brief induction to ANNs for training buildings which there are no analysis of them. Displacement and performance points were prediction using ANN.

IV. NONLINEAR STRUCTURAL ANALYSIS

Nonlinear analysis is performed for eight models of the building in this study. Nonlinear static pushover analysis has been performed to determine the structural earthquake behavior using ETABS nonlinear version 9.7 program[11]. However the earthquake response is determined by one of the structural analysis method as nonlinear analysis. This method is included two ways as nonlinear static pushover analysis and nonlinear dynamic time history analysis.

Nonlinear static pushover analysis has been suggested in FEMA365 and ATC40.

The guidelines ATC and FEMA mentioned in this paper include modeling procedures, acceptance criteria and analysis procedures for pushover analysis. These documents define force – deformation criteria for potential locations of lumped inelastic behavior, designated as plastic hinges used in pushover analysis.

ETABS implements the plastic hinge properties described in FEMA365 and ATC40 as shown in fig 11.five points labeled A, B, C, D and E define force–deformation behavior of the plastic hinge and performance level are Immediate Occupancy (IO), Life Safety (LS), Collapse Prevention (CP), A, B are performance points before immediate occupancy (elastic range), B, Care related to yieldand ultimate curvatures (plastic range) and D, E performance point beyond collapse are used to define the acceptance criteria for the hinge.[2,12].

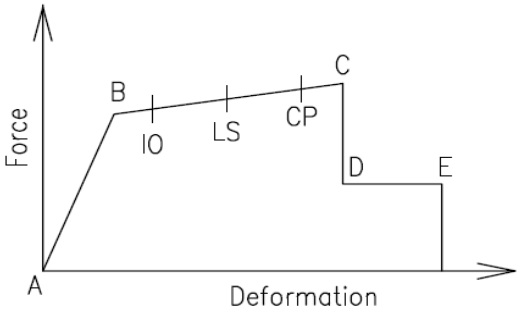


Fig11. Force – Deformation Relation for plastic Hinge in Pushover Analysis

V. ANALYSIS AND RESULTS

The nonlinear static pushover analysis was performed for all models; models were designed and checked as per IS456,[13]. The comparative results of story displacement,fundamental natural time period as per IS1893,[14]capacity curves along with performance levels as IO, LS and CP and neural networks for prediction of seismic behavior for all models are shown,tabulated in table 1 to 4.

5-1Storeydisplacement

The lateral displacement at top storey of various models is tabulated in table1.Displacement depends on the stiffness of each model, table 1 shows that where stiffness of infill walls are considered have significantly lower displacement as compared to bare frame. From table 1 it is observed that infill wall decreases displacement due to its stiffness, stiffness of infill walls decreases displacement from 25.87%, 24.62%, 17.1%, to16.01% for five, seven, nine, eleven stores (respectively), with respect to bare frame.

Table 1: Displacement at top storey level of various structural systems

Type of Structures	Model 1-0	Model 1-1	Model 2-0	Model 2-1	Model 3-0	Model 3-1	Model 4-0	Model 4-1
DispAt top story(cm)	1.38	1.023	1.99	1.50	2.28	1.89	2.81	2.36

5-2 fundamental natural period:

The approximate fundamental natural period of vibration from the empirical expression of the IS1893,[14] is compared with the analytical time period. As shown in table 2 analytical time period do not tally with empirical time period (caudal). The analytical natural period depends on the mass and stiffness, but empirical time period depends on the height of the building.

For models with stiffness of infill walls observed that analytical natural period have lower time period as compared to bare frame, and for models with higher level, empirical period have higher time period. Table 2 shows that analytical fundamental natural time period for models with infill walls are 1.94 to 1.88 times higher than empiricaltime period.

Table 2: Empirical and Analytical time period in all models

Type of Structures	Model 1-0	Model 1-1	Model 2-0	Model 2-1	Model 3-0	Model 3-1	Model 4-0	Model 4-1
Analytical	0.913	0.64	1.23	0.88	1.535	1.12	1.85	1.36
Caudal	0.572	0.33	0.736	0.45	0.888	0.59	1.033	0.72

5-3 Capacity curves along with performance level:

The capacity curves, displacement capacity and performance point values of each model obtained from pushover analysis.Pushover curves are given in fig 12 and also tabulated in table 3. From the data presented in table 3, the models with infill walls have the highest capacity as compared with bare frame. Pushover curves in fig 12 show that buildings with lower height have parabolic curves with clear life safety points. And they show that due to enhance height of the buildings parabolic curves transform in to the straight line with unclear point at life safety.

Performance point was determined from pushover analysis. The status of plastic hinges formed in the structure according to force – deformation curve define performance of the structure at performance point,when the structure reaches its performance point.

Table 4 shows status of hinges at performance point. From the data presented in table 4 for models with infill wall the number of plastic hinges in LS-CP stage are very less in number as compared with models without infill wall.

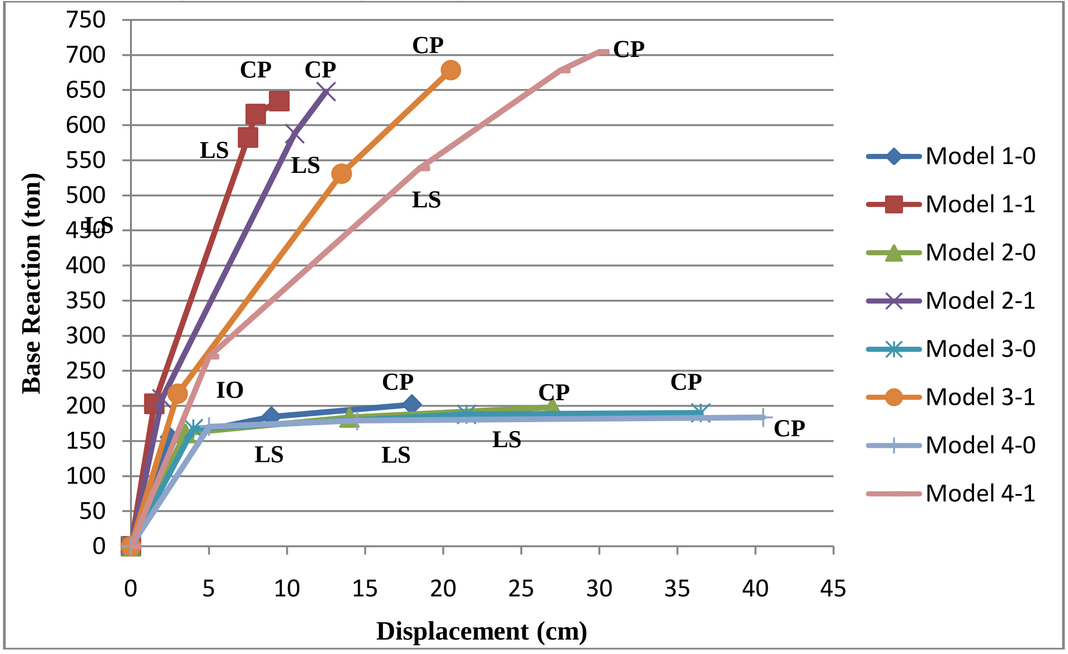


Fig12: Pushover curves for all models.

Table 3: Base shear (ton) and Displacement (cm) at Performance level for all models.

Typeof Structures			Model 1-0	Model 1-1	Model 2-0	Model 2-1	Model 3-0	Model 3-1	Model 4-0	Model 4-1
Performance Level	IO	Base Shear	155.5	203	161.3	210	167.7	217.5	170.5	270
		Disp	2.5	1.50	3.6	2.0	4.0	3.0	5.0	5.0
	LS	Base Shear	184.3	615.7	183.4	588	188	530.9	178	678
		Disp	9.0	8.0	14.0	10.5	21.5	13.5	14.5	27.5
	CP	Base Shear	201.6	634.1	198.2	648	190	678.3	183.4	704.2
		Disp	18.0	9.5	27	13	36.5	20.5	40.5	30.0

Table 4: Hinge status at performance point in x-direction for all models

Type of models	Disp (cm)	Base Shear (ton)	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	Total
Model 1-0	13.3	192.2	803	32	113	192	0	0	0	0	1140
Model 1-1	8.11	601.3	727	206	205	2	0	0	0	0	1140
Model 2-0	17.9	187.6	1149	62	85	299	0	1	0	0	1596
Model 2-1	11.4	594	1062	262	263	9	0	0	0	0	1596
Model 3-0	23.4	187.5	1512	0	120	420	0	0	0	0	2052
Model 3-1	14.6	551.3	1300	321	347	84	0	0	0	0	2052
Model 4-0	27.8	183.4	1855	148	145	360	0	0	0	0	2508
Model 4-1	17.6	520	1542	397	328	241	0	0	0	0	2508

5-4 Neural networks for prediction of seismic behavior:

MATLAB software is used to createneural network. For creation the network, totally 32 data set are used which are listed in table 5. These data sets were generated analytically using structures with infill walls. The network was trained and then tested by 4 and 4 data sets for displacement and base shear (respectively), at performance pointwhich are tabulated in table 6. And for trial model with thirteen storey input data are listed in table 7.Displacement and base shear at performance point predicted for building with thirteen storey using ANN is compared with actual values of ETABS output as shown in table 8. The result clearlyshows that predicted values using neural networkat displacement and base shear on the performance point are 3.0(cm) and 500(ton),(respectively) are close to actual value 2.86(cm) and 490(ton). It can be observed that overall prediction is very good.

Table 5: Data set used input for model with infill wall.

Input	Model 1-1	Model 2-1	Model 3-1	Model4-1
Number of storey	5	7	9	11
Height(m)	15	21	27	33
Seismic coefficient	0.051	0.0382	0.0292	0.024
Total weight(ton)	2103	3010	3882	4776
Total cross section of column(m^2)	22.67	34.85	55.8	72.42
Total cross section of beam(m^2)	31.5	44.1	56.7	69.3
Total area of reinforcement steel(m^2)	0.3617	0.7034	1.0852	1.7245
Total trust area(m^2)	12.67	17.738	22.806	27.874

Table 6: Data set used target for model with infill wall.

Target	Model 1-1	Model 2-1	Model 3-1	Model4-1
Displacement(cm)	1.023	1.50	1.89	2.36
Performance point(v)(ton)	601.3	594	551.27	520

Table 7: Data set used input for trial model.

Input	Trial model 5-1
Number of storey	13
Height(m)	39
Seismic coefficient	0.02
Total weight(ton)	5667
Total cross section of column(m^2)	88.255
Total cross section of beam(m^2)	89.1
Total area of reinforcement steel(m^2)	2.11
Total trust area(m^2)	32.942

Table 8: Displacement and Base shear at performance point in x-direction for trial model

Trial Model(thirteen storey)	Displacement atTop(cm)	Base shear at Performance Point(ton)
Model 5-1(ETABS Value)	2.86	490
Model 5-1(ANN Value)	3.0	500

VI. CONCLUSIONS

1. Due to presence of the infill wall displacement at top storey decreasesfrom 25.87%, 24.62%, 17.1%, to 16.01% for five, seven, nine, eleven stores (respectively) with respect to bare frame.From the above observationit can be seen that due to enhance height of the building influence of stiffness of the infill wall will be less, thus it should be used more lateral load resistant system to increase the stiffness of the multi storey building. And results show that stiffness of the infill walls is efficient for building with low and medium height.
2. It is observed that performance of all structures in elastic range have definite values for model with and without infill walls at immediateoccupancy,and performance of the structures with low-rise building in plastic range have clear point at life safety in comparison with multi storey buildings that have unclear point at life safety.
3. It can be seen that the performance of all the models lies in between life safety and collapsepervasion.Overall the performances of these models are satisfactory and some of the elements in some models require retrofitting.

4. The predicted values in displacement and base shear at performance point for trial building using artificial neural network vary only marginally maximum of 4.89% and 2.04% (respectively), from the actual values. The values show that prediction by artificial neural network is satisfactory.

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