"Comparative Study on Behaviour of RC Framed Buildings with Infills modelled using FEMA 356 & IS: 1893"

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Abstract- Infilled frames have continued the interest of researchers for a long period but they have been unable to shape a place in the codes of practices of many countries. Masonry wall imparts a sizeable amount of stiffness and strength to a building frame and used in the buildings for architectural or aesthetic reasons. Infills are normally considered as a non-structural constituent and its presence has been ignored by many engineers. The performance of the structure can be greatly enhanced by the increase of strength arising from the masonry infill. Infill frames are extensively constructed with brick masonry. The primary objective of this study is to review the performance of reinforced concrete frame structures with and without the presence of masonry infills modeled using FEMA 356 and IS: 1893 method. ETABS software is used for the behavioral study of all the RC frame models.

***Key Words –** Equivalent diagonal strut, masonry infilled frame, seismic.*

1. Introduction

Reinforced Concrete structures with infilled masonry frames are constructed at first because of simplicity of development and speedy work in advancement. RC frame buildings with masonry infill walls house families, cover school kids, and give office for laborers and so on. Infilled RC casings are compound structures shaped through union of moment resisting plane frame in addition to infill dividers. Infilled RC frame structures provide lateral resistance in areas of high seismicity, especially in those areas where masonry is still a convenient material, owed to economical and outmoded reasons and consistently reduce the bending moments in the frame and thus reducing the prospect of breakdown.

Infills are constructed using bricks or concrete blocks between beams and columns of a reinforced concrete casing. Infills afford an auditory blockade amongst spaces and from outside clamor, which is predominantly vital in residential areas. Masonry infills offer an effective fire barrier, and when made of brick or concrete block they give protection and fortress from interlopers. The masonry infills however built as auxiliary components performs as an integral part of the structural system. The sort of infill material utilized in nearby construction practice and its properties will have an imperative impact on the appropriateness of each design approach. Infills contribute to lateral rigidity as well as resistance of structures they belong. The differences of rigidity and strength are reliant on the mechanical possessions of the material used for the infill and likewise the interface prevailing amongst the infill and frame. Infill solidifies the frame laterally by a directive of scale and increases its ultimate strength to very high values. The interface amongst the frame and the infill wall is also powerfully influenced by the provision of infill wall in the frame.

The Indian Standard code (IS: 1893) in 2016 & FEMA 356 procurements afforded a procedure for the investigation and design of RC frames using infills. Appropriately designed infills can upsurge general strength, lateral resistance and energy dissipation of the building

[1] G Prasanna Lakshmi et al., (2016) conducted investigation on "Seismic evaluation of residential building with masonry wall using ETABS" in which precedent earthquakes showed poor performance of reinforced concrete frames without infilled masonry wall. A number of various researchers have found the measures to decrease earthquake damages. A lot of methods are suggested for modeling of brick masonry infills such as finite element, equivalent frame and equivalent strut method. New draft Indian standard criteria for earthquake resistant design of structures part 1 describe the diagonal equivalent strut method for analysis of masonry infill in RC building. The author has adopted IS code method in modelling of Infills. The investigation evidently shows that the diagonal strut approach is very efficient in simulating the seismic response of RC frame with masonry infill.

[2] M D Raghavendra Prasad et al., (2016) conducted investigation on "Nonlinear behavior of reinforced concrete infilled frames using ATENA 2D '' to understand the performance of the infilled frames. The numerical analysis is carried out using popular finite element software's ATENA 2D (2003).The codes of practice are generally silent on the infill material as the choice of infill material is random and it is believed to be a nonstructural component. The width of the equivalent diagonal strut varies between one-third and one-tenth of the diagonal length of masonry infill. The effect of infill has a significant role in performance of the building. The ultimate load carrying capacity is considerably enhanced along with the increase in lateral stiffness. The initial stiffness of the infilled frame is considerably more compared to bare frame till the peak load is reached.

The objective of the present work is to carry out modeling and analysis of masonry infilled R.C. framed structures. It includes studying the behavior of R.C framed structure with and without infills subjected to seismic forces and investigate the influence of masonry infill walls to lateral strength and lateral stiffness of the buildings. The infills are modelled as equivalent diagonal strut using FEMA 356 and IS: 1893 method.

2. Methodology

The diverse technique used for the numerical simulations of infilled frames can be separated into two group's specifically local or micro models and simplified macro models. The first group involves models that partition a structure into numerous elements to take into account the local effect in aspect and subsequent group consists of simplified models based on a physical accepting of the performance of the infill panel. This paper uses the second group's approach and considers the infill panels as equivalent diagonal struts, which carry loads only in compression. Infill walls are modelled as diagonal strut using FEMA 356 and IS: 1893 method. Parameters such as displacements, storey drifts, storey shear and time period are compared with buildings with infills modelled using FEMA 356 & IS: 1893.

3. Modelling

Various parameters such as load intensities, material properties, dimension of the structural member and the seismic data considered in the modelling of the various types of buildings considered for analysis are mentioned below.

Table 3.1: RC building details

Type of Building	**No of storeys**	**Plan area** (l*b*h)	**Column spacing**
Too tall	G+30	22.5m x 22.5m x 105m	7.5m
Too long in span	G+4	40m x 16m x 14m	4m
C type	G+10	16m x 28m x 35m	4m
I type	G+10	20m x 21m x 35m	4m

Table 3.2: Structural members of RC buildings

Type of Building	Slab thickness	Beam size	Column size	Wall thickness
Too tall	0.15 m	0.23 x 0.3 m	C_1= 0.23 x 0.75 m – upto 10 storey	0.23 m
			C_2 = 0.23 x 0.60 m – 10 to 20 storey	
			C_3 = 0.23 x 0.45 m – 20 to 30 storey	
Too long in span		0.23 x 0.3 m	0.3 x 0.45 m	
C Type		0.3 x 0.3 m	0.45 x 0.3 m	0.3 m
I Type		0.3 x 0.3 m	0.45 x 0.3 m	

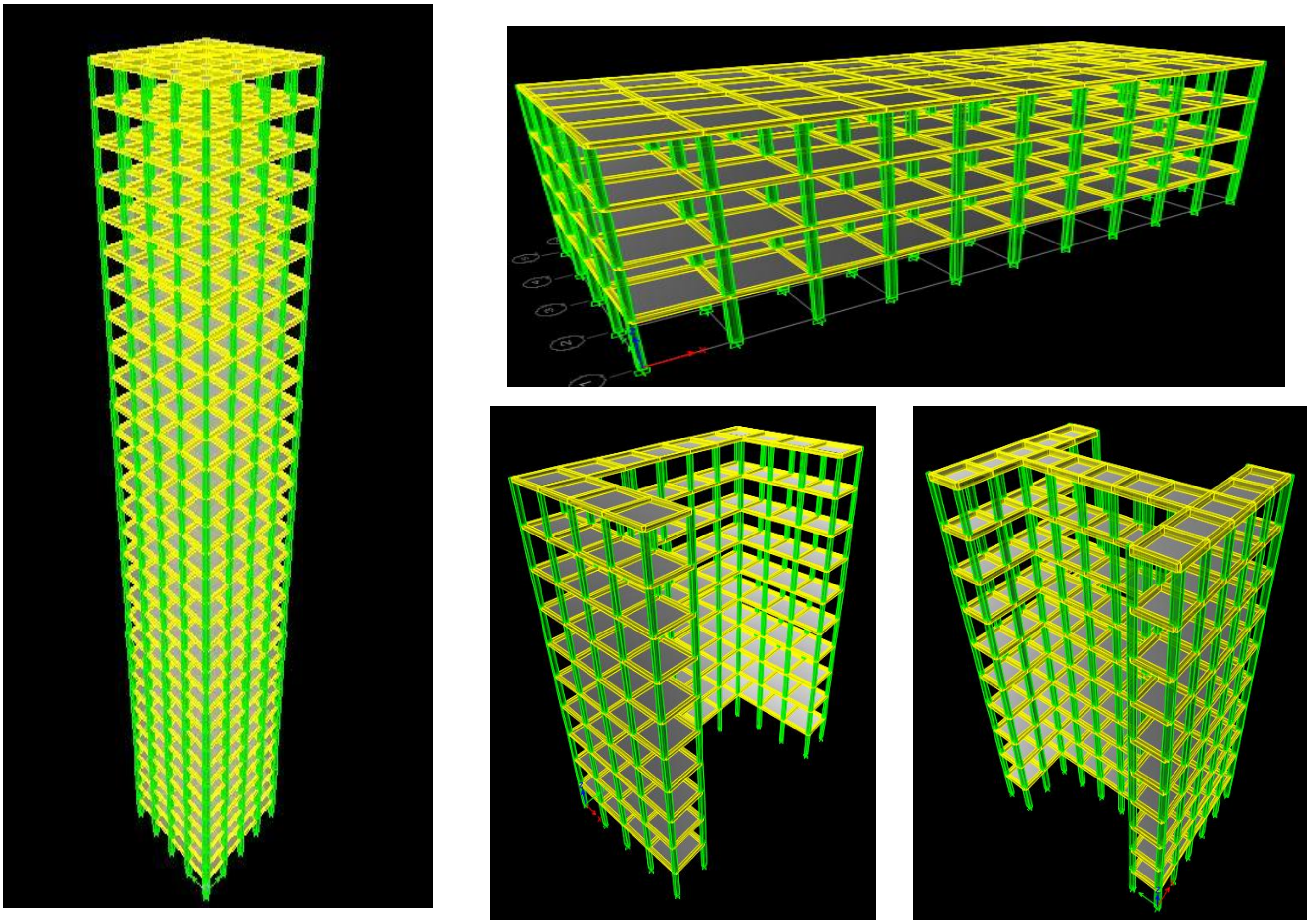

Fig: 3D model of buildings

Table 3.3: Material properties of RC buildings

Grade of concrete	M25, M30
Grade of Steel	Fe 500
Density of concrete	25 kN/m^3
Young's Modulus of Elasticity	27386 x 10^3 kN/m^2

Poison's ratio of concrete	0.2
Density of Block masonry	15 kN/m³

Table 3.4: Load intensities on RC buildings

Roof	
Roof finish	1.5 kN/m²
Live load	1.5 kN/m²
Parapet load	4.40 kN/m²
Typical Floors	
Floor finish	1.5 kN/m²
Live load	3.0 kN/m²
Wall load	Varies Based on storey height & beam size

Table 3.5: Seismic data for Earthquake analysis

Seismic Data	
Storey Height	3.5 m
Building frame system	SMRF
Seismic Zone	Zone 3
Soil Type	Medium soil (Type 2)
Response Reduction Factor	5
Importance Factor	1.5
Damping of Structure	5%

3.1 Modelling of infill wall

To evaluate the exact behaviour of the infill RC frame assembly in course of earthquakes, the masonry infill walls has to be modelled properly.

- Firstly the infills are modelled as "Equivalent compression diagonal strut" method which is derived from macro modelling technique. Because of its simplicity it is adopted in the FEMA 356. In the present study the formula provided by FEMA 356 is adopted to calculate the width 'a' of the equivalent diagonal strut.

This equation is given below:

$$a = 0.175 * (\lambda_1 * h_{col})^{-0.4} * r_{inf}$$

Where,

$$\lambda_1 = \left[\frac{E_{me} * t_{inf} * \sin 2\theta}{4 * E_{fe} * I_{col} * h_{inf}} \right]^{\frac{1}{4}}$$

λ_1 = Coefficient used to calculate equivalent width of infill strut.

h_{col} = Column height between center lines of beams in inches.

r_{inf} = Diagonal length of infill panel in inches.

E_{me} = Expected modulus of elasticity of frame material in Ksi.

t_{inf} = thickness of infill board and equivalent strut in inches.

θ = Angle whose tangent is the infill height to length aspect ratio in radians.

E_{fe} = Anticipated modulus of elasticity of infill material in Ksi.

I_{col} = Moment of inertia of column in in^4

h_{inf} = infill panel height in inches.

➢ Secondly the infills are modelled using IS: 1893 to calculate the width 'W_{ds}' of the equivalent diagonal strut.

This equation is given below:

$$W_{ds} = 0.175 * \left(\alpha_h * H_{inf}\right)^{-0.4} * L_{ds}$$

Where,

$$\alpha_h = \sqrt[4]{\frac{E_m * t * \sin(2*\theta)}{4 * E_f * I_c * H_{inf}}}$$

α_h= Coefficient used to calculate equivalent width of infill strut.

H_{inf} **=** Column height between outer to outer in mm.

L_{ds}= Diagonal length of infill panel in mm.

E_{me} = Expected modulus of elasticity of frame material in N/mm^2.

t_{inf} = thickness of infill board and equivalent strut in mm.

θ = Angle whose tangent is the infill height to length aspect ratio in radians.

E_{fe} = Anticipated modulus of elasticity of infill material in N/mm^2.

I_c= Moment of inertia of column in mm^4

Table 3.1.1: Equivalent diagonal strut width for different RC buildings modelled FEMA 356 & IS: 1893

Sl No.	Building type	Plan dimension (l*b*h) m	Column size mm	Beam size mm	Diagonal strut width Using	
					FEMA	IS 1893
1	Too tall	22.5x22.5x105	230 x 750	230 x 300	1885	1905
			230 x 600		1765	1783
			230 x 450		1617	1632
2	Too long in span	40 x 16 x 14	300 x 450	230 x 300	956	987
3	C Type	16 x 28 x 35	450 x 300	300 x 300	952	986
4	I Type	20 x 21 x 35	450 x 300	300 x 300	690	728

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4. Results and discussions

Comparison of various parameters such as displacement, storey drift, storey shear and time period of different types of reinforced concrete (RC) buildings with respect to existence and non existence of infills at various locations has been characterized in the below tables.

Table 4.1: Displacement for too tall buildings

Storey No.	DISPLACEMENT IN X –DIRECTION [EQX]			DISPLACEMENT IN Y–DIRECTION [EQY]		
	Without infill	With IS 1893	With FEMA 356	Without infill	With IS 1893	With FEMA 356
30	293	73.9	74.6	325.7	74.6	73.9
29	290	70.5	71.2	322.3	71.2	70.5
28	285.9	67.2	67.8	317.7	67.8	67.2
27	280.6	63.8	64.4	311.8	64.4	63.8
26	274.2	60.4	61	304.7	61	60.5
25	266.8	57.1	57.6	296.5	57.6	57.1
24	258.5	53.7	54.2	287.3	54.2	53.7
23	249.4	50.4	50.9	277.2	50.8	50.4
22	239.5	47	47.5	266.2	47.5	47.1
21	228.9	43.8	44.2	254.5	44.2	43.8
20	217.6	40.5	40.9	242.1	40.9	40.6
19	207.5	37.4	37.8	230.7	37.7	37.4
18	197	34.3	34.6	219	34.6	34.3
17	186.1	31.2	31.6	206.8	31.5	31.3
16	174.9	28.3	28.6	194.3	28.6	28.3
15	163.4	25.4	25.7	181.5	25.7	25.4
14	151.7	22.7	22.9	168.4	22.9	22.7
13	139.8	20	20.2	155.1	20.2	20
12	127.7	17.5	17.7	141.7	17.6	17.5
11	115.5	15.1	15.2	128.1	15.2	15.1
10	103.3	12.9	13	114.5	13	12.9
9	91.9	10.8	10.9	101.8	10.9	10.8
8	80.5	8.9	9	89.1	9	8.9
7	69.1	7.1	7.2	76.4	7.2	7.1
6	57.7	5.5	5.6	63.7	5.6	5.5
5	46.4	4.1	4.2	51.1	4.2	4.1
4	35.2	2.9	2.9	38.7	2.9	2.9
3	24.2	1.9	1.9	26.5	1.9	1.9
2	13.7	1	1	14.9	1	1
1	4.7	0.4	0.4	5	0.4	0.4

Table 4.2: Comparison of parameters w.r.t types of buildings

DISPLACEMENT			
Building Type	Without infill	With infill using IS 1893	With infills using FEMA
Too Tall	-	decreases by 74% to 80%	decreases by 72% to 84%
Too long	-	decreases by 90% to 95%	decreases by 90% to 95%
C type	-	decreases by 77% to 83%	decreases by 77% to 83%
I type	-	decreases by 59% to 71%	decreases by 57% to 66%
STOREY DRIFT			
Building Type	Without infill	With infill using IS 1893	With infills using FEMA
Too Tall	-	decreases by 66% to 83%	decreases by 66% to 83%
Too long	-	decreases by 62% to 95%	decreases by 92% to 95%
C type	-	decreases by 38% to 79%	decreases by 38% to 79%
I type	-	decreases by 38% to 79%	decreases by 38% to 79%
STOREY SHEAR			
Building Type	Without infill	With infill using IS 1893	With infills using FEMA
Too Tall	-	increases by 41% to 52%	increases by 42% to 52%
Too long	-	increases by 76% to 78%	increases by 76% to 78%
C type	-	increases by 81% to 84%	increases by 80% to 83%
I type	-	increases by 62% to 66%	increases by 61% to 65%
TIME PERIOD			
Building Type	Without infill	With infill using IS 1893	With infills using FEMA
Too Tall	-	decreases by 62% to 78%	decreases by 62% to 78%
Too long	-	decreases by 82% to 97%	decreases by 82% to 97%
C type	-	decreases by 77% to 81%	decreases by 77% to 81%
I type	-	decreases by 51% to 61%	decreases by 51% to 61%

5. Conclusions

In this study the behaviour of reinforced concrete frame infilled with concrete masonry infills modelled using FEMA 356 and IS 1893 methodology subjected to lateral loads have been studied. For the analysis four different types of buildings such as too tall, too long, C type and I type is chosen and was subjected to seismic load. As far as possible the structural model is kept simple and modelled it as the replica of the real life structure. Following conclusions were drawn based on the outcomes acquired.

1. Equivalent diagonal strut method (both in terms of FEMA 356 & IS: 1893) exhibits noticeable advantage in terms of computational easiness and efficiency. Their formulation is based on a physically reasonable representation of the structural behaviour of the entire infilled frame.

2. Seismic analysis of reinforced concrete frame must be done by considering the infill wall, which drives primary changes in the behaviour of the entire RC frame structure. Calculation of seismic forces without considering infill walls in RC frames leads to underestimation of base shear that may prompt to breakdown of structure.
3. RC frame structure with infills having no opening modelled using IS 1893 the parameters such as Drift, Displacement and time period decreases when compared with RC frame structure with infills modelled using FEMA 356.
4. RC frame structure with infills having no opening modelled using IS 1893 the storey shear parameter increases, when compared with RC frame structures with infills modelled using FEMA 356.
5. RC frame structure with infills having opening modelled using FEMA 356, the parameters such as storey drift, displacement and time period decreases upto 50% - 60% when compared with RC frame structure with infills modelled using FEMA 356 without openings.
6. The modelling of RC frame structures with infills in terms of IS 1893 in which openings in infills are not considered. Hence this may have a pessimistic impact on structural performance of the buildings in terms of displacement, storey drift and storey shears.

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