Effect of Location of Infills on Performance of Reinforced Concrete (RC) Framed Structure

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Abstract— Infilled frames have sustained the curiosity of researchers for a long period but they have been unable to carve a place in the codes of practices of any country. Masonry wall impart substantial amount of stiffness and strength to a building frame and used in the structures for architectural or aesthetic reasons, have been normally considered has non-structural elements and their presence has been ignored by engineers. The performance of structure can be greatly enhanced by the increase of strength arising from the masonry infill. Infill frames are widely constructed using brick masonry infill walls. The primary objective of this study is to present a general review of the performance of reinforced concrete frame structures with and without the presence of infills at different locations in the entire building models that include bare frame, building with infills around periphery and buildings with 100% infills. Masonry infills are modeled by equivalent diagonal strut method and the software ETABS is used for the study of all the RC frame models.

Key words: Equivalent Diagonal Strut, Masonry Infilled Frame, Seismic

I. INTRODUCTION

Reinforced Concrete structures with masonry infilled frames are constructed at first because of simplicity of development and speedy work in advancement. Reinforced concrete 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 are used to provide lateral resistance in areas of high seismicity, especially in those places where masonry is still a convenient material, owed to economical and outmoded reasons and consistently reduce the bending moments in the frame thus reducing the prospect of breakdown.

Masonry infill characteristically consists of bricks or concrete blocks constructed amongst 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 addition of the infill wall in the frame.

The Indian Standard (IS) code procurements don't afford any procedures 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.

[2] Haroon Rasheed Tamboli and Umesh.N.Karadi numerically analysed a G+10 building and presented a paper on "Seismic analysis of RC frame structure with and without masonry infill walls". In this paper seismic investigation has been executed using "Equivalent lateral force method" for various reinforced concrete frame building models comprising bare frame, infilled frame, and open storey frame. In modeling the masonry infill panels the equivalent diagonal strut method is adopted and ETABS software is used for the analysis of all the casing models. He concludes infilled frames must be favored in seismic regions than the open storey frame, attendance of infill wall can affect the seismic behaviour of frame structure to huge amount, and the infill wall surges the strength and stiffness of the structure. In case of open storey frame structure, the storey drift is very high than the upper storeys which may root the downfall of structure through strong earthquake.

[4] Manju G presented a paper on "Dynamic analysis of infills on R.C Framed structures". In which he circumstances the result of infills on bare frame, masonry infill and soft storey models. The vertical discontinuity of stiffness in the structure called as soft storey is considered in different places for different models i.e. from 1st storey to 10th storey. All the models are analysed by ETABS software in which response spectrum method is adopted for seismic analysis. Infills are modelled by equivalent diagonal strut technique. Factors like time period, displacement, storey shear, column forces and axial forces in columns are determined. He concludes infill wall increases strength, stiffness and also reduces BM and SF in bare frame respectively.

The objective of the present work is to carry out modeling, analysis of masonry infilled R.C. framed structures using macro model method. To understand the behavior of R.C framed structures with and without infill subjected to seismic forces and investigate the influence of masonry infill walls to lateral strength and lateral stiffness of the buildings.

II. 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 second group consists of simplified models based on a physical accepting of the behavior 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. It includes the modeling of brick infill panel as equivalent struts and studying the performance of a bare frame, infill frame at various locations. The performance of brick masonry infill panel for displacements, drifts, lateral force and maximum base shear are compared with the performance of bare frame.

III. MODELLING

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

Too tall buildings	
No of storeys	G+30
Plan Area	18m x 18m x 90m (l*b*h)
Column spacing	4.5m
Too long in span buildings	
No of storey	G+6
Plan Area	90m x 18m x 18m
Column spacing	6m
Too large in Area Buildings	
No of storey	G+6
Plan Area	90m x 90m x 18m
Column spacing	6m

Table 3.1: General details of RC buildings

Too tall buildings	
Thickness of slab	0.175 m
Beam	0.3 x 0.45 m
Column	C_1= 0.75 x 0.75m-upto 10 storey
	C_2 = 0.60 x 0.60m-10 to 20 storey
	C_3 = 0.45 x 0.45m-20 to 30 storey
Wall thickness	0.20 m
Too long in buildings	
Thickness of slab	0.175 m
Beam	0.3 x 0.6 m
Column	0.45 x 0.45 m
Wall thickness	0.20 m
Too large in area buildings	
Thickness of slab	0.175 m
Beam	0.3 x 0.6 m
Column	0.45 x 0.45 m
Wall thickness	0.20 m

Table 3.2: Structural members of RC buildings

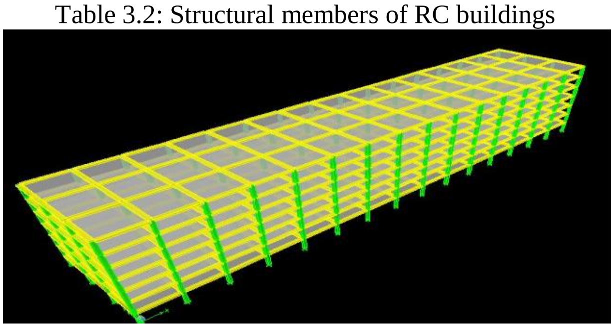
Fig. 3.1: Too Long Building

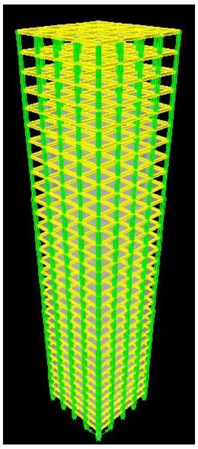
Fig. 3.2: Too Tall Building

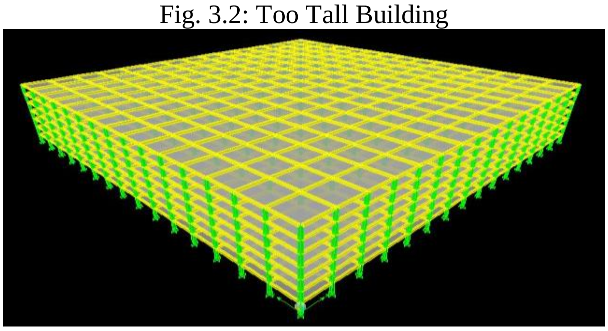
Fig. 3.3: Too Large Building

Grade of concrete	M30, M25
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/m^3

Table 3.3: Material properties of RC buildings

Roof	
Roof finish	1.5 kN/m^2
Live load	1.5 kN/m^2
Parapet load	4.40 kN/m^2
Typical Floors	
Floor finish	1.5 kN/m^2
Live load	3.0 kN/m^2
Wall load	13.22 kN/m^2, 10.56 kN/m^2

Table 3.4: Load intensities on RC buildings

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

Table 3.5: Seismic data for Earthquake analysis

A. Modelling of Infill Wall

To assess the exact behaviour of the infill RC frame assembly in course of earthquakes, the masonry infill walls has to be modelled properly. One of the methods suggested and approved by the researchers is the "Equivalent compression diagonal strut" method which is derived from macro modelling technique. Because of its simplicity it is adopted in the FEMA 356 and in the present study the masonry infill dividers are modelled as equivalent diagonal struts.

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.

For calculating the width of equivalent diagonal strut using the above stated equation is used. we need to have the modulus of elasticity of masonry which will be calculated from the compressive quality of masonry and the calculation of same is shown below all the other required information is obtained from the geometry of the structure and its elements.

Building type	Plan dimension	Column size Mm	Beam size Mm	strut width mm
Too tall	18 x 18 x 90	450 x 450	300 x 450	1047
		600 x 600		1140
		750 x 750		1243
Too long in span	90 x 18 x 18	450 x 450	300 x 600	1343
Too large in plan	90 x 90 x 18	450 x 450	300 x 600	1343

Table 3.1.1: Equivalent Diagonal Strut Width for Different Buildings

IV. RESULTS & DISCUSSIONS

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

No. of Modes	TIME PERIOD (SEC)					
	Without infill(1)		Infill around Periphery(2)		100% infill all-around(3)	
	EQX	EQY	EQX	EQY	EQX	EQY
1	5.608	5.608	5.220	5.220	4.828	4.828
2	5.608	5.608	5.220	5.220	4.827	4.827
3	4.494	4.494	3.896	3.896	3.860	3.860
4	1.840	1.840	1.717	1.717	1.592	1.592
5	1.840	1.840	1.717	1.717	1.591	1.591
6	1.548	1.548	1.342	1.342	1.329	1.329
7	1.047	1.047	0.975	0.975	0.900	0.900
8	1.047	1.047	0.975	0.975	0.900	0.900
9	0.916	0.916	0.800	0.800	0.792	0.792
10	0.717	0.717	0.669	0.669	0.619	0.619
11	0.717	0.717	0.669	0.669	0.619	0.619
12	0.629	0.629	0.553	0.553	0.547	0.547

Table 4.1: Time Period for Too Tall Buildings

No. of Modes	TIME PERIOD (SEC)					
	Without infill(1)		Infill around Periphery(2)		100% infill all-around(3)	
	EQX	EQY	EQX	EQY	EQX	EQY
1	2.229	2.229	0.906	0.906	0.695	0.695
2	2.096	2.096	0.685	0.685	0.664	0.664
3	2.028	2.028	0.667	0.667	0.656	0.656
4	0.665	0.665	0.288	0.288	0.150	0.150
5	0.629	0.629	0.169	0.169	0.128	0.128
6	0.616	0.616	0.147	0.147	0.103	0.103
7	0.353	0.353	0.135	0.135	0.061	0.061
8	0.335	0.335	0.101	0.101	0.057	0.057
9	0.334	0.334	0.086	0.086	0.051	0.051
10	0.223	0.223	0.079	0.079	0.041	0.041
11	0.215	0.215	0.070	0.070	0.039	0.039
12	0.212	0.212	0.066	0.066	0.036	0.036

Table 4.2: Time Period For Too Long In Span Buildings

No. of Modes	TIME PERIOD (SEC)					
	Without infill(1)		Infill around Periphery(2)		100% infill all-around(3)	
	EQX	EQY	EQX	EQY	EQX	EQY
1	1.415	1.415	0.790	0.790	0.670	0.670
2	1.415	1.415	0.788	0.788	0.660	0.660
3	1.353	1.353	0.657	0.657	0.640	0.640
4	0.458	0.457	0.238	0.238	0.115	0.115
5	0.458	0.457	0.237	0.237	0.107	0.107
6	0.438	0.438	0.156	0.156	0.101	0.101
7	0.267	0.267	0.132	0.132	0.058	0.058
8	0.267	0.267	0.132	0.132	0.053	0.053
9	0.256	0.256	0.093	0.093	0.053	0.053
10	0.187	0.187	0.093	0.093	0.040	0.040
11	0.187	0.187	0.084	0.084	0.037	0.037
12	0.179	0.179	0.074	0.074	0.037	0.037

Table 4.3: Time Period for Too Large in Plan Buildings

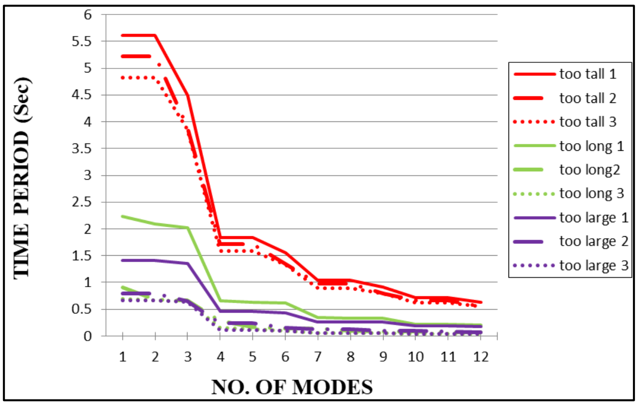

Fig. 4.1: Fig Shows Comparison of time period of too tall, too long & too large buildings along X axis

TIME PERIOD			
Building Type	Without infill	With infill around periphery	With 100% infills
Too Tall	-	decreases by 7% to 13%	decreases by 13% to 14%
Too long	-	decreases by 57% to 76%	decreases by 68% to 85%
Too large	-	decreases by 44% to 64%	decreases by 53% to 81%
DISPLACEMENT			
Building Type	Without infill	With infill around periphery	With 100% infills
Too Tall	-	decreases by 0.08% to 1%	decreases by 6% to 16%
Too long	-	decreases by 40% to 92%	decreases by 37% to 92%
Too large	-	decreases by 41% to 66%	decreases by 51% to 81%
STOREY SHEAR			
Building Type	Without infill	With infill around periphery	With 100% infills
Too Tall	-	increases by 18% to 19%	increases by 21% to 27%
Too long	-	increases by 15% to 21%	increases by 23% to 29%
Too large	-	increases by 33% to 35%	increases by 46% to 48%
LATERAL FORCE			
Building Type	Without infill	With infill around periphery	With 100% infills
Too Tall	-	increases by 11% to 20%	increases by 8% to 27%
Too long	-	increases by 6% to 21%	increases by 11% to 30%
Too large	-	increases by 23% to 35%	increases by 24% to 49%
STOREY DRIFT RATO			
Building Type	Without infill	With infill around periphery	With 100% infills
Too Tall	-	decreases by 3% to 4%	decreases by 6% to 17%
Too long	-	decreases by 41% to 98%	decreases by 38% to 98%
Too large	-	decreases by 76% to 80%	decreases by 90% to 98%

Table 4.4: Comparison of Parameters W.R.T Types of Buildings

V. CONCLUSION

In this study the behaviour of reinforced concrete frame infilled with concrete masonry units without openings subjected to in- plane lateral loads have been studied. For the analysis three different types of buildings such as too tall, too long and too large w.r.t structural configuration is chosen and subjected to equivalent static method. 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 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 the structure.
3) The strength of infill wall has a great significant role in global performance of the structure. As the time period decreases the stiffness of the structure increases. The structural response such as displacement in the infill wall reduces with increase in strength.
4) Presence of infills increase the lateral load carrying capacity and reduce the storey drifts compared to RC bare frame which in term increases energy dissipation capacity of the frame.
5) From the analysis we can conclude that the performance of RC frame structures with 100% infills is far better when compared with bare frame and RC frame with infill around periphery.
6) RC frame structures with openings around periphery will carry more strength and stiffness with the provision of intermediate infills when compared to structures without intermediate infill.

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