# RC Masonry Infilled Model and Prototype Frames on Dynamic Behaviour

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ABSTRACT

**Masonry infill (MI) have usually been used in the structures for architectural or aesthetic reasons, and hence considered as non-structural elements, thus their stiffness has been ignored. In the latest revision of IS 1893 in the year 2016, the Masonry Infill has been recommended to be modelled as a Equivalent Diagonal Strut which is Macro modeling technique adopting this code 3D RC masonry infilled(MI) Model and Prototype frames including 0% to 100% openings MI are analyzed using FE analysis. The comparison of natural frequencies obtained from modal analysis with natural frequencies obtained from IS 1893(part-1):2016 using time period formula is carried out tabulated and conclusions are drawn.**

***Keywords*— equivalent diagonal strut, macro model, openings, scaling laws**

## INTRODUCTION

Less- ductile RC frames with Infill is not a rare sight nowadays. Masonry infills are widely used to fill in the voids in Reinforced Concrete Frames. It is presumed that masonry infill is non-structural member of a structure due to brittleness in nature. Hence its consideration while analysis of frame is neglected. In fact, the masonry infill between horizontal and vertical members of frame helps to provide rigidity to the structure. The infills are merely considered as architectural component or just a partition but in fact there is utter need to advance in the analysis and performance check for the infill used.

Modal analysis is the method of determining the inherent dynamic characteristics of a system in forms of natural frequencies and mode shapes, and using them to create a mathematical model for its dynamic behavior. The dynamics of a structure are physically decomposed by frequency and position. Modal analysis gives the information concerning the different modes of vibration, different shape that can be taken up by the structure during vibration. These shapes during different modes are called mode shapes and all mode shapes have their corresponding natural frequencies

## LITRATURE REVIEW

Numerous studies have made on the dynamic analysis of RC frame structure with and without infill walls. As well frame with varying percentage of openings, bare frame. A brief review of the available information studies are presented below.

B.S.Smith and C Carter(1969)[1], Chethan K et.al(2009)[2],P.G Asteris et.al(2011)[3], Andre Furtado et.al(2015)[4], Raghu K et.al(2015)[5], Marco Tanganelli et.al(2018)[6] and many more carried out studies on Masonry infill Model and Prototype with Equivalent Diagonal Strut with openings. However they showed that the diagonal stiffness and strength of the infilling panel depends not only on its dimensions and physical properties but also on its length of contact with the surrounding frame.

## OBJECTIVES AND METHODOLOGY

1. To evaluate the modal response of 3D-RC MI Model and Prototype frame by varying the percentage of openings using Macro Modeling Technique.
2. To find out the width of the equivalent diagonal strut as per IS 1893(Part 1):2016
3. Development of Prototype by using Scaling Laws.

**The Methodology of proposed study**

1. To analyses the dynamic behavior of G+3 RC MI gabled roof bare frame of both model and prototype
2. Development of Prototype by increasing the dimensions in 1:4 scales by keeping same material property as that of Model by following the Scale factor using Scaling Laws.
3. Modal Analysis is carried out to obtain Natural Frequencies.
4. Comparison of Natural Frequencies obtained from modal analysis with natural frequencies obtained from IS 1893(part-1):2016 using time period formula.

## MODELLING AND ANALYSIS

### *A. Modeling of 3D RC MI Model and Prototype*

Over the past few decades, several methods for the analysis of infilled frames have been proposed by various investigators. These methods can be divided into two groups, depending on the degree of refinement used to represent the structure. The first group consists of the macro models to which belong the simplified models that are based on a physical understanding of the structure. The second group involves the micro models including the finite element formulations, taking into account local effects in detail.

### *B. Equivalent diagonal strut analogy*

The simplest most developed method for the analysis of non-integral MI frames a based on the concept of the equivalent diagonal strut. This concept was initially proposed by Polyakov (1956) and later developed by other investigators. In this method, the infilled frame structure is modeled as an equivalent braced frame system with a compression diagonal replacing the MI.

### *C. Parametric study*

The increase in rigidity and stiffness lead to vulnerability in out plane loadings like lateral loads and seismic loads. Thus it becomes important to consider the loads other than only wind and gravity loads, the seismic events act in 3 Dimensions to all members of structure leaving the infill the weakest component. Thus equivalent diagonal strut approach is adapted to estimate the stiffness provided to the whole structure.

The present work is focusing on the dynamic analysis G+3 gabled roof of bare frame structure, infilled structure, and varying percentage of opening in MI for both model and prototype.

Only few studies have been carried out on the similitude laws for the prototype structures with small scaled models built with a different material. Relating the natural frequency of the prototype and that of the model, given by

$$\mathbf{f_m = \sqrt{S}\, f_p} \quad \mathbf{(1)}$$

Where,

$f_m$ = frequency of model

$f_p$ = frequency of prototype

S = scale factor

### *D. FE Analysis*

The 3D- RC model is a three storey, two-bay structure with gable roof there are no central column and glass panels along the periphery of the top storey. The gable roof is having asbestos sheet. The three central columns along the gable frame are having hinge supports. The dimensions of the model are taken from the Chethan K (2009).The linear scale factor $S_L$ equals to 4 for 1:4 scaled model adopted in this work.

**Table 1: Material Property**

| **Material** | **Concrete** | **Steel** | **Bricks** |
|---|---|---|---|
| Modulus of elasticity($N/m^2$) | $2.5 x 10^{10}$ | $2 x 10^{11}$ | $14 x 10^6$ |
| Poisons ratio | 0.15 | 0.3 | 0.18 |
| Density ($kN/m^3$) | 25 | 78.6 | 19.2 |

**Table 2: Member Section Property**

| **Type of structure** | **Model** | **1:4 Prototype** |
|---|---|---|
| No. of storey's | 3 | 3 |
| Storey height(mm) | 900 | 3600 |
| Bay width(mm) | 1200 | 4800 |
| Beam(mm) | 75 x 100 | 300 x 400 |
| Column(mm) | 75 x 100 | 300 x 400 |

| | | |
|---|---|---|
| Slab(mm) | 50 | 150 |
| Breadth of beam/column(mm) | 75 | 300 |
| Depth of beam/column(mm) | 100 | 400 |
| Thickness of MI, t (mm) | 75 | 300 |
| Height of MI, h (mm) | 800 | 3200 |
| Length of MI, l(m) | 1.1 | 4400 |
| Diagonal length of MI, d (mm) | 1.36 | 5440 |
| Height of column, $h_{col}$ (m) | 0.9 | 3.6 |
| Moment of inertia of beam/column ($m^4$) $I_c$ | $6.25 \times 10^{-6}$ | $1.6 \times 10^{-3}$ |
| Modulus of elasticity of concrete ($kN/m^3$) $E_c$ | $2.5 \times 10^7$ | $2.5 \times 10^7$ |
| Modulus of elasticity of MI ($kN/m^3$)$E_m$ | $1.4 \times 10^7$ | $1.4 \times 10^7$ |

***E. Calculation of Width of Diagonal Strut (IS 1893-2016)***

URM infill walls shall be modelled using Equivalent Diagonal Strut.

a. End of diagonal shall be considered to be pin jointed to RC frame.

b. For URM infill walls without any opening Width of equivalent diagonal Strut-$W_{ds}$

$$\mathbf{W_{ds} = 0.175\ \alpha_h^{-0.4}\ L_{ds}} \qquad (2)$$

**c.** The relative stiffness of the frame to the infill and is given by,

$$\lambda_h = h \sqrt[4]{\frac{E_m t \sin 2\theta}{4 E_c I_c h}} \qquad (3)$$

Where,

$E_m$ =Modulus of elasticity of masonry infill

t = Thickness of masonry infill

h = Height of masonry infill

$E_c$= Modulus of elasticity of column

$I_c$ = Moment of inertia of the column

θ = Slope of the infill diagonal to the horizontal

***F. Width of the Strut:***

The width of the strut for model and prototype in both along gable frame(AGF) and perpendicular to gable frame(PGF) direction is obtained for different models of 3D RC structure by using the formula proposed in IS 1893(Part 1): 2016.Width of the diagonal strut for different structures are given below:

a. Model = 142mm
b. Prototype = 584mm

***G. The Masonry Stiffness Reduction Factor***

An analytical equation for obtaining the reduction factor, which is given below

$$\boldsymbol{\lambda = 1 - 2\alpha_w^{0.54} + \alpha_w^{1.14}} \qquad \textbf{(4)}$$

where,

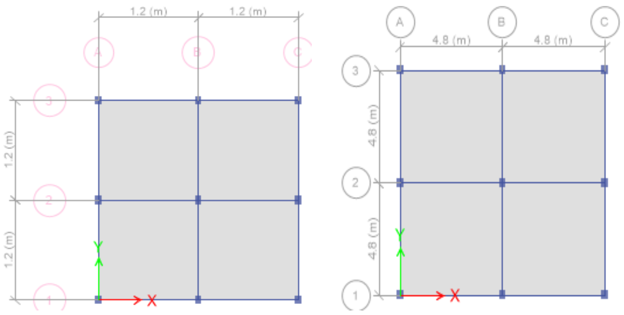
$\boldsymbol{\alpha_w}$ **=** is the infill wall opening percentage (area of opening to the area of infill wall).

The above coefficient could be used to find the equivalent width of a strut for the case of an infill with opening by multiplying the result with width of the strut and reduction factors from 0% to 100% openings in MI are shown in table 3.

**Table 3: Stiffness Reduction Factors**

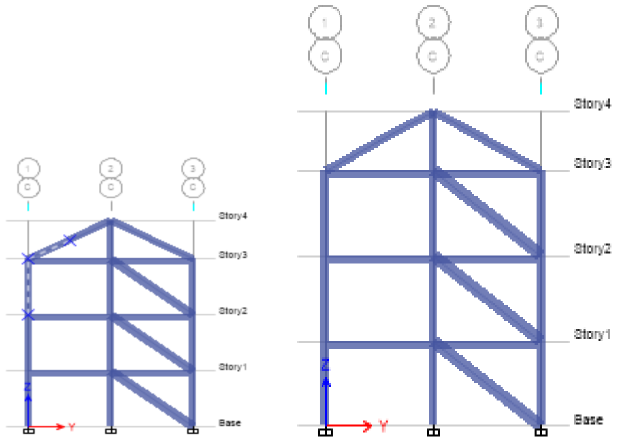
| Opening % | Stiffness Reduction Factors |
|---|---|
| 0 | 1.000 |
| 5 | 0.636 |
| 10 | 0.495 |
| 20 | 0.320 |

| | |
|---|---|
| 30 | 0.210 |
| 40 | 0.132 |
| 50 | 0.078 |
| 60 | 0.041 |
| 70 | 0.016 |
| 80 | 0.002 |
| 90 | 0.000 |
| 100 | 0.000 |



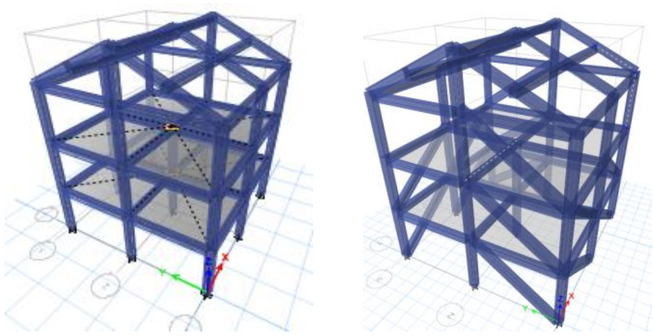

(a) (b)

**Fig 1: (a) plan of model, (b) plan of prototype**




(a) (b)

**Fig 2: (a) Masonry infill Model with Equivalent diagonal strut**
**(b) Masonry infill Prototype with equivalent diagonal strut**



(a) (b)

Fig 3: (a) 3D RC bare frame, (b) 3D RC infilled model with Equivalent diagonal strut

## RESULTS AND DISCUSSION

The modal analysis on 3D RC MI frames and varying percentage of openings with Equivalent diagonal strut as per IS 1893(part-1):2016 are discussed below.

### A. *Natural Frequency*

Calculation of Natural frequency of 3D RC infilled frame and Bare frame as per IS 1893(Part 1) 2016

**1.** For Bare Frame Model and prototype

Fundamental natural period, $T_a = 0.075\ h^{0.75}$ (5)

**2.** For 3D RC Infilled Frame condition for Model and prototype

Fundamental natural period, $T_a = 0.09h/\sqrt{d}$ (6)

where,

h = average height of the building

d = base dimension of the building along the considered direction of shaking

**Table 4: Natural Frequencies (Hz) For Both Bare Frame And 3d RC Gable Infilled Frame**

| MODEL | | IS 1893-2016 | Modal analysis | IS 1893-2016 | Modal analysis |
|---|---|---|---|---|---|
| | | **Model** | **Model** | **Prototype** | **Prototype** |
| BF | AGF | 5.83 | 2.061 | 2.061 | 1.59 |
| | PGF | 5.83 | 2.061 | 2.061 | 1.40 |
| 3D RC Infilled frame | AGF | 5.71 | 2.856 | 2.856 | 4.97 |
| | PGF | 5.71 | 2.856 | 2.856 | 2.65 |

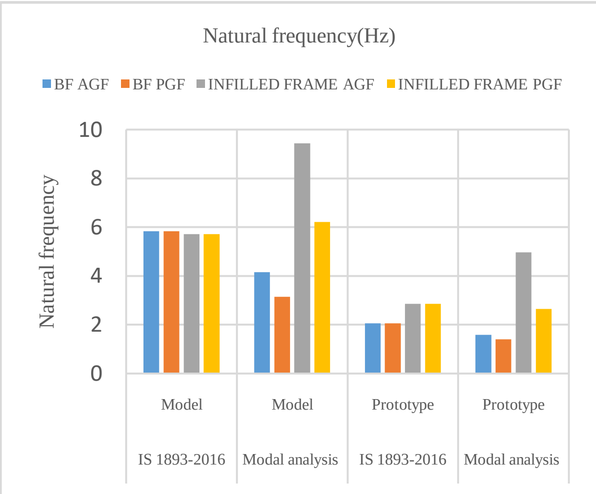



**Fig 4: Natural Frequencies (Hz) for both Bare Frame and 3D RC gable infilled frame**

The Natural Frequencies obtained from the modal analysis are not matching with IS Code results formation highlighting the shortfall of IS Code.

The Natural Frequency of 3D RC MI Model and Prototype in the AGF and PGF direction for 0% to 100% openings obtained from the Modal Analysis are tabulated in table 5 and graphs are shown in fig 5 and 6.

Table 5: Natural Frequencies (Hz) Along AGF ANF PGF Direction

| OPENINGS % | MODAL | | PROTOTYPE | |
|---|---|---|---|---|
| | AGF | PGF | AGF | PGF |
| 0% | 9.4330 | 6.2110 | 4.9720 | 2.6470 |
| 5% | 9.1740 | 6.0600 | 4.4000 | 2.5800 |

| | | | | |
|---|---|---|---|---|
| 10% | 9.0900 | 6.0000 | 4.0160 | 2.4290 |
| 20% | 8.2640 | 5.8820 | 2.8440 | 1.9580 |
| 30% | 7.9360 | 5.7470 | 2.5320 | 1.9010 |
| 40% | 7.1420 | 5.5860 | 2.1800 | 1.8280 |
| 50% | 6.2890 | 5.3190 | 1.8800 | 1.7200 |
| 60% | 5.3760 | 4.8300 | 1.8000 | 1.6600 |
| 70% | 4.5870 | 4.1840 | 1.7800 | 1.5800 |
| 80% | 4.0480 | 3.4840 | 1.6940 | 1.4550 |
| BF | 4.1490 | 3.4160 | 1.5920 | 1.4000 |

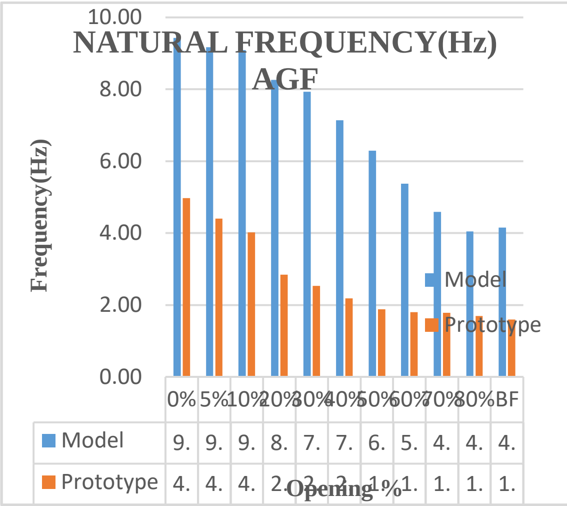



Fig 5: Natural Frequencies of Model and Prototype AGF

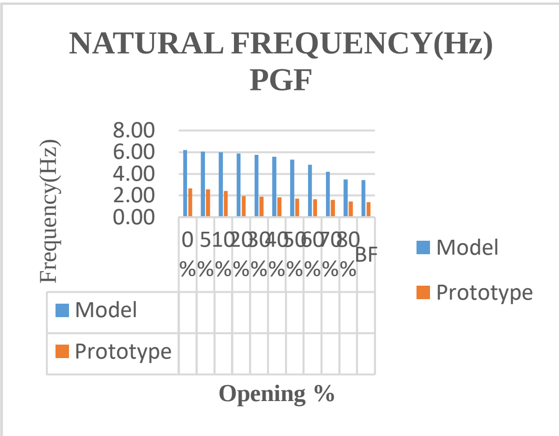



Fig 6: Natural Frequencies of Model and Prototype PGF

As the percentage of openings increases the Natural Frequency in both AGF and PGF directions decreases this is due to reduction in stiffness of the structure.

The Model Natural frequency has to be equal to square root times the scale factor multiplied by Prototype Natural frequency as per the scaling law.

## CONCLUSIONS

The Modal analysis is performed for 3D RC MI Model and Prototype with Strut and the following are the major conclusions drawn.

The Natural Frequencies obtained from the modal analysis are not matching with IS Code results formation highlighting the shortfall of IS Code.

As the percentage of openings increases the Natural Frequency in both AGF and PGF directions decreases this is due to reduction in stiffness of the structure.

The Model Natural frequency has to be equal to square root times the scale factor multiplied by Prototype Natural frequency as per the scaling law.

The influence of MI reduces drastically at 80% opening in AGF and PGF direction nullifying the influence of the masonry.

## REFERENCES

[1] B S Smith and C Carter (1969), "A Method of Analysis for Infilled Frames", proceedings of the Institute of Civil Engineers, vol.44, pp 31-48.
[2] Chethan K, Ramesh Babu, KattaVenkataramana and Akanshu Sharma (2009),"Studies on the Influence of Infill on Dynamic Characteristics of Reinforced Concrete Frames", Journal of CPRI, Vol 5 (2).
[3] Panagiotis G.Asteris1,Ioannis P. Giannopoulos,2 and Christis Z. Chrysostomou3 (2011), "Modeling of Infilled Frames With Openings", III ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering Greece, 26–28 May 2011
[4] Andre Furtado and Hugo Rodrigues (2015) "Modelling of masonry infill walls participation in the seismic behaviour of RC buildings using OpenSees" Int J Adv Struct Eng (2015) 7:117–127
[5] Raghu K and G Narayana (2015**)** "Analysis of RC Framed Structures with Central And Partial Openings in Masonry Infill Wall using Diagonal Strut Method" IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308
[6] Marco Tanganelli and TommasoRotunno (2017) "On the modelling of infilled RC frames through strut models" Cogent Engineering (2017), 4: 1371578

### CODES / STANDARDS

1. Indian Standard IS 1893-2016, "Criteria for Earthquake Resistant Design of Structures", Part 1: General Provisions and Buildings, Sixth Revision, BIS, New Delhi, India.
2. Indian Standard IS 456-2000 " Plain and Reinforced Concrete- code of Practice," BIS, New Delhi, India.