International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 01, January-2019

A REVIEW ON MODELLING OF INFILLED WALL AND EVALUATION OF ELASTIC CONSTANTS

Shivangi V. Sutariya[1], Dr. Mazhar A. Dhankot[2], Prof. Kunal P. Shukla[3]

[1]*Civil engineering department & Marwadi Education Foundation, Rajkot,*
[2] *Civil engineering department & Goverrment Engineering College, Rajkot,*
[3]*Civil engineering department & Marwadi Education Foundation, Rajkot,*

ABSTRACT
Masonry infill (MI) walls are usually used in existing RC buildings around the world. Masonry infill interacts with the surrounding RC frame and contributes to the overall strength and lateral stiffness of the structure. But generally in the wall panel, masonry infill is treated as a non-structural element at design stage. Hence require to find out the behaviour of RC frame with masonry infill under earthquake force. In Indian context the research is conducted on red bricks, whereas the maximum units used in today's scenario is Autoclaved Aerated Concrete blocks and newly developed Expanded Clay Aggregate blocks, whose property estimation in still required.

Keywords- masonry infill, lateral stiffness, equivalent diagonal strut, Young's Modulus & Modulus of Rigidity

I. INTRODUCTION

Masonry panels are broadly utilized in building development to divide the insides spaces of low buildings, as well as to make the outside walls of medium-height buildings. This wide spread is related to the economical mean they give to separate and enclose spaces to any required purposes. They are utilized since masonry units, particularly hollow clay blocks are cheaper, speedier, and simpler to erect than other potential wall infill materials. MI has good heat and sound insulation and waterproofing properties as results, greater occupant economy and comforts. Within the traditional examination of a masonry-infilled RC (reinforced concrete) frame structures, the masonry infill (MI) within the wall panel is treated as a non-structural component; in any case, ignoring its structural contribution comes about in an inaccurate analysis. In reality, the masonry infill (MI) interacts with the encompassing reinforced concrete frame and contributes to the in overall stiffness and strength of the structure, especially when the building is under the lateral forces. A comparative investigation of reinforced concrete (RC) frames with and without MI shows that the presence of MI causes alter within the anticipated structural behaviour of frame due to the participation of the masonry within the load transfer mechanism. This alters within the load transfer mechanism and behaviour of infilled reinforced concrete structures can result within the dispersion of forces to other components of structure which are not designed to resist them. [1, 2, 3, 4]

Behaviour of masonry infill is difficult to be anticipated since of critical varieties in material properties that can be utilized within the manufacturing of masonry infill walls and distinctive configurations by which they can be applied to buildings. [2, 3, 4] The presence of openings, such as windows and doors, in MI walls can decrease strength and stiffness of infilled frames and subsequently alter the expected behaviour. [2, 5]

The primary experimental work on contribution of MI to reinforced concrete frame behaviour was conducted by Polyakov, as detailed by Crisafuli who suggested that MI may be modelled as an equivalent diagonal strut. Afterward work by Holmes explored the behaviour of reinforced concrete outlines with concrete and clay masonry infill. Assist investigate was conducted by Staford Smith in this vein, who conducted arrangement of tests to explore the width of an equivalent diagonal strut. Tomazevicl and Zarnic more over explored the behaviour of MI reinforced concrete outlines with different sorts of MI (unreinforced and reinforced masonry). The test work conducted by Zovkovic et al. on single-bay, and single-story RC outlines with different sorts of masonry walls. The masonry units utilized in this test were clay brick blocks with high-strength, hollow clay brick blocks with medium-strength, and lightweight AAC blocks with low-strength. The behaviour of MI reinforced concrete outlines was too examined by Crisafuli, who represented that their behaviour can be progressed utilizing tapered beam column joints. Jiang et al. conducted attest study on single-story, and single-bay RC outline examples with different connections between MI and RC outlines. There are huge number of test examinations performed by different analysts on geometry, masonry units and materials. [1, 5, 10]

The scientific literature offers an assortment of models, which can be gathered in two classes. The primary one includes micro-modelling approaches, in which the masonry panel, the reinforced concrete outline and their common connections are separately modelled and depicted by legitimate constitutive laws. The second class, ordinarily characterized as ‘‘macro-modelling approach’’, is the foremost broadly utilized, and resorts to straightforward heuristic models for which the solution is direct. Among these, it is worth specifying the method of the ‘‘equivalent strut’’ and so called method of the ‘‘composite cantilever’’ determined from the perception that the load path mainly follows the diagonal within a infill panel, that's by distant the foremost popular. [7, 10]

II. DETERMINATION OF ELASTIC CONSTANTS

a. Determination of Young’s Modulus

Stress-Strain characteristics: - Utilizing linear regression analysis, a basic analytical model was suggested for getting the stress-strain curves for masonry which can be utilized in Hemant B. Kaushik, Durgesh C. Rai and Sudhir K. Jain [8] gave the method to determine the investigation and design methods. Approximate height of 5 brick tall masonry prism specimen with 10-mm-thick mortar joints was almost 400 mm which utilized for testing was done following codes ASTM C 1314-00a (ASTM 2001b) and IS 1905 (IS 1987). Test setup and stress-strain curve for masonry prisms are appeared in Figs. 1 and 2. The stress-strain curve was erected to be straight for up to around 1/3 of fm after which splits started to create within the bricks presenting the nonlinearity. Fig. 3 appears that Em varies between 250 and 1,100 times fm, and an average value of Em may be decided by,

$$Em \approx 550fm$$

Where, *Em* = modulus of elasticity of masonry, *fm* =compressive prism strength of masonry

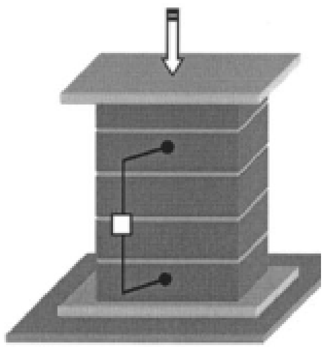

Fig. 1 Test setup of masonry [8]

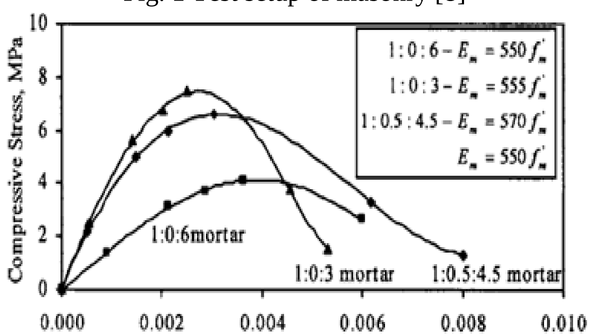

Fig. 2 Stress-strain curve of masonry [8]

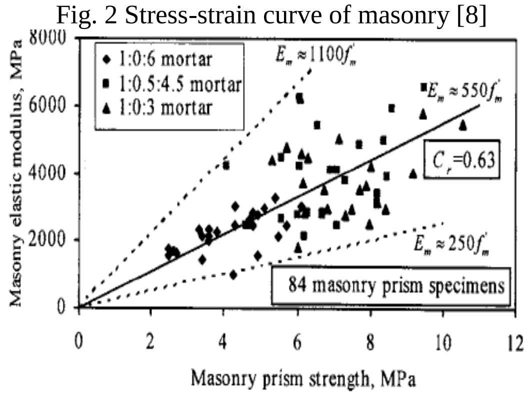

Fig. 3 Variation of modulus of elasticity with corresponding compressive strengths [8]

b. Determination of Modulus of Rigidity

Vlatko Bosiljkov, Yuri Z. Totoev and John M. Nichols [9] give a method to decide an estimate of the shear modulus for design purposes. Calculated masonry shear modulus from the effective stiffness got from shear tests of masonry walls, may shift from 6 to 25% of the measured E (elastic modulus) of the brick work. An outline table records the test methods for the 6 tests (Table 1) shown in Figure 4.

Table 1 Test Methods for the Experimental Program [9]

Test	Test Method Basis	Type of Test Protocol
A	European pre-norm prEN 1052-1	Compressive tests of masonry wallettes with monotonic loading in a displacement-controlled mode (0.3 mm/min)
B	ASTM C1391	Monotonic loading
C	Shear Loading	Not used
D	Nichols (2000)	Square masonry shear walls at distinctive levels of precompression and with dynamically applied shear The shear load was too sinusoidal with different frequencies
E	Shear Loading	No Protocol
F	Shear Tests with Harmonic Seismic Frequency	on the masonry cantilever walls, with the constant level of precompression and with forced horizontal loading history in sinusoidal cyclic way

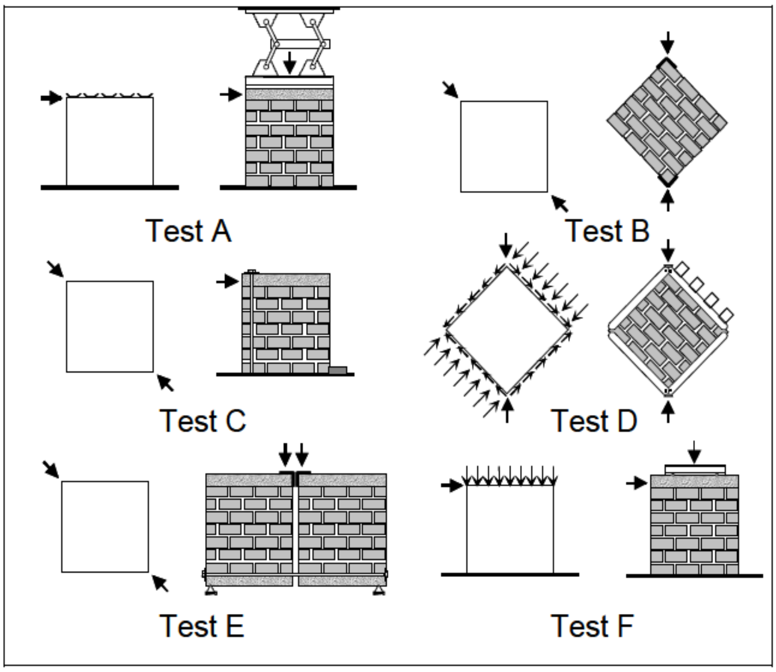

Fig. 4 Various Test Procedures for the Shear Tests of Masonry Structural Elements [9]

Arrangement for the shear modulus (G) of the masonry work (G=0.4 E) expressed in numerous national codes also in revise Eurocode 6 is correct in case the compressive loading is transcendent one. It too relates well with comes about of estimation of distortions of masonry as a construction material (on a little area of the examples) picked up through diagonal (little cross) and dynamic shear tests. In any case it can generally overestimate the stiffness of masonry structural components. For masonry of brickwork build with stiffer mortar mixtures outcome of simple diagonal tests can useful for estimating the effective stiffness of masonry components. Diagonal tests are unacceptable for assessing both stiffness and mechanical properties for reinforced masonry. Equations of shear stress (τ_{xy}), shear strain (γ_{xy}) and modulus of rigidity (G_d) are given below based on Figure 5.

$$\tau xy = \frac{p}{\sqrt{2}bt}$$

$$\gamma xy = \left(\tan\alpha + \frac{1}{\tan\alpha}\right)\left(\frac{\delta h + \delta v}{2d}\right)$$

$$Gd = \frac{\tau xy}{\gamma xy}$$

Where, p =applied force on specimen
b =breadth of section
t =depth of section
d =diagonal length of specimen
δ_h =horizontal diagonal extension
δ_v =vertical diagonal shortening

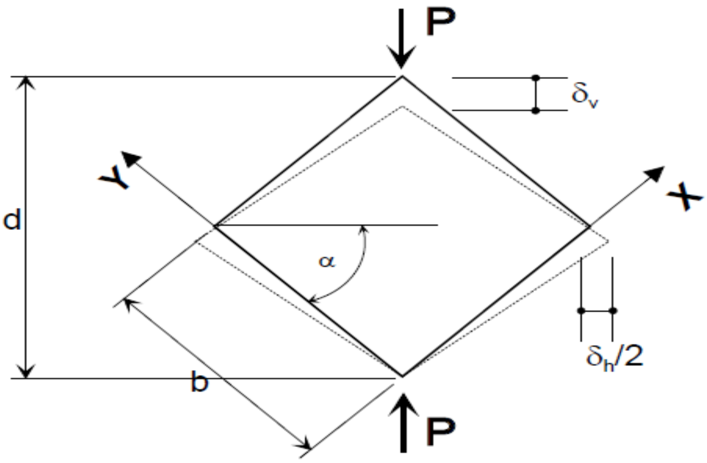

Fig. 5 Experiment setup for determination of modulus of rigidity [9]

III. MODELLING OF INFILLED FRAME STRUCTURES

The explanatory modelling of infilled outlines could be a complex issue since these structures show an exceedingly non-linear inelastic behaviour coming about from the interaction of the MI panel and encompassing outline. These days, the diagonal strut model is broadly accepted as a simple and level-headed way to depict the impact of the masonry panels on the infilled outline. The single diagonal strut model is simple and able of representing the impact of the MI panel in a worldwide sense. [10] Fig. 6 illustrates the single diagonal strut model. There are many researchers give equations for equivalent diagonal strut which are below:

a. FEMA 356 Method

Information on masonry infill frame has been clarified profoundly in FEMA 356 (Seismic Rehabilitation Pre-standard) [6, 11], particularly in section 7.5.2 on MI panel. The calculation of strength and stiffness of MI panel can be utilized for analysing structures with diagonal strut. The elastic stiffness of a MI panel (that's expected to have splits) can be represented to with α (equivalent diagonal strut) that has similar elastic modulus and thickness with the masonry panel.

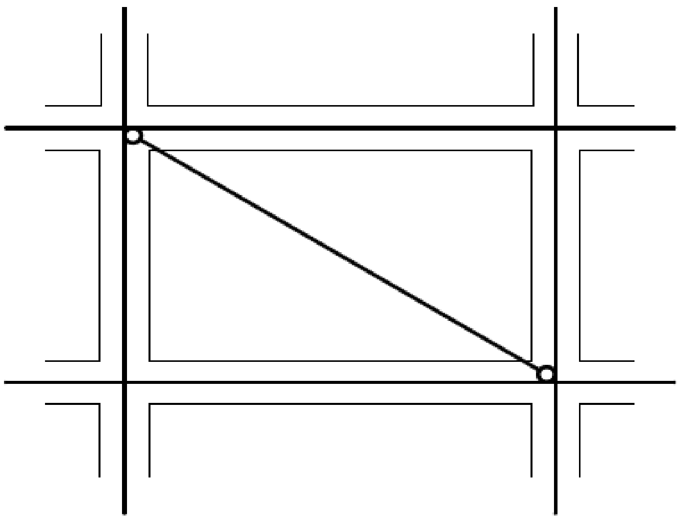

Fig. 6 Single diagonal strut model [2]

The calculation of equivalent diagonal strut width:

$$w = 0.175\ (\lambda h \cdot H)^{-0.4} dinf$$

$$\lambda h = \left[\frac{Einf \cdot tinf \cdot \sin 2\theta}{4\ Ec \cdot Ic \cdot Hinf}\right]^{0.25}$$

b. Equivalent Diagonal Strut - Holmes Method

Holmes [11, 12] states that the equivalent diagonal strut width should be 1/3of the diagonal of a MI frame, which comes about within the infill strength being free of the frame stiffness

$$w = \frac{1}{3} dinf$$

c. Equivalent Diagonal Strut - Stafford Smith and Carter Method

Stafford Smith and Carter [11, 13] proposed a theory on a diagonal strut width on basis of the relative stiffness of frame and infill:

$$w = 0.58\left(\frac{1}{H}\right)^{-0.445}(\lambda h \cdot Hinf)^{0.335} dinf\left(\frac{1}{H}\right)^{0.064}$$

$$\lambda h = \left[\frac{Einf \cdot tinf \cdot \sin 2\theta}{4\,Ec \cdot Ic \cdot Hinf}\right]^{0.25}$$

d. Equivalent Diagonal Strut – Mainstone

Mainstone [11, 14] concept is basis on the equivalent diagonal strut by performing tests on frame with bricks infill model. This approach evaluated the MI contribution both to the frame stiffness and to its total strength.

$$w = 0.16\,dinf(\lambda h \cdot Hinf)^{-0.3}$$

e. Equivalent Diagonal Strut - Mainstone And Weeks

References [11, 15], based on test data, proposed an experimental equation for computation of an equivalent diagonal strut width.

$$w = 0.175\,dinf(\lambda h \cdot Hinf)^{-0.4}$$

f. Equivalent Diagonal Strut - Bazan and Meli

Bazan and Meli [11, 16], on the premise of parametric finite-element considers for one-story, one-bay infill outlines, created an experimental equation to determine the equivalent width of a MI frame:

$$w = (0.35 + 0.22\beta)H$$

$$\beta = \frac{Ec \cdot Ac}{Ginf \cdot Ainf}$$

g. Equivalent Diagonal Strut - Liauwand Kwan

Liauw and Kwan [11, 17] proposed the following condition based on test and analytical data:

$$w = \frac{0.95\,Hinf \cdot \cos\theta}{\sqrt{\lambda h \cdot Hinf}}$$

h. Equivalent Diagonal Strut - Paulayand Priestley

Paulay and Priestley [11, 18] explained that a high value of width (w) will result in a stiffer structure, driving to a potentially higher seismic reaction. They proposed a basic equation valuable for structure design as appeared underneath:

$$w = 0.25\,dinf$$

i. Equivalent Diagonal Strut - Hendry

Hendry [11, 19] presented an equation to calculate the width of equivalent strut that can represent the brick work and contribute to resisting horizontal forces within the composite structure:

$$w = 0.5\sqrt{\alpha h^2 + \alpha l^2}$$

$$\alpha h^2 = \frac{\pi}{2}\left[\frac{4\,Ec \cdot Ic \cdot Hinf}{Einf \cdot t \cdot \sin 2\theta}\right]^{0.25}$$

$$\alpha l^2 = \pi\left[\frac{4\,Ec \cdot Ib \cdot Linf}{Einf \cdot t \cdot \sin 2\theta}\right]^{0.25}$$

Notations

w = width of equivalent strut
β = dimensionless parameter
H = Column height
A_c = gross area of the column
H_{inf} = Infill panel height
A_{inf} = gross area of the infill panel on the horizontal plane
E_c = Elastic modulus of frame
G_{inf} = shear modulus of the infill panel
E_{me} = Elastic modulus of infill panel
H = height of the frame
I_{col} = Inertia moment of column
I_b = Moment of Inertia of beam
L_{inf} = Width of infill panel
Ic = Moment of Inertia of column
d_{inf} = Diagonal length of infill panel
A_b = Cross sectional area of beam
t_{inf} = Thickness of infill panel

A_c = Cross sectional area of column
θ = the angle between diagonal length of the infill and the horizontal line
Z = empirical constant
λ_h = Coefficient used to define width of diagonal strut
V_{inf} = Poisson's ratio

IV. CONCLUDING REMARKS

Many times, infill walls are treated as non-structural elements and does not account for strength. But it has been observed from recent earthquake that stiffness of infill wall has significant impact on response of structure. Hence, consideration of infill wall is mandatory requirement and should be modelled in form of diagonal strut. Various method of designing an equivalent diagonal strut has been showcased in this paper. Evaluation of elastic constants (Modulus of Elasticity and Modulus of Rigidity) is a prime requirement for designing equivalent strut. Method for determining the elastic constant is also demonstrated in this paper.

REFERENCES

[1] Dautaj, Arton D., QaniKadiri, and Naser Kabashi. *"Experimental study on the contribution of masonry infill in the behavior of RC frame under seismic loading."* Engineering Structures 165 (2018): 27-37.
[2] Mohamed, W. A. E. *"Parametric study on the effect of masonry infill walls on the seismic resistance of RC buildings."* Journal of Engineering Sciences 40, no. 3 (2012): 701-721.
[3] Kaushik, Hemant B., Durgesh C. Rai, and Sudhir K. Jain. *"Code Approaches to Seismic Design of Masonry-Infilled Reinforced Concrete Frames: A State-of-the-Art Review."* Earthquake Spectra 22, no. 4 (2006): 961-983.
[4] Beall, Christine, and Rochelle Jaffe. *Concrete and masonry databook*. McGraw-Hill Professional Publishing, 2003.
[5]Mondal, Goutam, and Sudhir K. Jain. *"Lateral stiffness of masonry infilled reinforced concrete (RC) frames with central opening."* Earthquake spectra 24, no. 3 (2008): 701-723.
[6]FEMA, Prestandard. *"Commentary for the seismic rehabilitation of buildings."* FEMA-356, Federal Emergency Management Agency, Washington, DC (2000).
[7] Uva, G., D. Raffaele, F. Porco, and A. Fiore. *"On the role of equivalent strut models in the seismic assessment of infilled RC buildings."* Engineering Structures 42 (2012): 83-94.
[8] Kaushik, Hemant B., Durgesh C. Rai, and Sudhir K. Jain. *"Stress-strain characteristics of clay brick masonry under uniaxial compression."* Journal of materials in Civil Engineering 19, no. 9 (2007): 728-739.
[9] Bosiljkov, Vlatko Z., Yuri Z. Totoev, and John M. Nichols. *"Shear modulus and stiffness of brickwork masonry: an experimental perspective."* Structural engineering and mechanics 20, no. 1 (2005): 21-44.
[10]Crisafulli, Francisco J., Athol J. Carr, and Robert Park. *"Analytical modelling of infilled frame structures-a general review."* Bulletin-New Zealand Society for Earthquake Engineering 33, no. 1 (2000): 30-47.
[11] Amalia, AniendhitaRizki, and Data Iranata. *"Comparative study on diagonal equivalent methods of masonry infill panel."* In AIP Conference Proceedings, vol. 1855, no. 1, p. 030011. AIP Publishing, 2017.
[12]Holmes, Malcolm. *"Steel frames with brickwork and concrete infilling."* Proceedings of the Institution of Civil Engineers 19, no. 4 (1961): 473-478.
[13]Stafford Smith, Bryan, and C. Carter. *"A method of analysis for infilled frames."* Proceedings of the institution of civil engineers 44, no. 1 (1969): 31-48.
[14]Mainstone, Rowland J. *"Summary of Paper 7360. On the Stiffness and Strengths of Infilled Frames."* Proceedings of the Institution of Civil Engineers 49, no. 2 (1971): 230.
[15]Mainstone, R. J., and G. A. Weeks. *"27.-The Influence of a Bounding Frame on the Racking Stiffnesses and Strengths of Brick Walls."* In Proceedings of the 2nd International Brick Masonry Conference, Building Research Establishment, Watford, England, pp. 165-171. 1970.
[16]Bazan, Enrique, and Roberto Meli. *"Seismic analysis of structures with masonry walls."* In Proc., 7th World Conf. on Earthquake Engineering, vol. 5, pp. 633-640. Tokyo: International Association of Earthquake Engineering (IAEE), 1980.
[17]Te-Chang, Liauw, and Kwan Kwok-Hung. *"Nonlinear behaviour of non-integral infilled frames."* Computers & structures 18, no. 3 (1984): 551-560.
[18]Paulay, Thomas, and MJ Nigel Priestley. *"Seismic design of reinforced concrete and masonry buildings."* (1992).
[19]Hendry, Arnold W. *Structural masonry*. Scholium International, 1990.