A Critical Study on the Period Formulae of Various Design Codes

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***Abstract*- Various design codes provide us with the empirical formulae for fundamental time period of buildings. Most of these formulae consider building with no masonry infill where as some of the formulae consider the effect of masonry infill. In the present paper critical study has been made on of fundamental time period formulae of buildings. The adequacy of the formulae have been tested by designing buildings of various plans and heights.**

Three building plans have been considered for analysis. RC frame buildings based on these plans were designed using SAP2000 v.16 software. For each the number of stories were varied from 2 to 5. The buildings have been first designed without infill and then infill was struts have been introduced as per equivalent strut models of FEMA-356. Two types of equivalent strut models are considered, namely, concentric and eccentric struts.

I. INTRODUCTION

The fundamental time period of a building is the time period given by the first mode of vibration. This time period is dependent on the lateral stiffness and mass of the building. Consideration of masonry infill in the calculation of time period of building is necessary as these infill walls contribute to a large extent to the lateral stiffness and also the mass of the building. Many codes does not consider the effect of infill, whereas some codes try to give empirical formulae based on certain parameters like base dimension, infill thickness etc.

IS 1893:2002 recommends the following formula for moment resisting RC framed buildings with no infill panels:

$$T_a = 0.075h^{.075} \quad (1)$$

Also IS 1893:2002 recommends the following empirical formula for buildings with masonry infill:

$$T_a = \frac{0.09 \times h}{\sqrt{d}} \quad (2)$$

Where, T_a is the empirical time period of building, h is the height of building from the base and d is the base dimension. Codes like NBC-105 1995; NSR-98 1998; ESCP-1 1983; suggest the same empirical formula for calculating the fundamental time period of a building with masonry infill.

Eurocode-8 recommends the following empirical period formula:

$$T_a = C_t h^{.75} (3)$$

Where, $C_t = \frac{.075}{\sqrt{A_c}}$, $A_c = \sum A_i \left(0.2 + \frac{l_{wi}}{h}\right)^2$, $\backslash\frac{l_{wi}}{h} \leq 0.9$

Where C_t is the correction factor for infill, A_c is the combined effective area of Infill in the first story, A_i is the effective cross+-sectional area of wall *i* in the first story, and l_{wi} is length of the wall *i* in the first story in the considered direction. This formula can be used up to 40 m height.

French code AFPS 90-1990 recommends the following empirical formula:

$$T = 0.06 \times \frac{h}{\sqrt{d}} \times \sqrt{\frac{h}{2d+h}} \quad (4)$$

Costa Rican Code suggests the following formula for masonry infilled frame buildings:

$$T_a = 0.08N \quad (5)$$

Where N is the number of storeys in a building.

Israeli seismic code SI-413 1995 recommends the following formula:

$$T_a = 0.049h^{.75} \quad (6)$$

Also, according to the Israeli code, the natural period calculated by any structural dynamics method shall not be larger than the following:

$$T_a = 0.068h^{.75} \quad (7)$$

Algerian code 1998 specifies that T should be taken as the smaller value between the values given by the following equations:

$$T_a = \frac{0.09 \times h}{\sqrt{d}} \ , \quad T_a = 0.05h^{.75}$$

The Empirical formulae give by the different codes have been compared by drawing the time period vs. height curve for each formula, considering fixed base dimension of 20 m (Fig. 1)

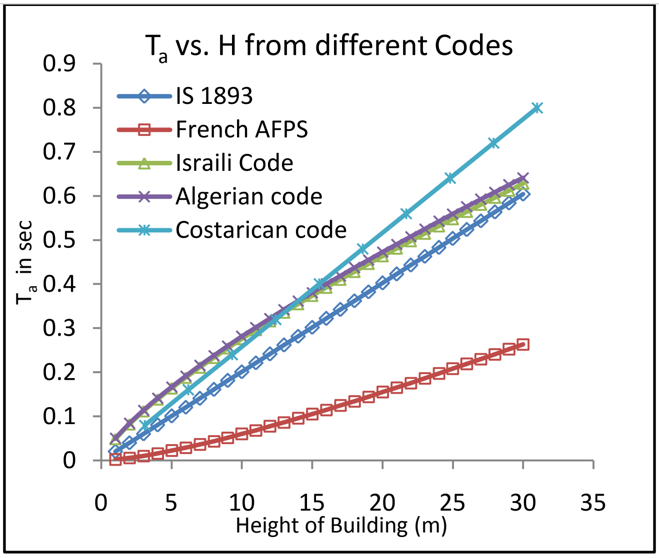

Fig. 1: Comparison of T_a vs. H curves for empirical formulae of different Codes.

II. LITERATURE REVIEW

Kaushik*et al.* (2006) presented a paper that concluded there is no single code that contains all the relevant information required for the seismic design of masonry infilled buildings. Most of the codes agree that masonry infilled RC frame buildings require special treatment, and they specify clauses on several important issues related to such buildings. However, the codes differ greatly in specifications of the individual clauses. George and Kanapitsas (2012) had presented a paper on evaluation of fundamental period of low-rise and mid-rise reinforced concrete buildings. They recommended an empirical formula for the estimation of the fundamental period of RC structures. Angel (2005) has submitted a thesis on Behaviour of concrete reinforced frames with masonry infill. Patel *et al.* (2011) presented a paper on effect of number of stories to natural time period of building. Their conclusion was, as the number of storeys increases natural time period increases although the height of the building remains same. Das and Murty (2004) presented a paper on Brick masonry infills in seismic design of RC framed buildings in which they discussed the equivalent braced frame method to consider the effect of infill in RC buildings. Uva*et al.* (2012) presented a paper on the role of equivalent strut models in the seismic assessment of infilled RC buildings where they discussed different ways of modelling infill panels. They also considered a model using multiple struts in order to model the formation of brittle shear mechanisms at the nodes of the frames.Fiore *et al.* (2012) proposed that the simulation of the complex behaviour of infill walls can be achieved by modelling an infill panel, for each direction and for each sign of the seismic action, through two equivalent struts whose position is expressed in function of the aspect ratio of the panel.

III. EQUIVALENT STRUT MODELS FOR INFILL PANELS

Two types of equivalent strut models specified in FEMA-356. In first model compression struts representing infill stiffness of solid infill panels was placed concentrically across the diagonals of the frame, effectively forming a concentrically braced frame system. In the other model, compression struts was placed eccentrically within the frames only at the columns. The thickness of the infill struts is given by the following formula:

$$A = 0.175(\lambda_1 h_{col})^{-0.4} r_{inf} \quad (9)$$

Where,

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

$h_{col}$is the column height between centre lines of beams, in.
$h_{inf}$is the height of infill panel, in.
$E_{fe}$is the expected modulus of elasticity of frame material, ksi
$E_{me}$is the expected modulus of elasticity of infill material, ksi
$I_{col}$is the moment of inertia of column, in^4.
$L_{inf}$is the length of infill panel, in.
$r_{inf}$is the diagonal length of infill panel, in.
$t_{inf}$is the thickness of infill panel and equivalent strut
$\theta$is the angle whose tangent is the infill height to length aspect ratio, radians
$\lambda_1$is the coefficient used to determine equivalent width of infill struts.

IV. RESULTS FROM THE PRESENT STUDY

The fundamental time period calculated from the analytical models are compared by graphical representation:

1. *Building Plan 1.*

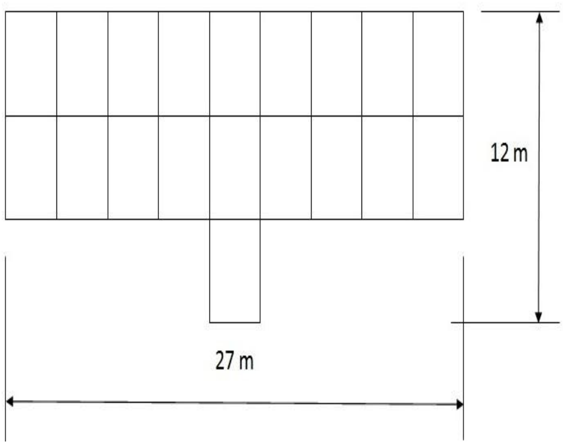

Fig. 2: Building Plan 1

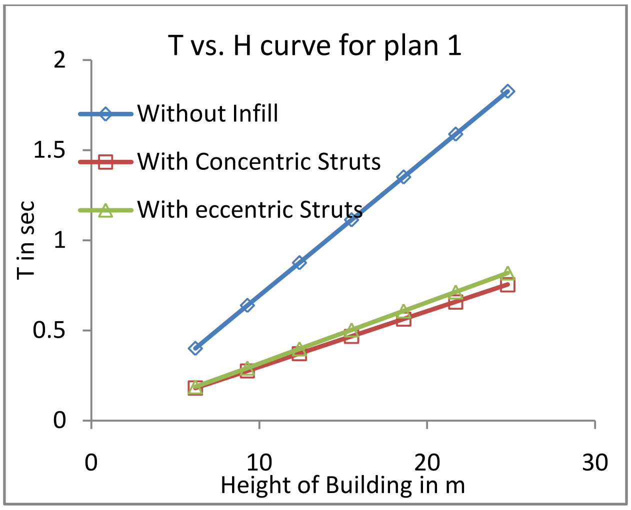

Fig. 3: T vs. H curve for Building Plan 1 with concentric and eccentric strut models.

2. *Building Plan 2:*

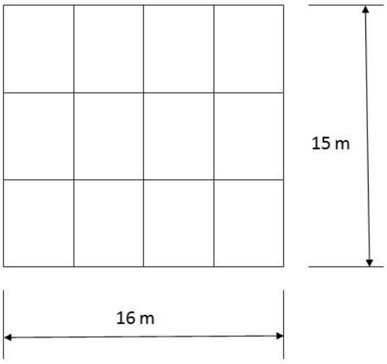

Fig. 4: Building Plan 2

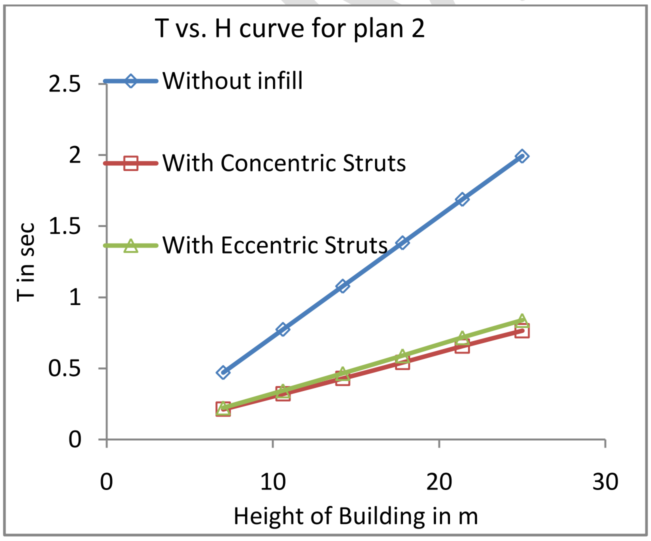

Fig. 5: T vs. H curve for Building Plan 2 with concentric and eccentric strut models.

3. *Building Plan 3:*

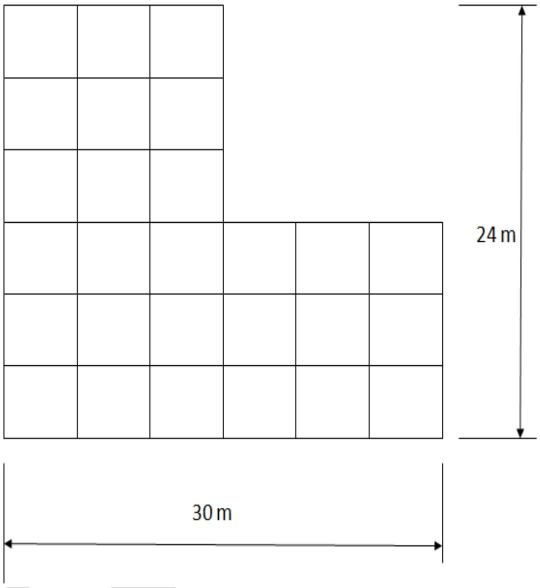

Fig. 6: Building Plan 3

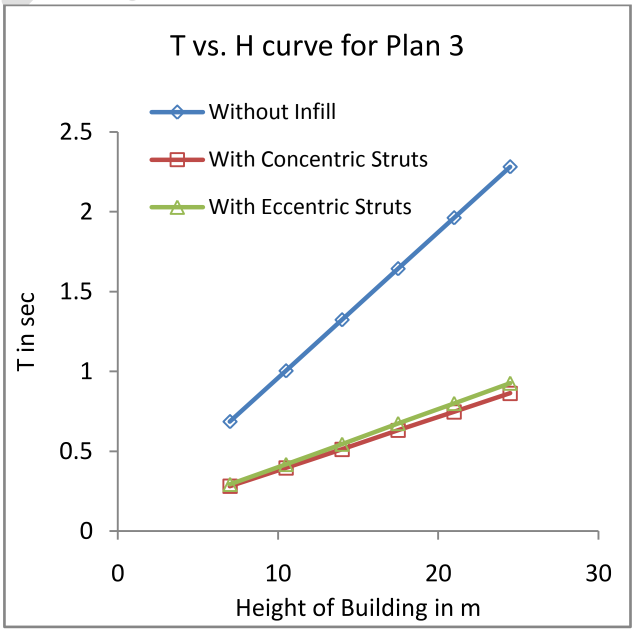

Fig. 7: T vs. H curve for Building Plan 3 with concentric and eccentric strut models.

The average of time periods of all the building models with infill struts were calculated and they were compared with the time period curve drawn using the empirical formula given in IS-1893-2002 for infilled frame. Base dimension was taken as 20 m.

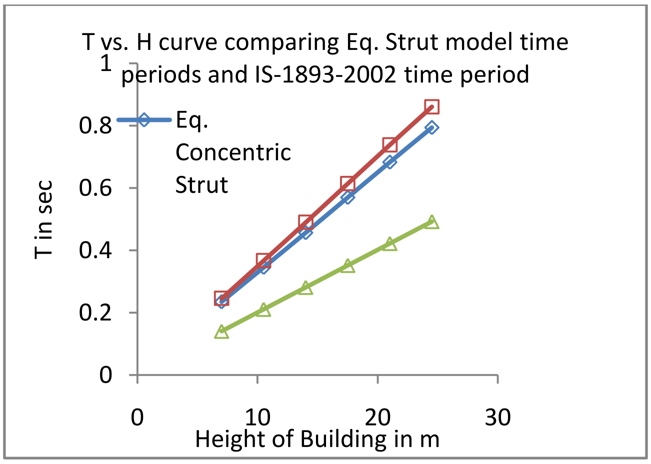

Fig. 8: T vs. H curve for Equivalent concentric Strut model, Equivalent eccentric Strut model and IS-1893 empirical formula for infill

V. CONCLUSIONS

1. The empirical formulae for fundamental time period of a building given by various codes has similar approach but the periods diverge with increase of height of building.
2. Infill panels affect greatly the time period of a building as it imparts a great lateral stiffness to RC frame building.
3. The time period calculated after applying equivalent struts for infill is almost 60% less than the time period of the same building when infill effect was neglected.
4. The equivalent Eccentric Strut model gives more time period than the Equivalent Concentric Strut model although the difference is very less.
5. The IS codal period formulae seems to be conservative as the time periods of buildings with strut models are higher than the codal period values.

REFERENCES

[1]. Asteris P.G., Antoniou S.T.,Sophianopoulos D.S. and Chrysostomou C.Z.(2011) “Mathematical Macromodeling of Infilled Frames: State of the Art”, *Journal of Structural Engineering , ASCE*, v. 137: pp.1508-1517.

[2]. Das Diptesh and Murty C.V.R (2004), “Brick masonry infills in seismic design of RC framed buildings”, *The Indian Concrete Journal*, July-2004: pp.39-44.

[3]. Eurocode 8, 1996. Design Provisions for Earthquake Resistance of Structures—Part 1–3: General Rules—Specific Rules for Various Materials and Elements, DD ENV 1998–1-3: European Committee of Standardization, Brussels, Belgium.

[4]. FEMA 356(2000), “Prestandard and Commentary for the Seismic Rehabilitation of Buildings.” Prepared by the American Society of Civil Engineers for the Federal Emergency Management Agency. FEMA,Washington, DC.

[5]. Fiore Alessandra, Netti Adriana and Monaco Pietro (2012),“The influence of masonry infill on the seismic behaviour of RC frame buildings”,*Engineering Structures* 44 pp.133–145.

[6]. Hatzigeorgiou George D. and Kanapitsas George (2013), “Evaluation of fundamental period of low-rise and mid-rise reinforced concrete buildings”, *Earthquake Engineering Structural Dynamics*, 2013; 42:pp.1599–1616.

[7]. IS-1893-2002, Indian Standard Criteria for Earthquake Resistant Design of Structures—Part 1: General Provisions and Buildings (Fifth Revision), Bureau of Indian Standards, New Delhi, India.

[8]. KaushikHemant B., RaiDurgesh C. And Jain Sudhir K.(November 2006) “Code Approaches to Seismic Design of Masonry-Infilled Reinforced Concrete Frames: A State-of-the-Art Review”, *Earthquake Spectra*, Volume 22, no.4:pp.961-983, Earthquake Engineering Research Institute.

[9]. NBC-201,1995. Nepal National Building Code for Mandatory Rules of Thumb for Reinforced Concrete Buildings with Masonry Infill, Ministry of Housing and Physical Planning, Department of Buildings, Kathmandu, Nepal.

[10]. Patel Sudhir K., Desai A.N. and Patel V.B. (2011), “Effect of Number of Storeys to Natural Time Period of Building”, National Conference on Recent Trends in Engineering & Technology, 13-14 May,2011.

[11]. Richard Angel (1994), “Behaviour of Concrete infill frames with masonry infills”,A doctoral thesis at the University of Illinois.

[12]. Uva G., Raffaele D., Porco F. And Fiore A.(2012), “On the role of equivalent strut models in the seismic assessment of infilled RC buildings”, *Engineering Structures* 42 (2012) :pp.83–94.