EVALUATION OF FNP FOR BARE FRAMED RC STRUCTURE

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Abstract – The Fundamental Natural Period (FNP) is a dynamic property of the building. It characterises the behaviour and performance of the structure to external forces. The FNP depends on the strength, stiffness and mass of the structure and it is influenced by many factors such as structure regularity, number of bays, number of storeys, infill panel properties, section dimensions and extent of concrete cracking. Expressions for estimating the FNP provided by seismic codes across the world consider only height or type of the building. The effect of mass, strength and stiffness of the infill walls are not considered in any of the seismic codes. The prime importance of the paper is to evaluate a new empirical formula by method of least squares (MLS), considering mass, modulus of elasticity, moment of inertia and average height of the building. Modelling and analysis are carried out by SAP v14.2. Gravity and seismic analysis are carried out as per IS 456: 2000 and IS 1893 (Part 1): 2002 code provisions respectively. All the models are bare framed Ordinary Moment Resisting Frame (OMRF) buildings. The FNP results by MLS are compared with different country codes. The authors propose new expression for calculating FNP by MLS which are accurate than the FNPs calculated from empirical formulae given in seismic codes across the world.

***Key words**: Bare frame, Natural period, OMRF, Seismic code.*

1. INTRODUCTION

The seismic force on the structure arises from the vibration of the mass of the structure. The determination of the natural period of vibration of a reinforced concrete structure is an essential procedure in earthquake design and assessment since it is the main property of the structure that determines the elastic demand and, indirectly, the required inelastic performance in static procedures. The natural period is an important parameter in the computation of the design base shear and lateral forces due to earthquakes. Seismic codes across the world provide expressions which depend on basic parameters such as building height or number of stories. Building periods predicted by these expressions are widely used in practice although it has been observed that there is scope for further improvement in these equations since the height alone is inadequate to explain period variability. The study reported in this paper is carried out to compare the fundamental natural period obtained by analysis of reinforced cement concrete (RCC) buildings by SAP-v14.2 considering various configuration parameter, with the values of fundamental natural period obtained from empirical formulae given in various seismic codes across the world. A new expression is derived on the basis of above comparison of fundamental natural period for RCC bare frame buildings, which is near to the fundamental natural period obtained from the SAP-v14.2.

2. OBJECTIVE AND SCOPE

The main objective of this paper is to evaluate the empirical equations provided in current building codes for the calculation of fundamental natural periods of buildings and recommend possible improvements i.e. compare the fundamental natural period obtained by Method of Least Squares and empirical formula given in IS 1893 (Part 1): 2002[1] for various RCC framed buildings configurations.

The scope is limited to reinforced concrete building which includes moment-resistant frame building and the formula evaluated for fundamental natural period is applicable for following different building configurations. The following outlines the scope:

- The buildings analysed are bare framed ordinary moment resisting (OMRF) RCC frames.
- The buildings are regular in plan and symmetric.
- The buildings are designed for gravity loads as per IS: 875-1987 and load combination as per IS 456:2000.

- Building up to 10 storeys and ten bays are considered.

3. METHODOLOGY FOR SEISMIC ANALYSIS

The slabs are given membrane type behaviour to provide in plane stiffness. The slab sections are modelled as rigid diaphragms so that the masses of the floor are automatically lumped at their centre of gravity.

Beams and columns are modelled as three dimensional frame elements with centreline dimensions. These are squares and rectangular in shape. Beam-column joints are assumed to be rigid; hence the rigid zone factor as one is assigned to obtain the shear forces and moments at the faces of the supports and at points within the clear length of the element.

Foundation is modelled as isolated footing in fixed condition at the base, without considering the soil-structure interaction.

Fig.1 and Fig.2 shows the building plan and 3-D model respectively.

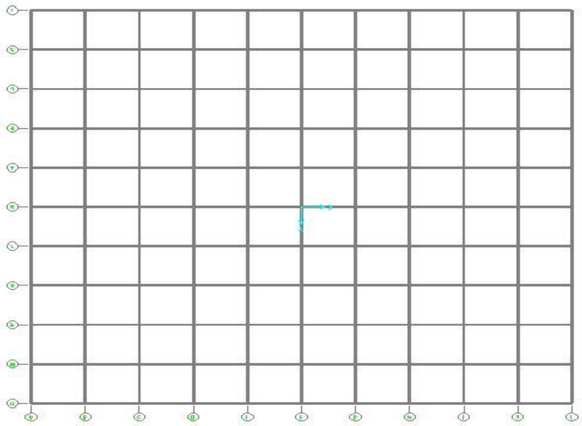

Fig.1: Plan of the Building

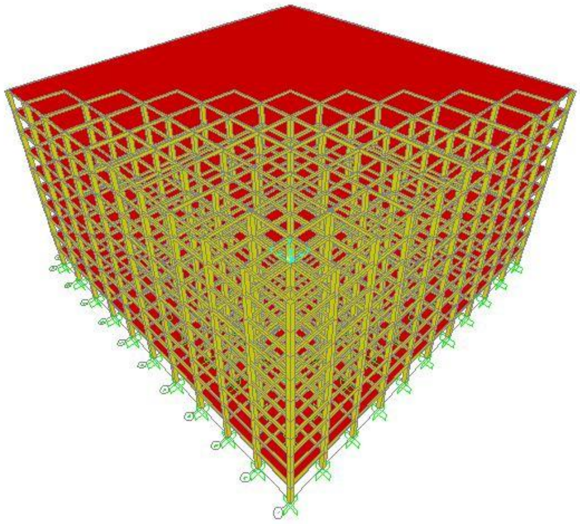

Fig.2: 3-D Model of Bare Frame Building

Table 1 and Table 2 shows Building description and Material properties respectively.

Table 1: Building Description

No of bays in X direction	10
No of bays in Y direction	10
Spacing along X direction	6 m
Spacing along Y direction	6 m
No of storeys	G+9
Storey height	3.5 m
Parapet height	1 m

Table 2: Material Properties

Characteristic strength of concrete, f_{ck}	25 Mpa
Characteristic strength of steel, f_y	415 Mpa
Modulus of elasticity of concrete, E_c	25000 Mpa
Density of concrete	25 kN/m^2
Poisson's ratio of concrete	0.3
Modulus of elasticity of steel, E_s	200000 Mpa

Equivalent Static Method

The total design lateral force or design base shear along any principal direction is given in terms of design horizontal seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the zone factor of the site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental period of the structure.

Response Spectrum Method

The response spectrum represents an interaction between ground acceleration and the structural system, by an envelope of several different ground motion records. For the purpose of the seismic analysis the design spectrum given in Fig 2 of IS 1893 (Part 1): 2002[1] is used. This spectrum is based on strong motion records of eight Indian earthquakes.

4. RESULT AND DISCUSSION

Building codes provide empirical formulae for estimating the fundamental period. These formulas are developed on the basis of observed periods of real buildings during ground motion and the period is generally expressed as a function of building height. It does not consider the variation in other factors like stiffness, storey height, loading etc. Building periods predicted by these empirical equations are widely used in practice. It has been pointed out by many authors that there is further scope for improvement in these equations. Building design codes generally impose some upper limit on the magnitude of the natural period. Determined from a rational numeral analysis the period is longer than that predicted by empirical code equations since derived on the basis of measuring the period of real buildings during an earthquake. In this study, the fundamental periods of vibration of a series of regular RC framed buildings are studied using 3D FE modeling and modal Eigen value analysis using SAP.

Method of Least Squares (MLS): The expression derived by modelling different models varying from one storey one bay to ten storey ten bays have been produced by fitting curves through Method of Least Squares on the buildings periods.

$$MLS = (0.0934+0.362n-0.027n^2+ \quad 0.0016n^3) \times \left(\frac{Mh^2}{EI}\right)^{(0.005\,+\,0.018\,n\,-\,0.023\,n^2\,+\,0.00018\,n^3)}$$

Where,

M is mass of the structure.

h is average height of the building.

E is modulus of elasticity of concrete

I is moment of Inertia of column.

N is number of Storey.

The above formula is evaluated on one hundred models from one bay to ten bays and one storey to ten storeys with square columns.

Empirical formulas of some of the countries are listed below.

IS 1893 (Part 1): 2002[1]: The approximate FNP of vibration (Ta) in seconds of a moment-resisting RCC framed building without brick infill panels estimated by the empirical expression:

$$T = 0.075\, h^{0.75}$$

Where, h is the height of building in meters.

IBC 2000 Edition**:** The building period can be estimated using the empirical formula:

$$Ta = C_t\, h_n^{3/4}$$

Where, Ct varies from 0.020 to 0.035 depending on the type of resting system h_n is the height of the building in feet.

An alternate formula is provided for steel and concrete moment frame buildings 12 storeys or less in height and with storey heights 10 feet or greater:

$$Ta = 0.1\, N$$

Where, N is the number of storeys.

Building Standard Law in JAPAN 1981 (BSLJ): In BSLJ the fundamental natural period of the building, T, shall be determined by expression:

$$T = H\,(0.02 + 0.01\,\alpha)$$

Where, H is height of building in meters.α is the ratio of total height of steel construction to height of building. (α = 0 for concrete & α = 1 for steel).

Costa Rican Code (1986): The Costa Rican code in the year 1986 gave the expression for fundamental natural period of masonry infill reinforced concrete frame building as

$$Ta = 0.08\, N$$

Where, N = number of storeys

A flat 20% reduction from that of bare frame (Ta=0.1N) is specified to account for increased stiffness of frame due to masonry infill.

Algerian Code (1988): According to Algerian code the expression for fundamental natural period is

$$T = 0.05\, h^{0.75}$$

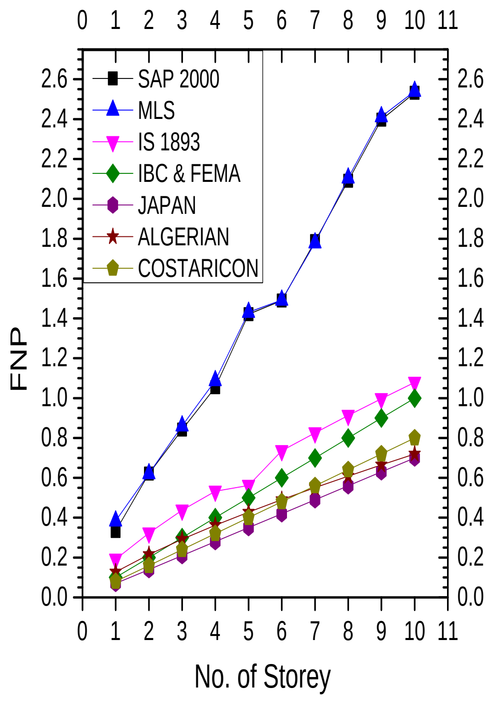

Fig.3: Variation of FNP for one bay

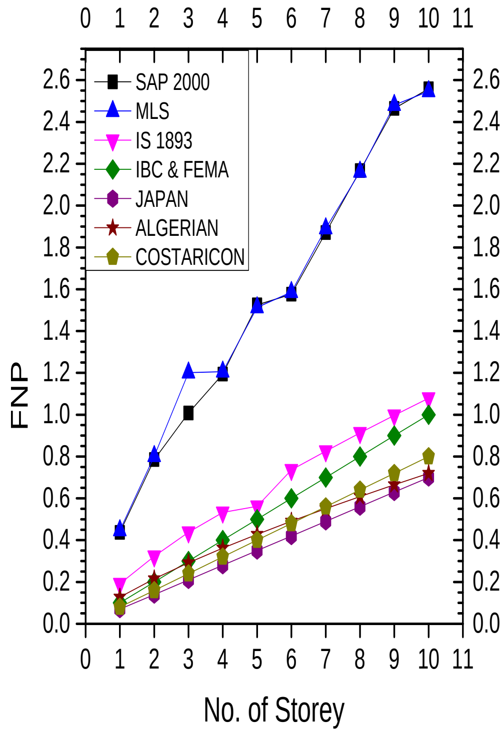

Fig.5: Variation of FNP for five bay

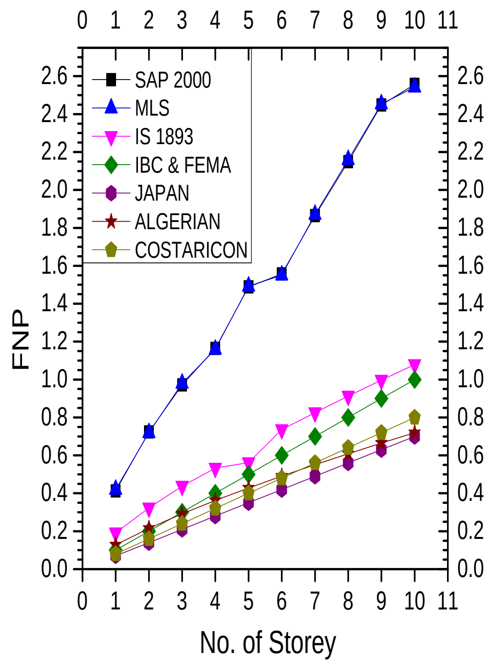

Fig.4: Variation of FNP for three bay

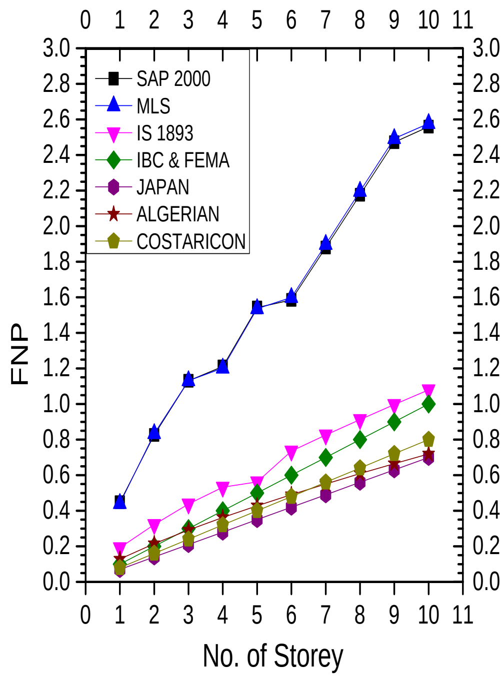

Fig.6: Variation of FNP for seven bay

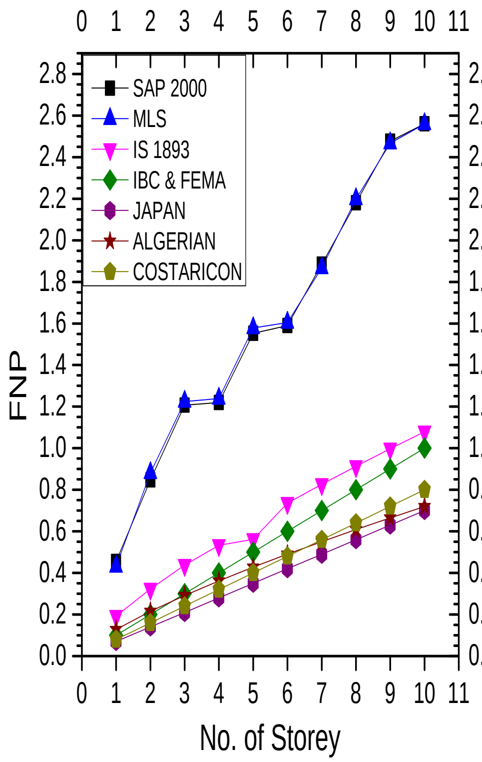

Fig.7: Variation of FNP for nine bay

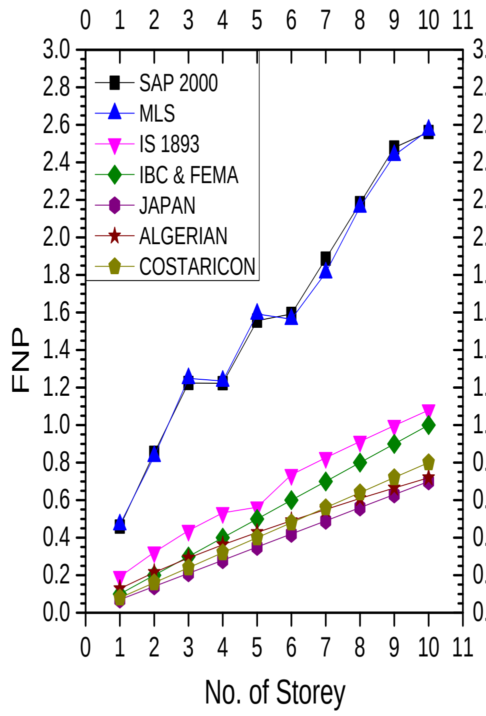

Fig.8: Variation of FNP for ten bay

By keeping bay constant and varying number of storey, from Fig. 3 to Fig. 6 it is observed that the graph varies linearly as the number of storey increases. FNP values of MLS are similar to SAP values. FNP obtained from earthquake codes across the world are shorter than SAP results by an error of IS 1893 (Part I): 2002 (60%-90%). IBC or FEMA (69%-76%). Japan code (79%-83%). Algerian code (71%-77%). Costaricon code (52%-63%).

5. CONCLUSIONS

The findings of the study emphasizes the fact that code underestimate the value of fundamental natural time period of the buildings as it depends only on the height of the building whereas the time period depends on various other parameters like span length, no. of stories, mass of the structure, stiffness of the members etc.

From the results discussed with respect to the building models considered leads to the following conclusions:

- Derived equations for fundamental natural periods from Method of Least Squares are similar to SAP 2000 v.14.2.
- Fundamental natural periods obtained by Method of Least Squares are accurate than the fundamental natural periods calculated from the empirical expressions given in IS 1893 (Part I): 2002 and other country codes in this paper.
- The expressions derived are applicable only to symmetrical and regular reinforced cement concrete framed buildings.
- The base shear calculated using the Method of Least Squares are lesser compared to those by code expressions leading to economical design of buildings.

The expressions to calculate FNP mentioned in various seismic codes in India and across the world may be revised.

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