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EVALUATION OF FUNDAMENTAL NATURAL PERIOD FOR SYMMETRIC MULTISTOREY BARE FRAMED BUILDINGS

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ABSTRACT

The seismic design codes across the world are subject of intensive research work. The prime importance of this work is evaluation of formula for fundamental natural period and compare the periods with empirical formulae given in seismic codes across the world. The analysis is carried using SAP v14.2 for gravity and seismic loading. Gravity analysis is carried out using IS 456: 2000 code provisions. Seismic analysis is carried out as per IS 1893 (Part 1): 2002 procedures for multistoryed ordinary moment resisting frame (OMRF) buildings. All the models are constructed in seismic zone IV. The parameters considered are breadth, width, height, plan regularity, considering different materials for the building. The authors conclude that, fundamental natural periods obtained by Method of Least Squares are more accurate than the fundamental natural periods calculated from the empirical expression given in seismic codes of other countries considered in the study.

Keywords: Fundamental Natural Period, Medium Soil, Method of Least Squares, OMRF.

I. INTRODUCTION

The exact forces that will occur during the life of the structure cannot be known. The seismic force on the structure arises from the vibration of the mass of the structure. The fundamental natural period (FNP) appears in the equation specified in building codes to calculate the design base shear and lateral forces. It is, therefore, important that careful consideration be given to calculate the fundamental natural period of a building in its planning and design stages. 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, 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.

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II. 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 analyzed are 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[12] and load combination as per IS 456:2000[7].

III. 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.
Ten story and ten bays building has considered for the study. Fig.1 and Fig.2 shows the building plan and 3-D model respectively.

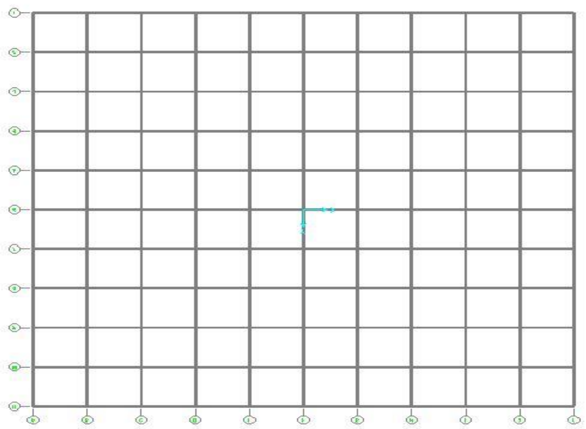

Fig.1: Plan of the Building

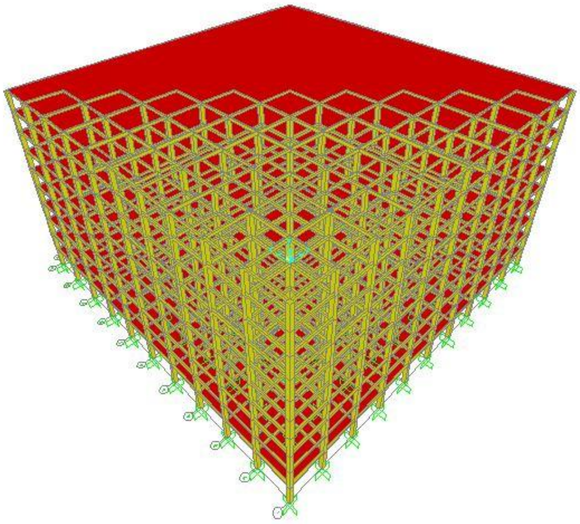

Fig.2: 3-D Model of Bare Frame Building

Spacing in X and Y direction is 6m. The storey height is 3.5m. Characteristic strength of concrete, f_{ck} is25 Mpa. Characteristic strength of steel, $f_y$is 415 Mpa. Modulus of elasticity of concrete, E_c is 25000 Mpa. Density of concrete is 25 kN/m^3. Poisson's ratio of concrete is 0.3. Modulus of elasticity of steel, E_s is 200000 Mpa. Dead Loads are considered as per IS 875 (Part I): 1987[11]. Live loads are considered according to IS 875 (Part II): 1987[12]. In the seismic weight calculations, only 25% of the live load is considered. The building is modelled to represent all existing components that influence the mass, strength, stiffness, and deformability of the structure.

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.

IV. 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):

MLS= (0.2047 + 0.2371 N) x $\left(\frac{Mh^2}{EI}\right)^{(-0.0188 + 0.0413\, n - 0.0135\, n^2 + 0.0017\, n^3 - 0.00007\, n^4)}$

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.

Indian Standard Code 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.

International Building Code, IBC 2000 Edition[2]**:** 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.

ISRAELI SEISMIC CODE (SI-413 1995**)** [3]**:** According to Israeli seismic code (SI-413 1995) the expression of fundamental natural period is

$$T = 0.49\, h^{0.75}$$

In addition Israeli seismic code recommends that fundamental natural period calculated by structural dynamic method shall not be greater than

$$T = 0.068\, h^{0.75}$$

This ensures that the seismic design base shear is not less than 80% of the base shear determined by the first formula given by Israeli code.

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Iranian Code for Seismic Resistance Design of Buildings (ICS)[4]:In ICS, T, depending on the characteristics of the building, is determined with Equation

$$T = 0.08\ H^{3/4} \text{ (concrete)}$$

$$T = 0.07\ H^{3/4} \text{ (steel)}$$

$$T = 0.05\ H^{3/4} \text{ (other buildings)}$$

Where H is the height of the building.

Building Standard Law in JAPAN 1981 (BSLJ)[5]: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).

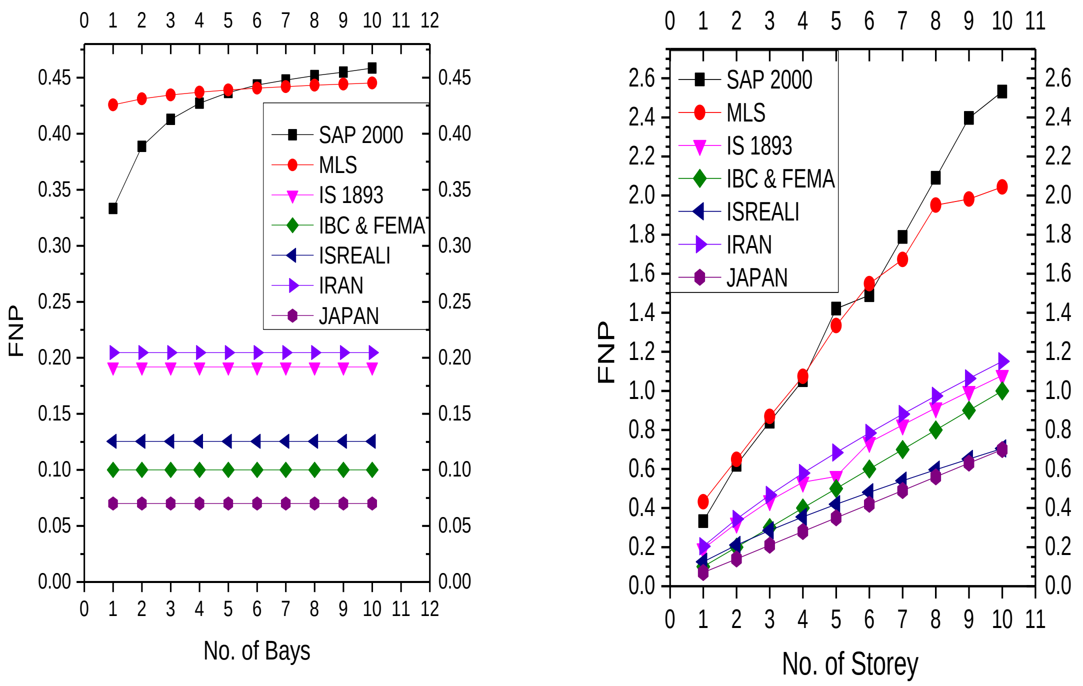

Fig 3 a) Variation of FNP for One Storey **b) variation of FNP for One Bay**

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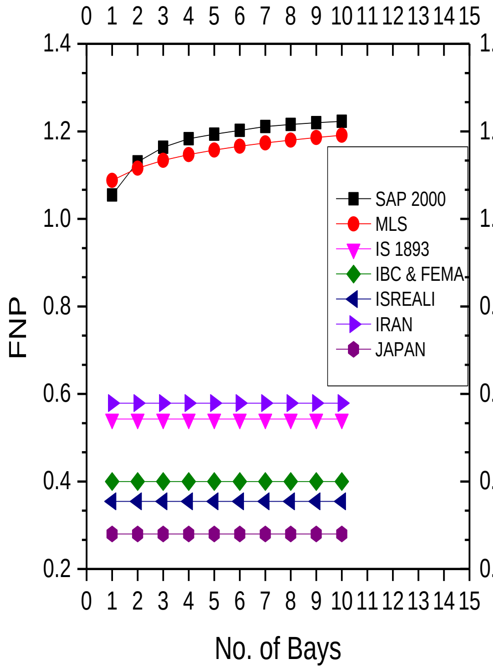


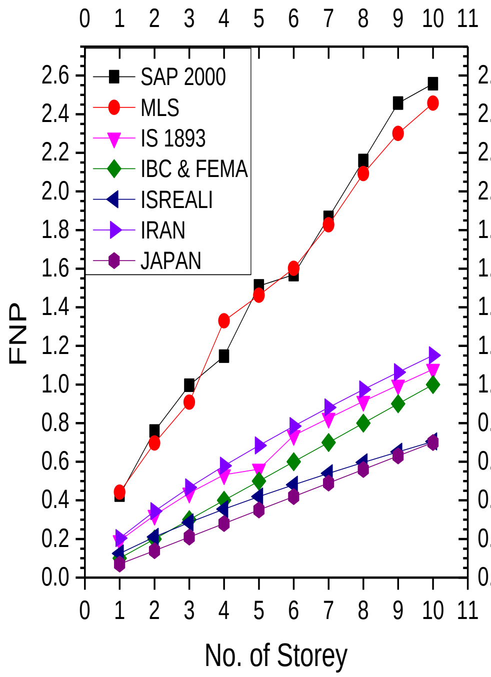
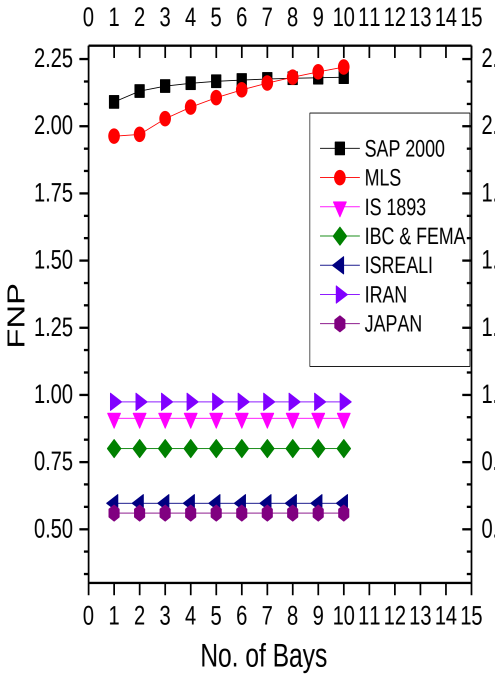


Fig 4 a) Variation of FNP for four storey **b) Variation of FNP for four bay**



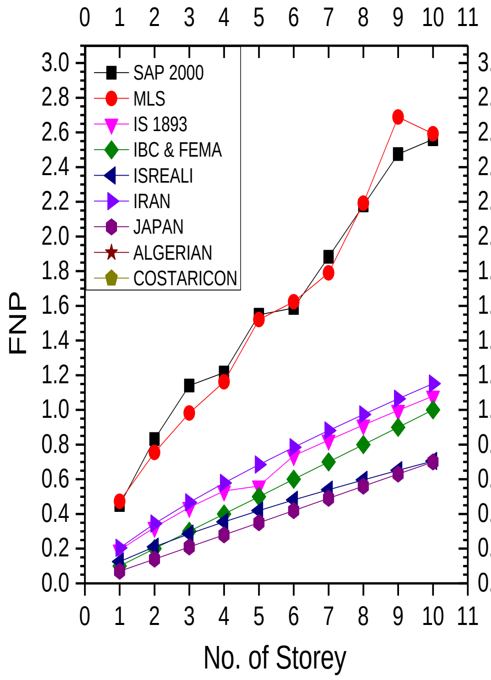


Fig 5 a) Variation of FNP for eight storey **b) Variation of FNP for eight bay**

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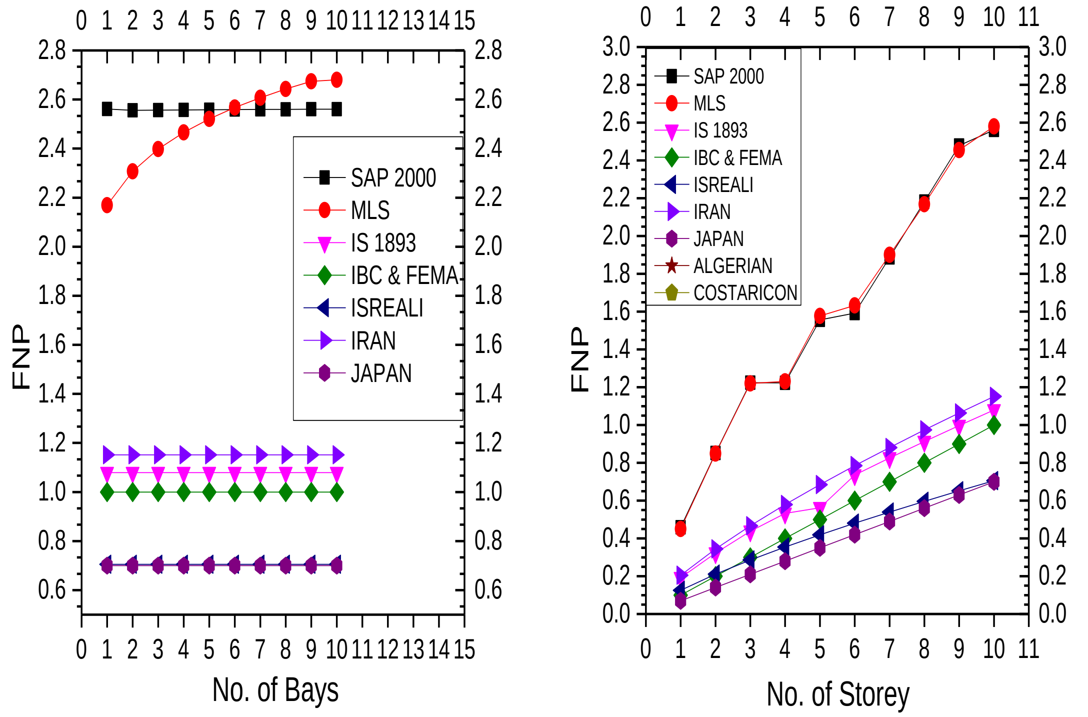

Fig 6 a) Variation of FNP for ten storey b) Variation of FNP for ten bay

From 3 to 6 it is observed that the values for fundamental natural period obtained from MLS and SAP values are nearly same, while the values for IS 1893(Part 1): 2002, IBC 2000, ISREALI, IRAN, JAPAN are of the monotonically increasing curve. This indicates that the result obtained by Method of Least Squares is more close to that of EVA. The expression obtained by MLS analysis give fundamental natural period value with an error of 5%-10% till fourth storey whereas the error is reduced as the number of storey increases and fundamental natural period of the building is almost the same as that of EVA. The graph varies linearly as the number of storey increases whereas it varies parabolic with respect to number of bays. Expression for fundamental natural period given in IBC 2000 gives shorter periods compared to that of EVA with an error of 70%-80%. The error given by IS 1893(Part 1): 2002 varies from 60%-70% compared to EVA. The error given by ISREALI code varies from 65%-75% compared to EVA. The error given by IRAN code varies from 40%-60%. The error given by JAPAN code varies from 72%-85%.

V. CONCLUSIONS

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

- 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.
- Derived equations for fundamental natural periods from Method of Least Squares are similar to SAP 2000 v.14.2.

- The base shear calculated using the Method of Least Squares are lesser compared to those by code expressions leading to economical design of buildings.
- These formulas are applicable to any type of soil profile.

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

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