

Comparison of codal provisions suggested by various countries

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ABSTRACT: The present paper compares the seismic provisions for multistoreyed framed buildings of various countries. The provisions compared are Building Standard law of Japan (BSLJ) 1981, Criteria for Earthquake Resistant Design of Structures IS:1893-1984 (IS), National Building Code of Canada 1985 (NBC), New Zealand Standard (NZS) 4203:1984 and Uniform Building Code-1988 (UBC). In general the provisions of five countries can be related to one another in terms of component. The study presents and compares the distribution of seismic shear along the height of building according to these five codes and the distribution pattern obtained by dynamic analysis.

BASE SHEAR

All the five codes adopt the pseudostatic method of analysis. The seismic base shear assumed to act at base is given by equation (1). Table 1 compares various terms used in different codes for calculating the base shear.

$$V_B = C_B W \quad (1)$$

where, W = Total weight of building

$$C_B = \text{Base Shear Coefficient} = \frac{\beta I K C \alpha_0}{\beta I K C \alpha_0}$$

where, α_0 - is Seismic Hazard coefficient; C is spectral content coefficient; I is important factor; β is soil Foundation Factor and K is Structural Behaviour factor.

Seismic Hazard Coefficient

In IS Code, these coefficients are given on the basis of expected intensity of the earthquake in different zones. In BSLJ for severe earthquake it is five times the moderate earthquake. NZS does not give any direct numerical coefficient and seismic hazard coefficient depends on time period of structure and type of soil. NBCC and UBC gives coefficient for different zones.

Spectral Content

In IS, BSLJ and UBC it depends on time period and given as a separate factor while in NZS it also depends on period but is combined with basic seismic coefficient.

Structural Behaviour Coefficient

This coefficient considers the ductile performance of buildings and for five codes values for most ductile structure and usual structure are listed in Table 2. The ratio of this coefficient for most ductile building to usual building is about 0.3 to 0.6 in all the codes. Ratio is maximum in IS and lowest in NZS.

Importance Factor

BSLJ does not include this factor therefore minimum standard is applicable to all the buildings. In all other codes the factors vary from 1 to 1.5-1.6 for ordinary to important buildings.

Soil Foundation Factor

Factor is defined on the basis of type of soil in IS, BSLJ, NBCC and UBC, while NZS does not explicitly stipulate soil or foundation factor but it is included in the basic seismic coefficient itself.

Table 1. Terms used in different codes for seismic loads.

Terms	Equivalent term in five standards				
	IS	BSIJ	NZS	NBC	UBC
C_B	$\beta I K C \alpha_o$	$Z R_t C_o$ (for moderate EQ)	CSMR	vSKIF	ZIC/R _w
α_o	α_o (Basic seismic coefficient)	$Z C_o$ (Z=zoning coefficient for 3 zones and C_o =standard shear coefficient)	C (Basic seismic coeff. for 3 zones which includes the effect of spectral content and base flexibility depending on time period and soil type)	(Zonal velocity ratio)	Z (seismic zone factor)
C	C (Flexibility coefficient given as a function of time period)	R_t (Design spectral coefficient) which depends upon fundamental time period and soil profile type)	C (Defined as above)	S (Seismic response factor depending on time period.	C (Numerical coefficient which depends on soil Characteristics and time period.
K	K (Performance factor given for structural framing system depending on its ductility and energy absorption capacity)	D (Structural coefficient given for elastic or inelastic response)	SM S (Structural type factor depending on force resisting element M-Structural material factor).	K (Numerical coefficient for structural behaviour which depends on damping, ductility and energy absorption capacity)	R _w (Structural system factor)
I	I (Importance factor)	----	R (Risk factor)	I (Importance factor)	I (Importance factor)
β	β (Soil foundation factor which depends type of soil foundation system)	R_t (Defined as above)	C (Defined as above)	F (Soil-foundation factor)	S (site-coefficient)

Table 2. Structural behaviour coefficients

Code	Coefficient	Most ductile	Usual structure
IS	K	1	1.6
BSIJ	D	0.30	0.55
NZS	S	0.8	1.6
NBCC	K	0.7	1.3
UBC	R _w	7	12

Therefore almost all the countries adopt a similar definition for the coefficients. However, direct comparison of seismic forces is not possible because there are great differences in the seismic intensity from country to country.

FOUNDAMENTAL PERIOD ESTIMATION

The empirical formulae suggested by five codes, to estimate the natural periods of buildings are tabulated in Table 3. All five codes permit the period T to be calculated by more refined method.

Table 3. Summary of period estimates

Code	Formula suggested
IS	$T = 0.1n$ and $0.09H/\sqrt{D}$
BSIJ	$T = 0.02 H$
NZS	$T = 0.063 \sqrt{\Delta}$
NBCC	$T = 0.1n$ and $0.09H/\sqrt{D}$
UBC	$T = 0.030 H^{3/4}$

n is number of storey, H is height of building, D is base width along the direction of earthquake motion and Δ is deflection at the top.

DISTRIBUTION OF BASE SHEAR

The methods for working out lateral forces at different levels suggested by various code are given in Table 4. Except IS and BSIJ all code recommends lumping of some lateral load at top on the basis of aspect ratio or time period of the building.

Table 4. Details of shear distribution.

Code	Shear distribution
IS	$Q_i = V_B \frac{W_i h_i^2}{\sum_{i=1}^n W_i h_i^2}$
BSIJ	$Q_i = C_b A_i \sum_{i=i+1}^n W_i$ $A_i = 1 + \left(\frac{1}{\sqrt{\alpha_i}} - \alpha_i \right) \frac{2T}{1+3T}$ $\alpha_{i,i} = \frac{\sum_{i=i+1}^n W_i}{\sum_{i=1}^n W_i}$

NZS For $\frac{h}{D} < 3$

$$Q_i = V_B \frac{W_i h_i}{\sum_{i=1}^n W_i h_i}$$

For $\frac{h}{D} \geq 3$

$$Q_n = 0.1V_B + 0.9V_B \frac{W_n h_n}{\sum_{i=1}^n W_i h_i}$$

$$Q_i = 0.9 V_B \frac{W_i h_i}{\sum_{i=1}^n W_i h_i}$$

NBCC
$$Q_n = F_t + (V_B - F_t) \frac{W_n h_n}{\sum_{i=1}^n W_i h_i}$$

$$Q_i = (V_B - F_t) \frac{W_i h_i}{\sum_{i=1}^n W_i h_i}$$

$$F_t = 0.004 V_B \left\{ \frac{h}{D} \right\}^2 \text{ but } \not\geq 0.15 V_B$$

$$F_t = 0 \text{ if } \left\{ \frac{h}{D} \right\} < 3$$

UBC
$$Q_n = F_t + (V_B - F_t) \frac{W_n h_n}{\sum_{i=1}^n W_i h_i}$$

$$Q_i = (V_B - F_t) \frac{W_i h_i}{\sum_{i=1}^n W_i h_i}$$

$$F_t = 0.07 TV_B \text{ but } F_t \not\geq 0.25 V_B$$

$$F_t = 0 \text{ for } T \leq 0.7$$

Q_i is lateral force at ith floor.

V_B is base shear.

W_i is lumped weight at ith floor.

h_i is height of ith floor from ground.

C_B is base shear coefficient.
 h_n is height of nth floor
 n is number of storeys
 D is base width along the direction of earthquake motion.
 Q_n is lateral force at top floor.
 T^n is time period.

NUMERICAL STUDY

For comparison a ten storey building was analysed by modal analysis mode superposition method and actual base shear worked out by 2D analysis was distributed along the height as per various standards. The lateral loads, and shear distribution are compared in Fig. 1 and Fig. 2. The comparison of time period with actual time period is given in Table 5 for the same building.

Table 5. Comparison of fundamental time periods of ten storey building.

Code	By Code	Time period (sec)	
		% diff. from dynamic analysis values in	
		Longitudinal Direction	Transverse Direction
IS	1.00	+ 15.07	+ 26.74
NBCC	1.00	+ 15.07	+ 26.74
UBC	0.983	+ 13.12	+ 24.59
BSLJ	0.64	- 26.35	- 18.88
Longitudinal direction dynamic analysis.	0.87	-	-
Transverse direction dynamic analysis.	0.79	-	-

CONCLUSIONS

1. All five codes include the effect of seismic risk, spectral content, structural behaviour and soil foundation effects. The importance of building is included in all the code except in BSLJ, because BSLJ stipulate the minimum standard applicable to all buildings.
2. For modelling the building, a portion of live load is considered by BSLJ, IS and NZS only.
3. The empirical formula, for time period recommended by IS and NBCC in based on number of stories, while it is based on total height in BSLJ and UBC. Where the time period actually depends on many more factors. However for the example studied UBC gives closes values.

4. The distribution of base shear based on inverted triangle shape as assumed by UBC, NBCC and NZS is more close to exact analysis.

REFERENCES

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 Yazdi, M.A. (1990), Seismic Analysis of R.C. framed Buildings, M.E. Dissertation, Earthquake Engineering Department, University of Roorkee, Roorkee.

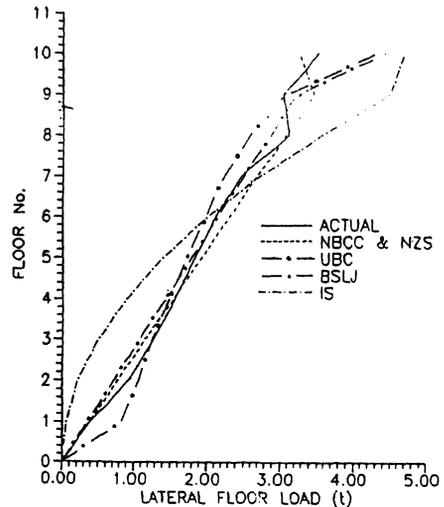


Figure 1. Comparison of lateral floor load distribution.

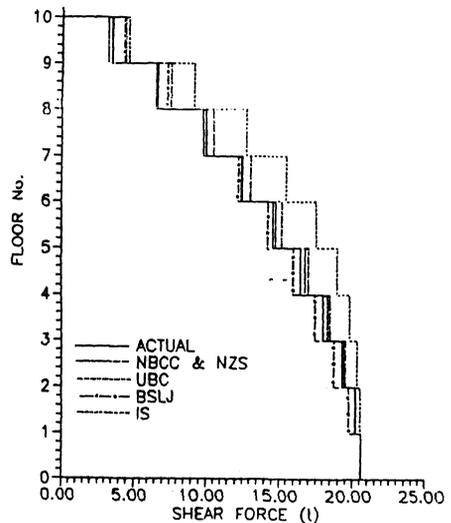


Figure 2. Comparison of lateral shear force distribution.