REVIEW OF VARIOUS PROVISIONS IN VARIOUS BUILDING SEISMIC DESIGN CODES

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Abstract - *It has been found that the design of high-rise Buildings in seismically active areas vary greatly from one region to the next.; In many other nations, a classic design based on power reduction factors is all that is required. In this paper seismic provisions of RC building are compared which are related to seismic design. The provision from IS1893, ASCE7, EN8 and NZS1170.5 are discussed. Parameters like Soil* categorization, *Hazard Specification, The Importance Factors are compared and contrasted. The Response Reduction / Behaviour Factor and Building Ductility classification are discussed. Four seismic codes are compared to Design Response Spectra and Seismic Base Shear. Despite the fact that the underlying approach to design is similar, the different seismic design codes have numerous key variances. Each code is superior to the other in various ways.*

Key Words: IS1893, ASCE7, Eurocode 8, NZS1170.5, Seismic Codes Provisions

1.INTRODUCTION

Modern seismic design codes combine design methods and sophisticated topics. To ensure intended performance, most contemporary codes are based on a set of rules with distinct design characteristics such as design base shear, ductility capability, ductility demand, and drift. Nonetheless, the design base shear is the most critical factor affecting a ductile class structure's seismic performance. These are based on the prescriptive force-based design method, in which the design is carried out using a linear elastic analysis and, through the response reduction factor, is treated as an inelastic energy dissipation (or behaviour factor). The response reduction factor, as considered in the design codes, depends on the flexibility and overstrength of the structure. However, different national codes vary due to the different features that control the design force level. Another important issue that controls the design of a building and the expected seismic performance is the control of drift. Drift is recognized by all codes as an important control parameter; however, they differ in terms of the effective rigidity of RC members. In this present study Indian (IS1893), New Zealand (NZS1170.5), American (ASCE7) and European (EN8) are compared. Various seismic parameters are considered in this study.

2. SEISMIC PARAMETERS

The parameters studies are included in this section. Parameter considered are soil categorization, IMP factor, zone factor, Response reduction factors and design spectrum.

2.1 Soil Categorization

Soil has a strong influence on the ground motions characteristics and thus have an effect on the design response spectrum. In the seismic code, soil effects are taken as a simple site class and the soil factors. Five site classes are categories in ASCE7 and NZS1170.5. Eurocode 8 has four site classes which are A-D. There are three types of soil class I-III in IS 1893 class. The table 2.1 compares the soil categorization according to the four selected codes. As a basis for categorization, IS 1893 specifies only SPT values, while other codes generally use V_{S30} for soil categorization.

Table 2.1 Soil Classification according to four codes

Parameter	IS1893	Eurocode8	ASCE7	NZS1170.5
Avg. Shear Wave Velocity (V_{S30})	X	✓	✓	✓
SPT Value (N)	✓	✓	✓	✓

*X – Parameter is not defined, **✓ - Parameter is used.

A comparison of site classes according to different selected seismic codes is shown in fig. 2.1 (a) & (b). The ASCE7, EN8 and NZS1170.5 are compared because they have V_{S30} as their common parameter. Since IS1893 is based solely on SPT values, it can only be compared to ASCE7 and EN8 because they have SPT values used as soil categorization parameter. SPT values for site class E was provided by NZS1170.5. Based on V_{S30} and SPT values different codes can be compared. Table 2.2 shows different selected seismic codes similar to ASCE7 site classes. Table 2.3 shows the Description of site classes according to different selected seismic code.

Table 2.2 Different selected seismic codes equivalent to ASCE 7 site classes (Khose et.al.2012)

ASCE 7	IS 1893	Eurocode 8	NZS 1170.5
A	I	-	A
B	I	A	B
C	I	B	B
D	I, II	C	C, D
E	III	D	E

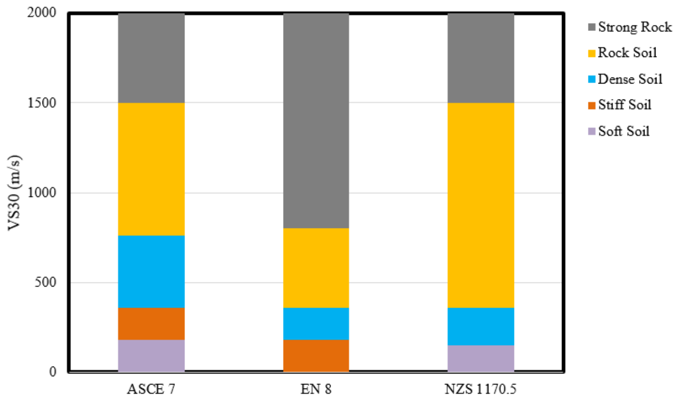

Fig. 2.1 a)

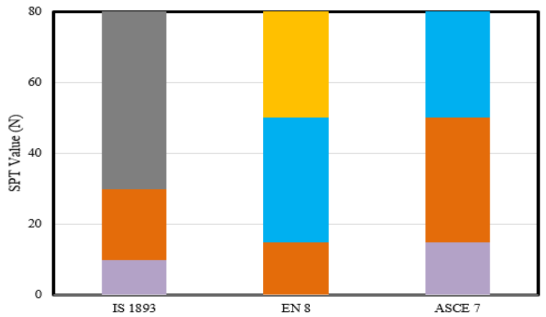

Fig. 2.1 (b)

Fig. 2.1 Comparison of different site classes according to different selected seismic codes: (a) Comparison on the basis of V_{S30} &(b) Comparison on the basis on SPT value (Khose et.al2012)

Table 2.3 Site condition according to different selected seismic code

Soil Condition	IS 1893	Eurocode 8	ASCE 7	NZS 1170.5
Hard Rock	I	A	A	A
Rock	I	A	B	B
Very Dense Soil and Soft Rock	II	B	C	C
Stiff Soil	II	C	D	D
Soft Clay Soil	III	D	E	E

2.2 Hazard Specification

Different codes use different methods to determine the level of design hazard. GM intensity measure and return period are two major issues related to hazard Specification. Peak Ground Acceleration (PGA) represents seismic hazard for various seismic design codes as a single parameter. IS1893 specifies the zone factor. Hazard factor represents as Effective PGA. For a period of 0.1 to 0.3 seconds, EPGA acquired as 0.4 multiple the 5% damped avg. spectral acceleration. Spectral acceleration. Design ground acceleration, also known as reference peak ground acceleration, is defined by Eurocode 8. The hazard factor is defined by NZS1170.5. It corresponds to the highest ground acceleration in g (equivalent to 0.0 sec time) for site classes A and B. (NZS1170.5 Supp1.2004). The zone factor is 0.5 times the magnitude-weighted 5% damped response spectrum acceleration over a period of 0.5 seconds for site class C (shallow soils) with a return period of 500 years. To anchor the design spectrum, ASCE 7 uses numerous spectral ordinates, including short-period spectral acceleration at 0.2 sec duration (Ss) and spectral acceleration at 1.0 sec duration (Ss) (S1). IS1893 divides the map into four seismic zones. ASCE7 employs mapped spectral acceleration at certain locations (SS and S1). The settings for ground types 1 and 2 are provided by Eurocode8. Z values indicate fault spacing in NZS1170.5 risk factor (Z).

2.3 Importance Factor

The IS1893 standard specifies three Imp. factors: 1.0, 1.2, and 1.5. ASCE7 assigns priority levels to risk categories. The Imp. Factors for ASCE7 are 1.0, 1.0, 1.25, and 1.5, respectively. While NZS1170.5 assigns five priority levels to building types based on the risk of collapse posing a harm to human life. Based on the risk to human life, Eurocode8 separated Imp. Factors into four sorts (I, II, III, and IV). EN8 has significance factors of 0.8, 1.0, 1.2, and 1.4, respectively.

2.4 Building Ductility Categorization and Response Reduction/Behavior Factor

The inelastic energy dissipation caused by reducing the design seismic force is assumed to be the cause of the response reduction factor (also known as behaviour factor). For various ductility classes of buildings, response reduction factor values are supplied. In addition to the ductility factor, NZS 1170.5 takes into account a second structural performance component. In all other seismic codes, constant response reduction factors are supplied. As illustrated in Table 2.4, the various selected codes give ductility classes and response reductio factors.

2.5 Design Response Spectra

The seismic design code uses a 5% damped elastic acceleration response spectrum as a reference design spectrum. Seismic codes give standard spectral forms for different site classes in order to get design spectra, which are calculated/scaled by PGA and modified for site characteristics and return period. For each site class, soil amplification factors are supplied to account for the impact of local soil conditions on the design spectrum. The codes recognize the changing effect of soil in the short-period and long-period portions of the spectrum. IS1893 entirely disregards the short-period range of soil amplification effect. Because soil is a highly nonlinear material, it is now well understood that earthquake ground motion amplification is a function of both local soil characteristics and ground motion. ASCE7 calculates soil amplification factors based on spectral acceleration data. In other codes, however, the site coefficients are unaffected by PGA.

Table 2.4 ductility classes and Response Reduction/Behavior factors		
Seismic Code	**Ductility Class**	**Response Reduction/ Behavior Factor**
IS 1893	Ordinary Moment Resisting Frame (OMRF)	3.0
	Special Moment Resisting Frame (SMRF)	5.0
ASCE 7	Ordinary Moment Resisting Frame (OMRF)	3.0
	Intermediate Moment Resisting Frames (IMRF)	5.0
	Special Moment Resisting Frames (SMRF)	8.0
Eurocode 8	Ductile Class Low (DCL)	1.5
	Ductile Class Medium (DCM)	$3.0\alpha_u/\alpha_1$
	Ductile Class High (DCH)	$4.5\alpha_u/\alpha_1$
NZS 1170.5	Nominal Ductile Structures (NDS)	1 to 1.25
	Structures of Limited Ductility (SLD)	1.25 to 3
	Ductile Structures (DS)	1.25 < R > 6

2.6 Seismic Base Shear

The numerous provisions governing the design base shear differ widely between selected codes. In ASCE7, the minimum design base shear coefficient is determined by the ductility class and mapped spectral acceleration, S1 at 1 sec period, however in NZS1170.5, it is determined by the PGA (hazard factor) and is independent of the ductility class. Table 2.5 (a), (b), (c), and (d) show the steps for estimating the design base shear.

Table 2.5 (a) Calculation of Design Base Shear				
DESCRIPTION	**IS1893**	**ASCE 7**	**EUROCODE 8**	**NZS 1170.5**
Design Base Shear	$V_B = A_h.W$	$v = c_s \cdot w$	$F_b = \lambda \cdot m \cdot s_d$	$V = C_d(T_1) \cdot w_t$

Table 2.5 (b) Calculation of Design Base Shear				
DESCRIPTION	**IS1893**	**ASCE 7**	**EUROCODE 8**	**NZS 1170.5**
Coefficients	$A_h = \frac{Z}{2} \cdot \frac{I}{R} \cdot \frac{s_a}{g}$	$C_S = \frac{S_{DS}}{\left(\frac{R}{I_e}\right)}$	$\lambda = 0.85 \ldots T_1 < 2T_c$ $\lambda = 1 \ldots T_1 > 2T_c$	$C_d(T) = \frac{C_{(T)} \cdot S_P}{k_\mu} \geq \left[\frac{z}{20} + 0.02\right] R_u$ $> 0.03\ R_u$

Table 2.5 (c) Calculation of Design Base Shear				
DESCRIPTION	**IS1893**	**ASCE 7**	**EUROCODE 8**	**NZS 1170.5**
Coefficients	S_a / g for Equivalent static - For Rocky or Hard soil sites 2.5…0<T<0.40s 1 / T…0.40s<T<4.00s 0.25…T > 4.00s For Medium stiff soil sites 2.5…0<T<0.55s 1.36 / T…0.55s<T<4.00s 0.34…T > 4.00 s For Soft soil sites 2.5…0<T<0.67s 1.67 / T…0.67s<T<4.00s 0.42…T > 4.00 s	Where, C_s should not exceed $C_s = \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)}$ $\ldots T \leq T_L$ $C_s = \frac{S_{D1} \cdot T_L}{T^2\left(\frac{R}{I_e}\right)}$ $\ldots T > T_L$	Design spectrum for elastic analysis $[S_d(T_1)]$ – $0 \leq T \leq T_B$: $S_d(T)=a_g.S.\{(2/3)+(T/T_B).[(2.5/q)-(2/3)]\}$ $T_B \leq T \leq T_C$: $S_d(T)=a_g.S.(2.5/q)$ $T_C \leq T \leq T_D$: $S_d(T)= a_g.S.(2.5/q).[T_C/T] \geq \beta.a_g$ $T_D \leq T$: $S_d(T)=a_g.S.(2.5/q).[T_C.T_D/T^2] \geq \beta.a_g$	$C_{(T)} = C_h(T) \cdot Z \cdot R \cdot N \cdot (T, D)$

Table 2.5 (d) Calculation of Design Base Shear				
DESCRIPTION	**IS1893**	**ASCE 7**	**EUROCODE 8**	**NZS 1170.5**
Coefficients	S_a / g for Response Spectrum Method - For Rocky or Hard soil sites 1 + 15T… T < 0.1s 2.5…0.10s<T<0.40s 1 / T…0.40s<T<4.00s 0.25…T > 4.00 s For Medium stiff soil sites 1 + 15T…T<0.10s 2.5…0.10s<T <0.55s 1.36/T…0.55s<T<4.00s 0.34…T > 4.00 s For Soft soil sites 1 + 15T…T < 0.10s 2.5…0.10s < T < 0.67s 1.67/T…0.67s<T<4.00s 0.42…T > 4.00 s	C_S shall not be less than $C_S = 0.044.S_{DS}.I_e$ ≥ 0.01 Shall not be less than when S_1 is equal to or greater than 0.6g $C_s = \frac{0.5.S_1}{\left(\frac{R}{I_e}\right)}$	-	-

3. CONCLUSIONS

Four seismic design codes, IS1893, ASCE7, NZS1170.5, EN8 are compared. Some of the conclusions from study are listed below:

- Other codes do not consider the effect of period on response reduction factors, but NZS 1170.5 has a large difference in reduction factors for long-period and short-period structures.
- Eurocode 8 reduction factors are very low. In case of IS1893, NZS1170.5 and ASCE7 are close to the reduction factors for the medium and high ductile classes are close.
- The IS1893 and ASCE7 response reduction factors are similar and are twice that of Eurocode 8. For low ductility class NZS1170.5 and Eurocode 8 response reduction factor are close.
- Effect of ground motion amplitude considered by ASCE7 on the site amplification factor.
- The natural site period and the soil depth of the site are taken into consideration for assigning site class by NZS1170.5
- The difference in spectral acceleration in the design spectra makes a significant difference in terms of displacement.

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