Comparative of Study the Design Spectra Defined by Various Seismic Codes

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Abstract: The main objective of this study is to compare various seismic design codes, to evaluate and assess the performance of seismic structures. The standard seismic codes USA, European, Turkey, and Indian which mainly considered the most seismic active regions are covering for this study; focus on some fundamental points such as seismic hazard specifications, soil amplification, elastic design spectra, reduction and behavior factors, and seismic analysis procedure. In this study Reinforced Concrete Moment Frames are considered in the design and the structure is applied the seismic input obtained from these contemporary seismic codes, the seismic analysis was performed the SAP 2000 v 20. 2 Software and the result obtained from these seismic codes, were emphasized the alteration and resemblances among these building codes, Such as the base shear and Inter-story drift of the structure.

Key words: Seismic Codes, Comparative Study, Drift Ratio, Base Shear, Design Spectra, Site Classification

INTRODUCTION

Since the earthquake has become the major disaster for structures, the seismic codes were designed to reduce the damage of structure and to keep quality structures also to minimize the economic loss caused by the earthquakes. The seismic codes are updated and revised when a strong earthquake occurs frequently, notably, Turkish is the most seismic active regions in the world, a numerous strong earthquake ground motions were happened for the past decades, the Turkish seismic code is revised several times. Two remarkable earthquake were strike Turkey in 1999 (Kocaeli and Düzce) due to these earthquakes over 18,000 are recorded for death and more than 51,000 building are heavily damaged or collapsed. The material used for the construction had less quality, poor design for the structures and the range of strong ground motions are caused that earthquake problem. (1) The Turkish seismic code 1998 were revised in 1997, however due to this strong earthquake, another seismic code is published 2007 and finally 2018, however during that past earthquakes are recognized that structures are designed for lateral loads due to the wind loads are much better than the structures are designed for the gravity loads only, the modern seismic codes based on the seismic design force based methodology for elastic analysis. (2) Structures will be expected to behave non-linear variety, producing huge deformation and dissipating an enormous quantity of energy, according to this the structures will be intended and detailed imperatively to convince the essential capacity of energy dissipation. But later is developed the displacement based design which is importance of displacement control for the structures particularly the damage of non-structural elements. The perspectives of seismic codes are to control the parameters such as base shear, drift ratio, ductile demand and capacity demand to endorse the behavior of structure. (3) The design base shear for structures is very crucial to control the performance of structures given by a ductility class. This study is covering the comparative of major seismic building codes by studying the independent and the multiple aspects that affects the building codes for the design base shear.

SOIL CLASSIFICATION

The effects of soil in to the structures plays vital important for damage structures in to contrary ways, Structures behave differently when subject to earthquake in different types of soil conditions for example dense soil and soft soil. [4]. The response of structure for flexible soil and hard soil is not same, so for that mostly seismic codes defined soil classes or ground types based on the average shear wave velocity at top of 30 m(Vs 30) and SPT. The seismic codes such as Eurocode defines five different ground types vary A to E and two soil factors which is depends on the damping factor, the Indian seismic code defines three different soil types, Type I, Type II and Type III, which is represented by hard rock soil, medium and soft soil respectively and Indian code not considered or based on the soil average wave velocity but considered the SPT. The Turkish soil are classify five different soil vary A to E, respectively

<table>
<thead>
<tr>
<th>Soil Classificaiton</th>
<th>Seismic Code Design</th>
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<tbody>
<tr>
<td>EC8 A</td>
<td>ASCE7-16 A</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

Table 1 Comparison of Site Classes of EC8, ASCE7-16 and TSC-2018
DEPOSITS OF LOOSE-TO-MEDIUM COHESION LESS SOIL VS < 180 M/S

STIFF SOIL VS > 366 M/S

MEDIUM TIGHT - LAYERS OF TIGHT SAND, GRAVEL OR VERY SOLID CLAY 180 M/S < VS > 360 M/S

A SURFACE OF ALLUVIUM LAYER WITH WATER TABLE A LAYER OF TYPE C OR D ON ROCK

SOFT SOIL VS > 366 M/S

LOOSE SAND, GRAVEL OR SOFT VS < 180 M/S

A LAYER OF AT LEAST 10 M THICK SOFT CLAYS/SILT REQUIRING SITE-SPECIFIC RESEARCH AND EVALUATION

FLOORS REQUIRING SITE-SPECIFIC RESEARCH AND EVALUATION

SENSITIVE CLAYS, OR ANY OTHER SOIL PROFILE NOT INCLUDED IN TYPES A – E OR S1


Figure 1 Typical Elastic Design Spectra [6]

The points $T_B$ and $T_C$ describe the acceleration control region, where the $T_C$ and $T_D$ show the constant velocity control region and the $T_D$ is where the displacement control regions begin. The elastic design spectra in EC8 it recommended to adopt two horizontal spectra Type 1 which commonly used for the higher seismicity regions and the Type 2 which is adopt if the earthquake is less than the magnitude 5.5 or less seismicity regions as defined the probabilistic hazard assessments. As well as EC8 described

GROUND MOTION INTENSITY AND RETURN PERIOD ARE TWO FUNDAMENTAL CONCERNS RELATED TO THE HAZARD SPECIFICATIONS, SEISMIC CODES MOSTLY USE THE SEISMIC HAZARD AS THE SINGLE PARAMETER CHARACTERIZED BY THE PEAK GROUND ACCELERATION (PGA). AS MENTIONED EARLY THAT BUILDING CODES CONSIDERED AND DEFINED DIFFERENT CRITERIA FOR THE HAZARD LEVELS, ACCORDING TO THESE SEISMIC CODES HAVE BEEN USED IN THE STUDY WAS FOUND THAT EUROCODE 8 CONSIDER A REFERENCE PEAK GROUND ACCELERATION AND IS1893 DESCRIBES A ZONE FACTOR DEFINED BY “EFFECTIVE PEAK GROUND ACCELERATION (EPGA)” AND OBTAINED BY THE 0.4 TIMES THE 5% DAMPED FOR AVERAGE SPECTRAL ACCELERATION AMONG THE PERIOD 0.1 TO 0.3 SEC. THE TURKISH NEW VERSION 2018 AND ASCE7-16 DOES NOT CONSIDER SEISMIC ZONE FACTOR BUT USES FOR DESIGN GROUND MOTION MULTIPLE SPECTRAL ORDINATES SUCH AS SHORT AND LONG PERIODS RESPECTIVELY, DESPITE SLIGHTLY DIFFERENT THE CONSTRUCTION DESIGN SPECTRA. IN ADDITION TO SEISMIC CODES USE FOR SEISMIC HAZARD LEVELS FOR PROBABILITY OF RETURN PERIOD AND THE SEISMIC CODES, BUT COMMONLY EC8 DESCRIBES THE SEISMIC HAZARD AT 10% PROBABILITY EXCEEDENCE IN 50 YEARS FOR RETURN PERIOD 475 YEARS AS THE SEISMIC ACTIONS REFERENCE.
and long period $T=0.2$ s and $1$ s are defined by the site-specific acceleration maps are developed for stiff soil sites. The Turkish seismic code is also considered for the spectral ordinates such as short and long periods. The Eurocode is considered for two different spectra, but, for this case Type 1 is considered for the design and applied for strong ground motion which produced a magnitude greater than 5.5, the soil classes are considered the design is rock soil, soft soil, and medium soil. The modal response spectrum in modes should not be less than 90% the mass of the structure (EC8-2004) while American code considers 85% the modal analysis in base shear force [7].

REDUCTION FACTOR IN SEISMIC CODES

The seismic design codes specify the inelastic dissipation energy effects to design to decrease the design force [8]. Despite Seismic codes are use different for the design, but commonly seismic codes use force based methodology, however, the classification according to the structural type is different such as detailing. Detailing significantly affects the structural strength, the elastic response spectrum shape as well are different however seismic codes considers reduction factor which structures hold the capacity to resist earthquake beyond the elastic limit, structures will be expected to behave non-linear variety, producing huge deformation and dissipating an enormous quantity of energy, according to this the structures will be intended and detailed imperatively to convince the essential capacity of energy dissipation. The supply of ductility in structural system tolerates the reduction of elastic response spectrum, ductility reduction factor generally rely upon the period of structure. Seismic codes describes reduction factors changing in to elastic spectra in design spectra in a purpose of structural systems, mostly the reduction factors defines the purpose of ductility classes. In addition to seismic codes use for different ductility classes ASCE7 defines three ductility classes, Ordinary Moment Resistance Frame, Intermediate Moment Resistance Frame and Special Moment Resistance Frame and IS 1893 only considered two ductility class Ordinary Moment Resistance Frame and Special Moment Resistance Frame and each one is corresponding to different reduction factor.

NUMERICAL EXAMPLE

The layout of the building basically bisymmetric in plan, which assumed by regular form, the number of bays is four that have a same width of 5 m in both directions. The storey height is used for 3 m which is normally the height of residential buildings and the bottom of the structure was assumed for fixed. 12 story building for moment frame is used for the design and three different soil conditions is considered the design to understand the impact of soil condition for design spectra, while four contrary seismic codes is considered to perform the structure. The structural concrete element of structure also is assumed as correctly to keep the failure structure, the compressive strength of concrete is considered grade C30 for design spectrum to design a new structure. Hence the building is reinforced concrete the constant properties such as modulus of elasticity will be assumed poisons ration is 0.2. The density of concrete used by 24 KN/m$^3$ the damping ratio is taken by 5%, the design for gravity loads includes the dead loads and self-weight, the live load is considered 2.5kN/m$^2$, for another side the overall mass of the building including the self-weight and floor cover plus 25% of live load will be considered in the seismic design. The medium soil is considered for the design and the ductility classes are considered as the each seismic code defines. The spectral acceleration for long period and short period for considerations Turkish and American code were used $S_s=0.927$ and $S_1=0.259$, $S_s=1.573$ and $S_1=0.701$, respectively, [9] [10]. Where Eurocode was use the shape of spectrum Type 1 and $A_g = 0.25g$ and the Indian code is consider the design zone IV [11] [12]. Table 2 describes the required section elements for reinforced concrete elements such as beam, column and slab.

### Table 2 the section of RC elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Dimension (mm)</th>
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<tbody>
<tr>
<td>Column</td>
<td>500 X 500</td>
</tr>
<tr>
<td>Beam</td>
<td>350 X 500</td>
</tr>
<tr>
<td>Slab</td>
<td>150</td>
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ANALYSIS AND RESULT
The analysis of the structure has been carried out by SAP2000 v20.2 using four different seismic codes, the results obtained the design response spectrum and equivalent lateral force for the standard seismic codes has been compared them, to make the possible comparison such as base shear and displacement elastic spectra have been performing the analysis and the reduction factors and behavior factor are consider for the inelastic design spectra. The fundamental period is obtained for the structure is 1.572 for longitudinal direction of the building and the model analysis obtained the total mass of the building in 98% in horizontal direction and transversal direction.

STORY-DRIFT
The structures deform when subjected to the seismic actions and that deform causes structure to move its actual position to another position except only the bottom of the structure that is fixed. However, the story drift ratio of the structure can be found to the percentage of displacement between the two floors divided by the height of the structure. The most codes give the drift ratio a limit, the story drift indicates the damage of the building in both structural and non-structural damages. According to the ASCE7, the limit of story drift should not be less than for the moment frames building 0.025 times the height of the structure for the category III and 0.002 for the design category I and II. If the drift ratio should be greater than the allowable drift ratio should not be acceptable. The lower floors are greater drift when compared to the top floors. The IS 1893 limits the interstorey drift 0.4% for design load. And it is depends on the ductility class.
The Base shear is defined by the approximation of the maximum contemplated lateral force which happens according to the ground motion at bottom of the building. However, the base shear rely upon some significance factors such as the ground motion, natural period, and the main factor which is reduced the base shear is reduction factor. However, the result of base shear obtained from the spectral analysis and the equivalent lateral force method describes that spectral analysis is more conservative than the equivalent lateral force method. However, as the figure 5 describes that base shear obtained from the TSC code is more than the other codes and this significance difference is due to the reduction and behavior factors are considered for the design and as well as the difference peak ground acceleration is considered when performing the design for this contrary seismic design codes.

CONCLUSION
The main objective of this study is to compare various seismic design codes, to evaluate and assess the performance of seismic structures. These contemporary seismic codes are fundamental for earthquake resistance design, the seismic codes provide level ductility due to the energy dissipation range, however, seismic codes, are considered reduction factors and behavior factor to reduce even the design force. Seismic codes use for seismic hazard levels for probability of return period and the EC8 describes the seismic hazard at 10% probability exceedance in 50 years for return period 475 years as the seismic actions reference. Four different ground motion levels are defined by the new Turkish seismic code, DD-1: 2% probability of exceeding in 50 years, and recurrence is 2475, DD-2: 10%, probability of exceeding in 50 years, and recurrence is 475, DD-3: 50% probability of exceeding in 50 years, and recurrence is 72 and finally DD-4: 50% probability of exceeding in 50 years, and recurrence is 43. IS 1893 does not consider for return period but use for the effective peak ground acceleration design 0.5 times the effective peak ground acceleration and

**Figure: 4 Story Drift for Medium Soil**

**Figure: 5 Base Shear X Direction**
ASCE7-16 describes the return period 2475 years, the probability of 2% seismic inputs exceeded in 50 years, corresponding the MCE. The base shear obtained the spectral analysis for Indian seismic code is underestimated and non-conservative when compared to the other seismic codes because of the lack of soil amplification for the short period range, it only considered the longer period range. The main difference among these seismic codes is the design spectra, for the designing ground motion parameters ASCE7, and TSC-2018 are used to spectral ordinates rather than seismic zone factor, the Indian seismic code is considered for the design spectra 4 sec only, also ignores the soil amplification for the short period range.

REFERENCES

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