Comparative Study of Seismic Performance of Reinforced Concrete Building Designed Accordance with Indian Codes and American Codes

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Abstract -*Earthquake forces on the structures are of great concern for the engineers. Codes and standards are the conventional source of information to the design of civil engineering structures .The seismic codes are primarily based on ground motion that erratic in direction, magnitude , duration and sequence and the results of the research were carried out to understand the consequence of the ground motion of the structures This study presents a comparative study of the seismic design provision of the Indian Seismic code IS 1893 (part 1) : 2002 ,recent code IS 1893 (part 1) : 2016 and American Seismic code ASCE / SEI 7-10 Minimum Design Loads for Building and Other Structures to address the differences in their philosophies and applicability .In present study a geometrically similar 4 Story , 7 story and 10 story reinforced concrete special moment resisting frame are considered. Equivalent static analysis and Response spectrum analysis and nonlinear dynamic analysis are done over all the models of this study .The structural performance of each building is compared in terms of parameter base shear, roof and interstory drift in order to understand differences between these international standard*

Key Words**: ASCE 7-10, IS 1893(part 1): 2002, IS 1893 (part 1): 2016, Seismic design provision**

1. INTRODUCTION

Earthquakes have been always a natural occurrence on our planet. The slow, constant shifting of tectonic plates builds strain between two plates and once it reaches a critical value, the strain energy is released in the form of ground motion. The motion is felt as acceleration, and continues until all of this strain energy is dissipated. The large acceleration of the ground develops internal lateral interior forces on a structure. As tectonic plates are continuously moving, this process is repeated [FEMA]. Therefore, earthquakes will always be an important consideration in structural engineering [3]

Codes and standards are the conformist source of information to the designers of civil engineering structures. The seismic codes are primarily based on comprehensive data on ground motion that are erratic in direction, magnitude, duration and sequence and the results of the research were carried out to understand the consequence of these ground motion on the structures. In the last several decades, the seismic codes are becoming sophisticated with rapid development in earthquake engineering practice. [2] To minimize damage and loss of life, seismic design codes have been developed. Designed codes in america are advanced and updated in nearly three to five years in order to preserve with advances in earthquake engineering and to include research findings, and are reflected in American Society of Civil Engineers, ASCE 7-10 The first Indian seismic code was published in 1962, has been revised only six times in the last 50 years; the most recent revision being in 2016 It had been revised six times from last 50 years. Recently, the Indian seismic design and detailing codes both went under major revisions which are IS 1893 Part 1 2016 and IS 13920:2016

Some studies have pointed out a number of limitations of the code in terms of seismic hazard protection. During Bhuj earthquake RC frame were heavily damaged, Reinforced concrete frame buildings were severely damaged and majority of them undergo sudden failure according to a reconnaissance report prepared by World Seismic Safety Initiative. Based on the observations and lessons learned from Bhuj earthquake, most of the flaws in the 1984 edition of IS-1893 were eliminated in the 2002 version of the code. RC frame designed according to the U.S. seismic provisions are generally predictable to perform well. Although the three design codes which are ASCE 7-10 , IS 1893 : 2002 and IS 1893 : 2016 share some commonalities, it is unclear whether a building designed according to ASCE 7-10, and IS-1893 codes would perform as intended when the building is subjected to a design level ground motion that has a response spectrum comparable to the one used in design

First Indian standard was published in 1962 IS 1893 : 1962 and revised in 1966, 1970, 1975 and 1984. Further, in 2002, the Committee decided to present the provisions for different types of structures in separate parts, splitting seismic code into five parts and Part 1 general provisions and building were discussed [8] This study consist only part 1 of IS 1893 :2002 and IS 1893 : 2016 for comparing Indian and American seismic code

2. LITERATURE SURVEY

A comparison was made among seismic design codes of building among design provision in Bangladesh (BNBC -1993), India (IS -1893 2002) and U.S. (ASCE 7-10) in relation to analysis, design and seismic performance of RC structures based on these codes [1]. Chistopher Zajac compered equivalent lateral force design provisions for determining the seismic base shear found in six seismic international design standard which were from Canada, USA, Eurocode, Uganda, India and china [3] Rita debnath compared seismic provision of the previous Indian seismic code IS 1893[Part 1]: 2002 and recent revision IS 1893 [Part 1] : 2016 vision to address the differences in their philosophies and application Author observed significant differences in these codes by specifying different parameter such as empirical formulas for calculating building importance factor, response reduction factor, time period, design acceleration coefficient. [2] R..D. Mcintosh explained about comparison of National Earthquake explained about comparison of National Earthquake hazard reduction programme(1995), Structural engineers association of California (SEAOC), ASCE (7-95) and uniform building code (1994) Y.K.Chock studied on assessment of the current seismic design procedure in the United States , China , and Japan based on the various parameter which were design ground motion, classification of building structures , soil/site classification, design response spectrum, base shear calculation, analysis procedure and drift limits Mayur Pisode explained about the non linear dynamic response of the geometrically similar 4 and 8 story building and its seismic parameter using IS 1893 : 2002 and IS 1893 : 2016 S.H. C. Santos focused on comparative study of codes from of various international standard which were covering US, European, Italian, Greek, Romanian, Brazilian and Bulgarian Standards

3. METHODOLOGY

3.1 Equivalent Static Method

It is linear static analysis .It is based on formulas given in seismic code. In this method design lateral force shall be calculted for RC frame. This design lateral force shall then be distributed to the various floor levels. The overall design seismic force thus got at each floor level, shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action. Applicability of equivalent static method for regular building as per IS 1893 : 2002 , IS 1893 : 2016 and ASCE 7-10 as shown in table 1

Table 1: Applicability of Static Analysis Method For Regular Building

Particular	IS 1893 2002	IS 1893 2016	ASCE 7-10
Regular building	Applicable for height less than 40 m zone IV and V and those height less than 90 m in zone II and III	Applicable for height less than 15 m in seismic zone II	Structures with no irregularities and not exceeding 48.76 m

3.2 Response Spectrum Method

It is linear statistical dynamic analysis method which measures the contribution from each mode of vibration to indicate the likely maximum seismic response of an elastic structures. Response spectrum Analysis provides insight into dynamic behavior by measuring pseudo – spectral acceleration, velocity or displacement as a function of structural period for a given time history and level of damping. Response-spectrum analysis is useful for design decision making because it relates structures of shorter period experience greater displacement. Applicability of response spectrum analysis for regular building as per IS 1893: 2002 , IS 1893 : 2016 and ASCE 7-10 as shown in table 2

Table 2 :Applicability of Dynamic Analysis Method Of Regular Building

Particular	IS 1893 2002	IS 1893 2016	ASCE 7-10
Regular building	Applicable for height greater than 40 m zone IV and V and those greater than 90 m in zone II and III	Applicable for other building and height greater than 15 m in seismic zone II	Structures with no irregularities and not exceeding 48.76 m

3.3 Nonlinear Dynamic Analysis:

Nonlinear time-history analysis is the most comprehensive method for seismic analysis. The earthquake record in the form of acceleration time history is input at the base of the structure. The response of the structure is computed at each second for the entire duration of an earthquake. In this method the effect of "time" is considered For analysis purpose Imperial Valley(6.95), Kern country(7.36) , San Fernando (6.61) time histories with their Richter magnitude are selected .

4. ANALYSIS AND DESIGN

Geometrically similar 4,7 and 10 story , 3-bay by 5-bay reinforced concrete special moment resisting frame has taken for all three codes. The height of bottom story is 4.27 m and remaining stories are 3.66 m each, resulting height 15.25 m, 26.23m and 37.21 m respectively. The width and length of structure was 15 m and 25 m, respectively with column spacing 5 m in both direction. The plan view of structure is as per fig no 1 the selected structure is commercial building according to that importance factor was taken according to respective code

The buildings are assumed to be located in high seismic region Bhuj (India)and San Francisco (USA) . The site soil classification and the spectral response acceleration parameter or zone factors are as shown in table no 4. Details of Dead and live loads has given in table no III. Details of dimension of building model are as shown in table V

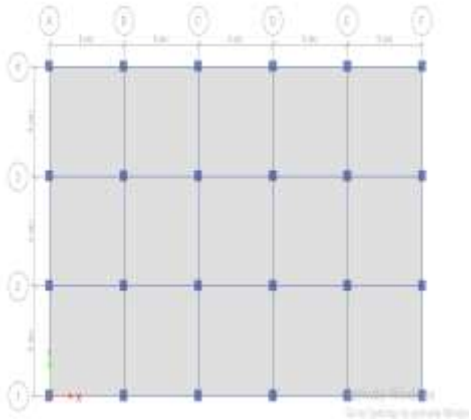

Fig 1 : Plan view of the structure

Table 3: Dead and Live Loads

Loads	ASCE 7-10	IS 875 (1987)
Live load	Floor 2.4 kN/m2 Roof 1 kN/m2	Floor2.5 kN/m2 Roof 1.5 kN/m2
Concrete	23.6 kN/m3	25 kN/m2
Mechanical loading	0.24 kN/m2	0.24kN/m2
Partion wall loading	2.63kN/m	4.392 kN/m
Cladding	4.38 kN/m	4.5 kN/m

Table 4: Site Location and Classification

Code	Location	Zone coefficient	Site class
ASCE 7-10	San Francisco, USA	Spectral response acceleration parameter Ss=1.83 ,S1=0.85	Site class D, Stiff soil
IS 1893	Bhuj, Gujrat, India	Seismic zone :V, Zone factor =0.36	Type II (Medium soil)

Table 5: Details and Dimension of Building Model

Story	Column	Beam
4 story	(450 X 450)mm	(300 X 450)mm
7 story	(500 X 500)mm	(300 X500)mm
10 story	(600X 600)mm	(300X600)mm

4.1 Modelling and analysis of structure for design

The structure were modeled three dimensionally in the commercial structural analysis and design software ETABS 17.0.1.The column were assumed to be fixed at the foundation . Rigid diaphragm action of slab was simulated Dead load, live load and seismic loads were applied Using the calculated design forces, the columns and beams members were designed and detailed as per the applicability . The material used were concrete compressive strength fc=48 Mpa and ASTM grade 60 reinforcing steel yield strength, fy=414 Mpa conforming to ACI 318-14 M50 concrete and HYSD 415 Mpa conforming to IS 456-2000 Table VI gives details of frame considered for study

Table 6: Details of frames considered for study

Sr no	Model description	Model Name
1.	4 Story RC Frame using IS 1893 2002	4ISTT
2.	4 story RC frame using IS 1893 2016	4ISTS
3.	4 story RC frame using ASCE 7-10	4ASST
4.	7 story RC frame using IS 1893 2002	7ISTT
5.	7 story RC frame using IS 1893 2016	7ISTS
6.	7 story RC frame using ASCE 7-10	7ASST
7.	10 story RC frame using IS 1893 2002	10ISTT
8.	10 story RC frame using IS 1893 2016	10ISTS
9.	10 story RC frame using ASCE 7-10	10ASST

5. RESULTS & GRAPH

5.1Results of Equivalent Static Analysis

Geometrically similar 4 storey, 7 storey and 10 storey RC frame are modelled and analysed in ETABS 17 software using Equivalent static method. According to EQM American code has higher base shear value than Indian code. Fig 4.1 shows comparison of base shear using column chart for EQM Maximum storey response is displacement of story with respect to base of the structure. American code shows higher max storey response than Indian code Fig 2 Comparison of seismic code for EQM using maximum storey response. following fig 4 ,fig 5 and fig 6 represent story versus drift plot using EQM method.. Following fig 7, fig 8 and fig 9represent story versus drift plot using EQM method

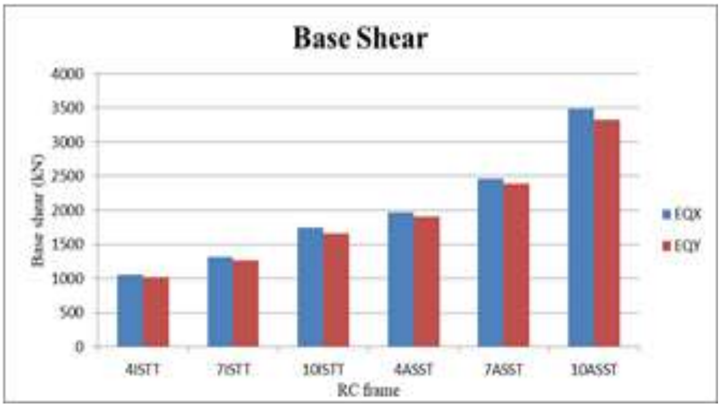

Fig 2: Comparison of seismic code using base shear values for EQM

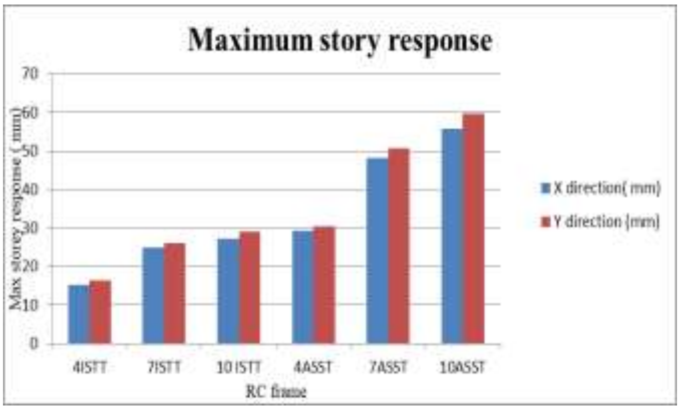

Fig 3:Comparison of seismic code for EQM using maximum storey response

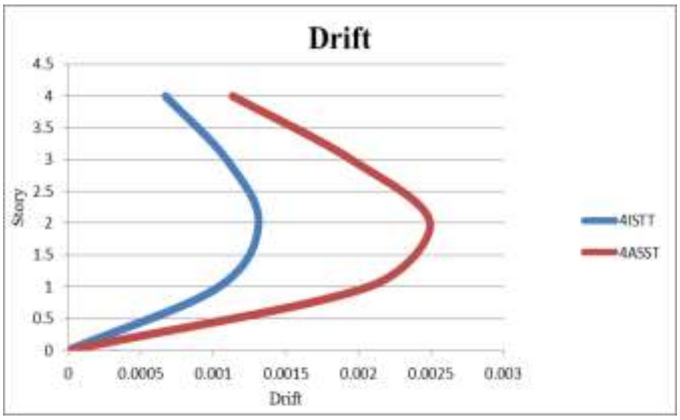

Fig 4:story versus drift plot for models 4ISTT, and 4 ASST for X –direction

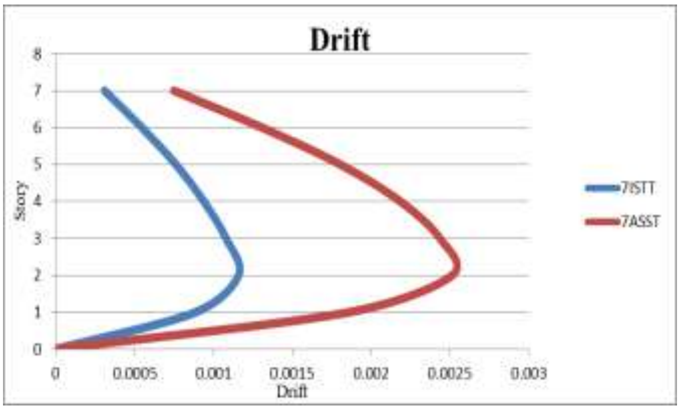

Fig 5 :story versus drift plot for models 7 ISTT and 7 ASST for X-direction

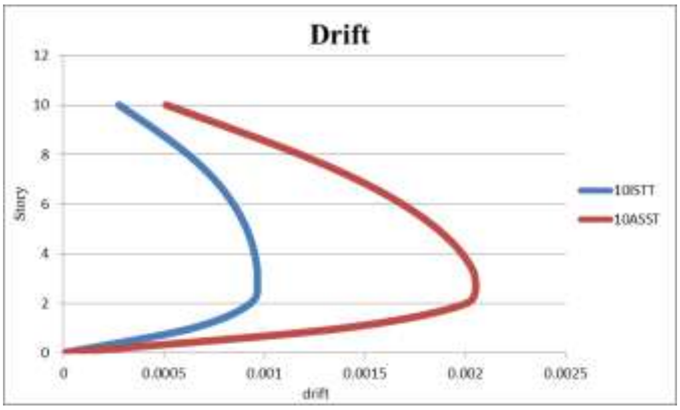

Fig 6 :story versus drift plot for models 10 ISTT and 10ASST X-direction

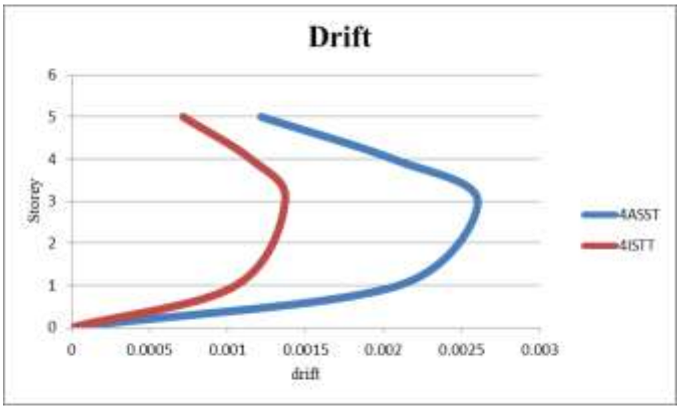

Fig 7:story versus drift plot for models 4ISTT, and 4ASST for X-direction

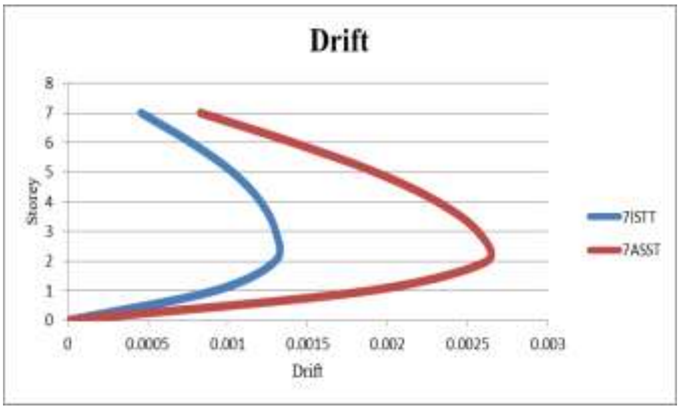

Fig 8:story versus drift plot for models 7 ISTT and 7 ASST for Y-direction

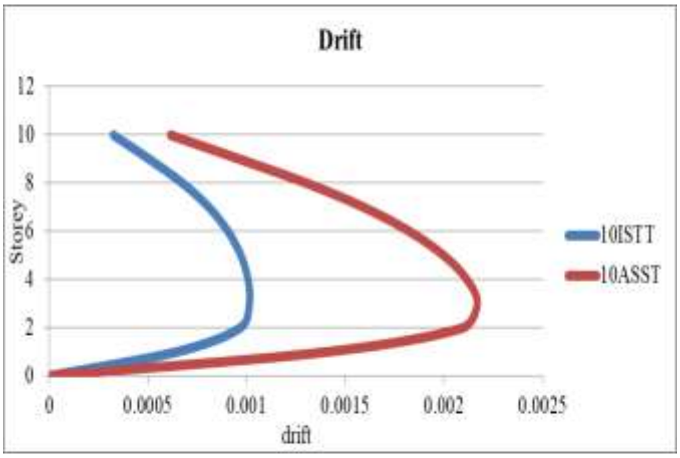

Fig 9:story versus drift plot for models 10 ISTT, and 10ASST for Y –direction

5.2 Response Spectrum Analysis

Applicability of response spectrum analysis for regular building as per IS 1893 : 2002 , IS 1893 :2016 and ASCE 7-10 as shown in table I.A geometrically similar 4,7 and 10 storey RC special moment resisting frame are consider and modelled also analysed using response spectrum method Following fig 4.9 represents column chart for base shear values . According to RSM method American code has higher base shear value than Indian code RC frame designed according IS 1893: 2002 has higher value of base shear than IS 1893 : 2016

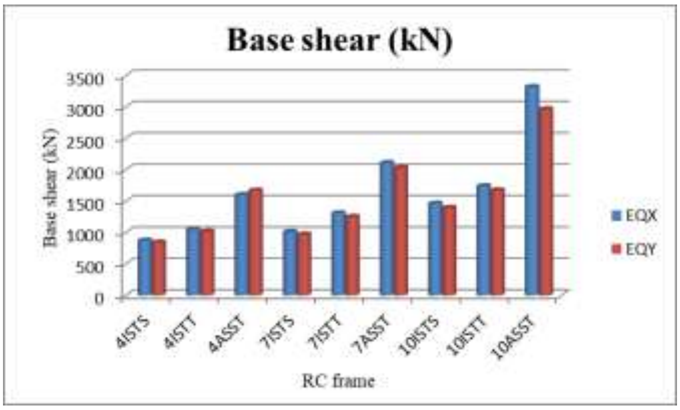

Fig 10: Comparison of seismic code for using base shear values

Interstorey drift is relative displacement between the floors above and or below one storey under considerations As per criteria given in clause 7.11.1 of IS 1893 : 2002 and IS 1893 : 2016 drifts are within given limit All RC frame comes under risk category II which can satisfy as per criteria given in section 12.12.1 in ASCE 7-10 all drift values are limit following fig 4.11, fig 4.12 and fig 4.13 represent story versus drift plot using RSM method fig 4.14, fig 4.15 and fig 4.16 represent story versus drift plot using RSM

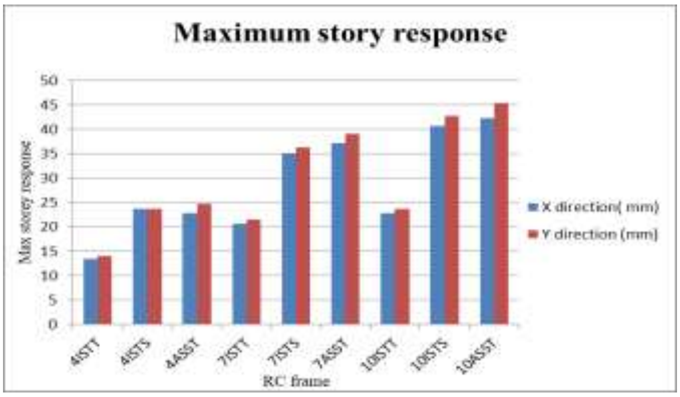

Fig 11: Comparison of seismic code for RSM using maximum storey response

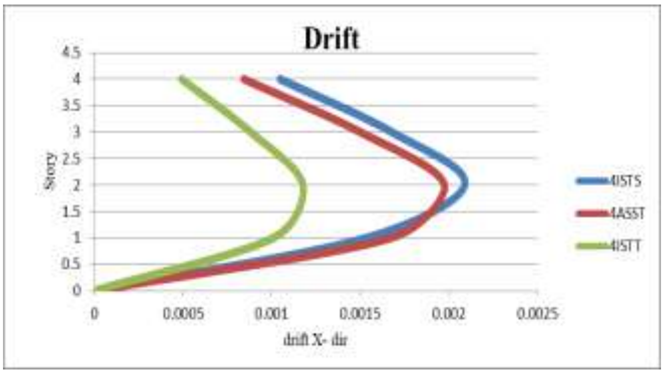

Fig 12 :story versus drift plot for models 4ISTT, 4ISTS and 4 ASST for X-direction

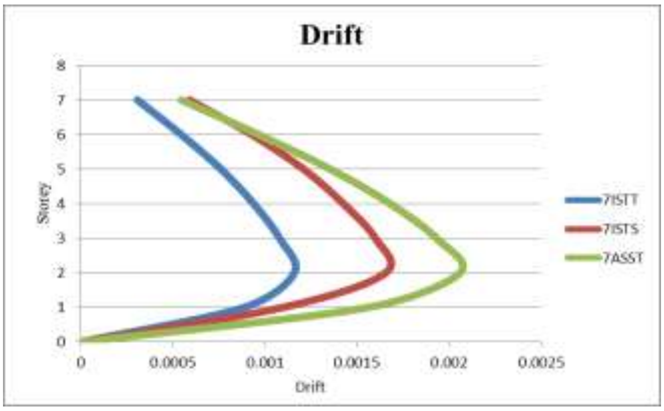

Fig 13:Story versus drift plot for models 7 ISTT, 7 ISTS and 7 ASST for X-direction

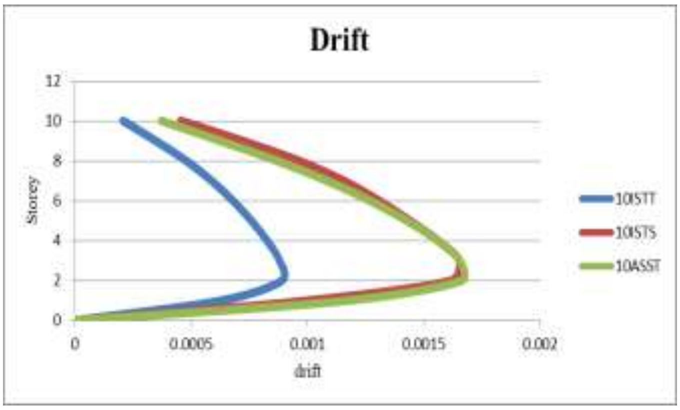

Fig 14 :story versus drift plot for models 10 ISTT, 10ISTS and 10ASST X –direction

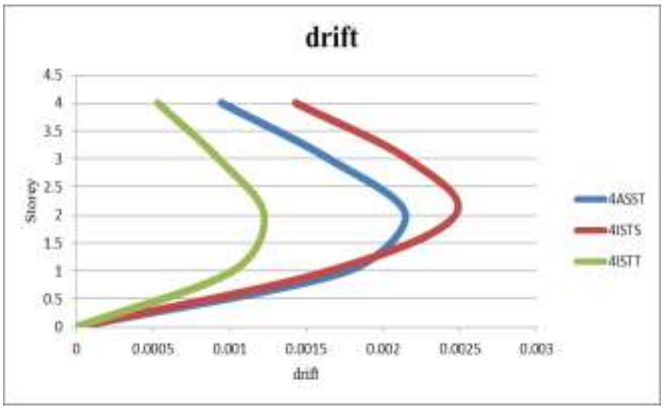

Fig 15 :story versus drift plot for models 4ISTT, 4ISTS and 4 ASST forY direction

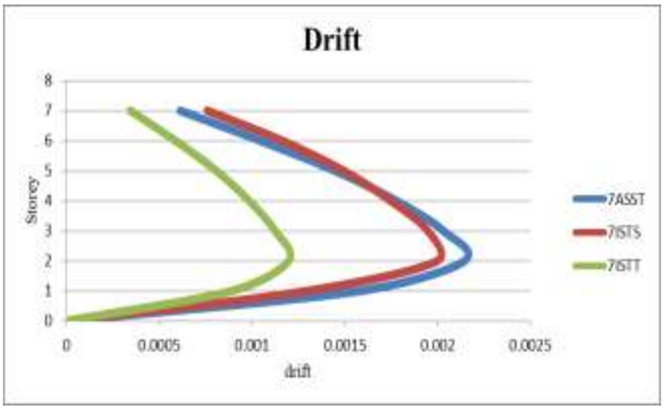

Fig16 :story versus drift plot for models 4ISTT, 4ISTS and 4 ASST for Y-direction

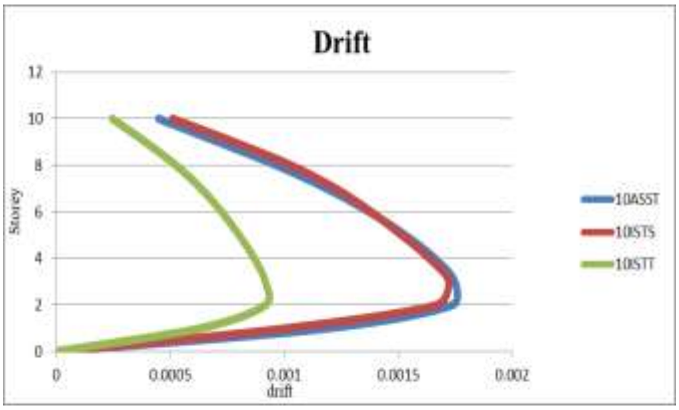

Fig 17:story versus drift plot for models 10 ISTT, 10ISTS and 10ASST for Y –direction

5.3 Results of Nonlinear Dynamic Analysis

It is an analysis of the dynamic response of the structure at each instant of the time, when it is subjected to a specific ground motion time history Distribution of base shear due to lateral load pattern is presented in table 4.16 for considered building under Imperial valley, Kern pel pel and San Fernando ground motion records in both X and Y direction respectively The plotted column chart shows significant differences between cases of considered RC frames . Base shear results of RC frame model according to IS 1893: 2016 than RC frame designed in accordance with IS 1893 : 2002 . Base shear results of RC frame model according to IS 1893: 2002 lower than ASCE 7-10

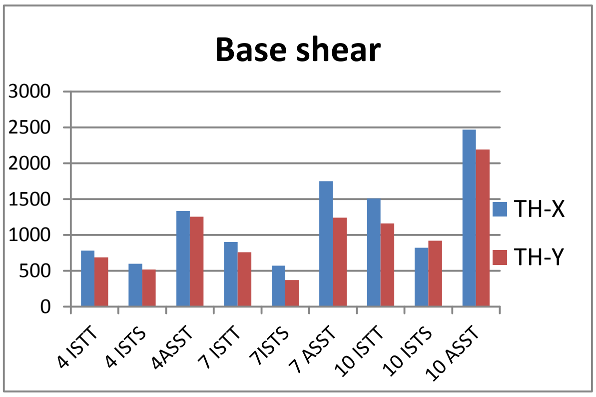

Fig 18 :Comparison of seismic code for base shear values using time history method

Maximum storey response of the 4-storey , 7-storey and 10-storey of RC frame under three different time history earthquake record are presented in this section .The three earthquake records are applied in two orthogonal direction .Maximum response of the structure are represented in the following Fig 4.18 shows Comparison of seismic code for maximum storey response using time history analysis RC frame model designed in according to American code having higher displacement than Indian code As per criteria given in clause 7.11.1 of IS 1893 : 2002 and IS 1893 : 2016 drifts are within given limit All RC frame comes under risk category II which can satisfy as per criteria given in section 12.12.1 in ASCE 7-10 all drift values are limit following fig 4.20, fig 4.21 and fig 4.22 represent story versus drift plot using THA method fig 4.23, fig 4.24 and fig 4.25 represent story versus drift plot using RSM

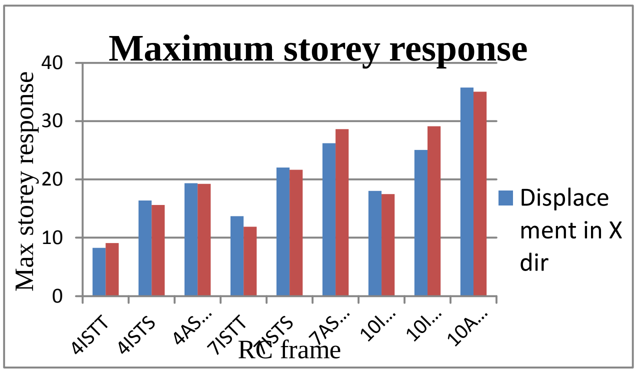

Fig 19: Comparison of seismic code for maximum storey response using time history analysis

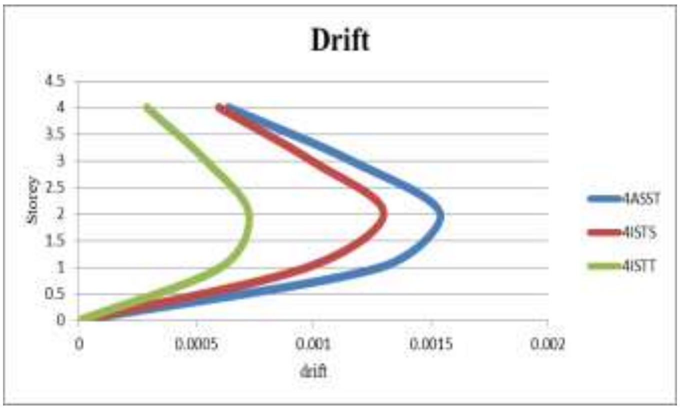

Fig 20 : story versus drift plot for models 4ISTT, 4ISTS and 4 ASST in X-direction for time history method

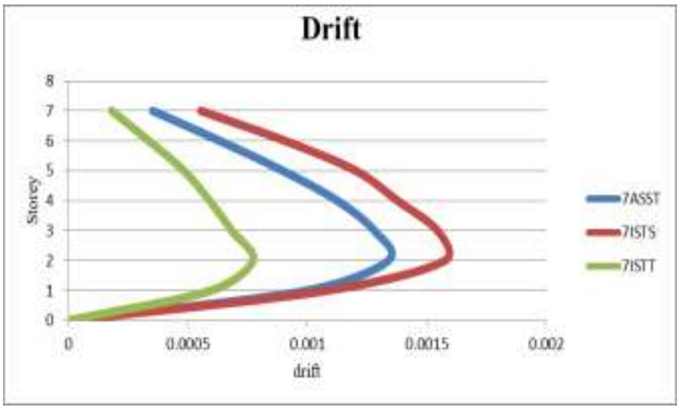

Fig 4.21: story versus drift plot for models 7 ISTT, 7 ISTS and 7 ASST for X-direction

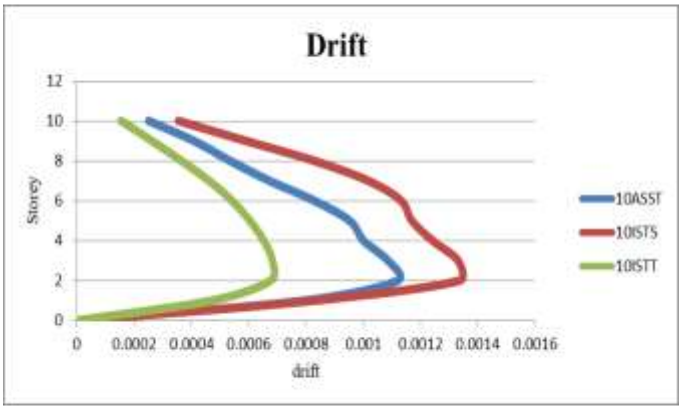

Fig 4.22: storey versus drift plot for models 10 ISTT, 10ISTS and 10ASST for X –direction

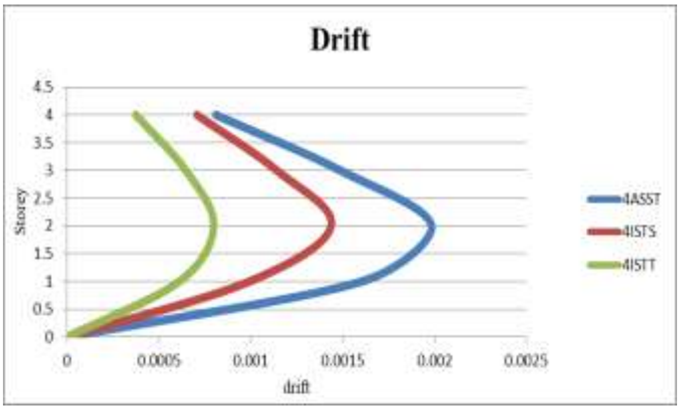

Fig 4.23 :story versus drift plot for models 4ISTT, 4ISTS and 4 ASST in Y-dir for THM

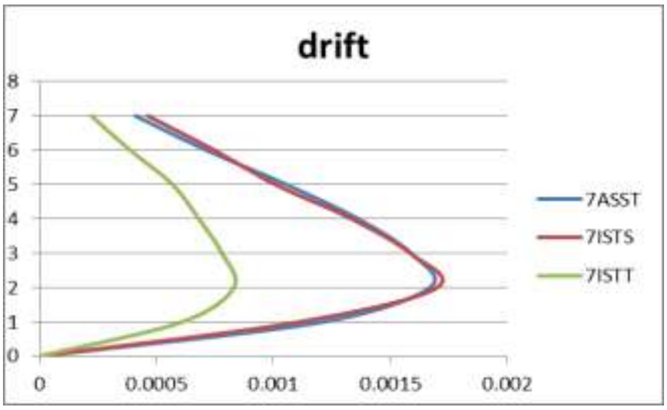

Fig 4.24:story versus drift plot for models 7 ISTT, 7 ISTS and 7 ASST for Y-direction

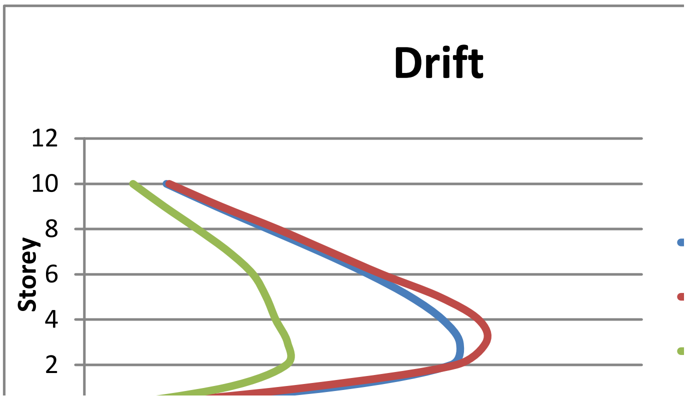

Fig 25:story versus drift plot for models 10 ISTT, 10ISTS and 10ASST for Y –direction

6. CONCLUSIONS

The seismic assessment of RC frames with different storey heights and different seismic code is presented in this study Three buildings with different heights, viz. 4 storey, 7 storey and 10 storey and with three different seismic code which are IS 1893 : 2002, IS 1893 : 2016 and ASCE 7-10 are modelled in ETABS 17 and equivalent static analysis, response spectrum analysis and nonlinear dynamic analysis were performed results has been carried out on these RC frames in ETABS 17 .Indian and American codes are compared in terms of parameter Base shear, maximum storey response and storey drift results are presented in above results and graphs It shows American code has maximum base shear value than Indian code Data shown in table represents base shear values for the structure designed according to IS 1893 : 2002 are higher than IS 1893 : 2016 It shows American code has maximum storey response value than Indian code and RC frame designed according to IS 1893 : 2016 show nearly similar values than ASCE 7-10 . RC frame designed in according IS 1893 : 2002 show less drift than designed with IS 1893 : 2016 and ASCE 7-10 . Drift are nearly same for RC frame designed in according to IS 1893 : 2016 and ASCE 7-10

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