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Comparison between Ibc and isc codes using pushover analysis

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Abstract- Basra city as known, is lying in the southern part of Iraq. In previous it is thought that this city is not subjected to earthquake or subjected but in so minor intensity that not taken in consideration but recent seismological studies stated that Basra city is lying near to an active fault with a high damage intensity besides, the alluvial thick layer of the soil of Basra is susceptible to liquefaction during an earthquakes.Hence the evaluation against seismic force of the existing buildings takes an increased attention and become urgent and public demand.In this work a nonlinear static analysis (Pushover analysis) based on FEMA356 coefficient method is done for analyzing an existing G+5 stories reinforced concrete building.The building was analyzed in three cases, (regular, irregular in plan and irregular in height). The seismic coefficients of the design earthquake used in the analysis are based on IBC2012 code once and ISC code once again to know how effective the difference between them. Results showed that the building in all its three cases for IBC2012 code is within life safety (L.S) performance level and this means that building has cracks and remains out of serviceability until rehabilitation is done but for ISC code the building is within immediate occupancy (IO) performance level and this means that building is still serviceable and it has minor cracks can be retrofitted rapidly.Also the building showed the behavior of strong column- weak beam. Thus the building expected to be safe during any seismic force less or equal to the design one.
Keywords:- nonlinear static analysis, pushover analysis, performance levels, RC buildings, plastic hinges

I. INTRODUCTION

Previously the buildings in the southern part of Iraq including Basra province were designed for gravity loads only and no seismic forces were taken in consideration for many reasons, one of those reasons is that the area was considered not subjected to seismic activities as no previous earthquakes felt and no seismological stations were exist for recording seismic activities. Another cause is that legislations are not found for mandating the inclusion of seismic forces in the buildings' design, anyhow the publishing of first Iraqi seismic code[1] was in 1997 but it neither included a probabilistic seismic hazard assessment for Iraq[2,3] nor mandated the inclusion of a defined seismic forces in buildings. Recent seismological studies in Iraq showed that the Iraqi-Iranian border zone is a seismically active area as it presents part of the convergent plate between the Arabian, Anatolian and Iranian plates [4,5]. Abdulnaby et al 2016 [6] stated that the fault of Badra-Amara which is started about 180km to the Basrah north and extended to Badra (north of province of Kut) as shown in figure 1 is an active fault and it is part of a seismic zone of major damage with intensity of VIII (Modified Mercaly magnitudes).The soil in the southern part of Iraq is described as thick alluvial sediments and can be susceptible to liquefaction during shaking of earthquake[5]. The new Iraqi seismic code[7] was released in 2017 which is depended on the probabilistic seismic hazard assessments (PSHA) for Iraq, but it has not been mandated yet. On November 12th 2017 people in all of Basra and other provinces in Iraq south felt the ground shaking from an earthquake at the Iraqi-Iranian border to the north of Diyala city (around 500km from Basra), Furthermore in 2018 and 2019 people in all provinces of Iraq felt the ground shaking from an earthquake ranged from minor to major intensity and caused influent damages especially the buildings in north of Iraq. This influent event changed the idea of engineers and landlords in Basra province toward seismic design of new buildings and evaluation of the performance of existing buildings.

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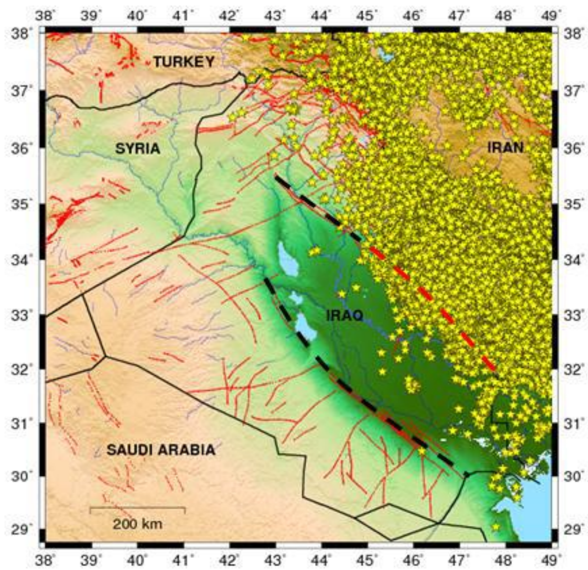

Fig. 1: Iraq and adjacent areasSeismicitywhich is taken from the IranianRecords of Seismic Catalogue IRSC (from 1/1/2006 to 1/10/2014)

II. PUSHOVER ANALYSIS

Although nonlinear time history analysis is the most comprehensive method for analyzing and evaluating seismically the existing structures, but this analysis is complicated and consumes longtime therefore its use is limited[8]. The simplicity of nonlinear static analysis (pushover analysis) procedure and its proved ability to evaluate the performance of existing structures subjected to seismic loads gave it the superiority for utilizing specially in case low to moderately high buildings [9,10,11] which is the case considered here in the area of this work. The pushover analysis is able to predict the degradation in the stiffness of structure, the formation and locations of plastic hinges with increasing the lateral loads, identify members which probably reach critical states during an earthquake and finally evaluate the building performance to the considered earthquake [12]. In nonlinear static analysis the structure is under permanent vertical load and it is subjected to incrementally increasing lateral forces with a predefined invariant height-wise distribution until reaching a target displacement or the structure reaches unstable state. The distributions of lateral load which used in nonlinear static analysis are usually proportional to the height raised to the power of k (where k can be among 0 for distribution of uniform load, 1 for distribution of triangular load and 2 for parabolic distribution). FEMA356 [13] requires k to be depended on the time period of the structure T (k = 1 for T less or equal 0.5 seconds, k = 2 for T more or equal 2.5 seconds and interpolated for intermediate values).The requirements of ATC40 [14] is at least two different load patterns to be utilized in the nonlinear static analysis and result envelope to be utilized. A plot of total lateral load (base shear) with a roof displacement is then drawn which represent the capacity curve of the structure (pushover curve). The capacity curve intersects with the demand on the structure giving the performance point of the structure (in base shear versus roof displacement) to the considered earthquake. FEMA356 and modified FEMA440 [15] use a displacement coefficient method in which the target displacement can be computed based on different factors.

In this study, the pushover analysis based on FEMA356 is utilizedfor evaluating an existing reinforced concrete typical structure in the area according to the design seismicity in Basrah. The analysis was performed to three cases of the building (regular, irregular in plan and irregular in height) using SAP2000 V18 program [16]. Default plastic hinge description and the FEMA356 performance levels shown in figure 2 are utilized in the analysis.

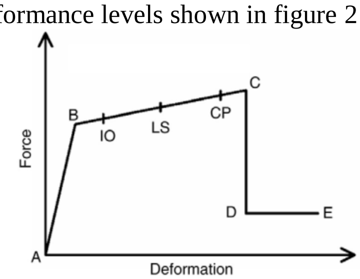

Figure 2: Force-deformation relationship for a typical plastic hinge.

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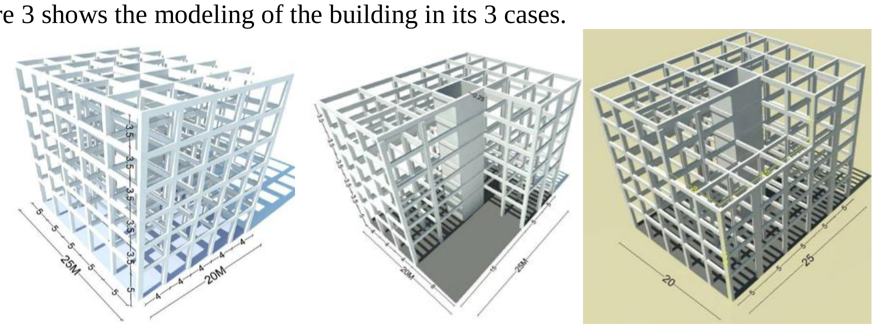
III. BUILDING MODELING AND DESCRIPTION OF MATERIALS

3.1. Buildings Details

The regular building has 5 bays at 4m center to center in X-direction and 5 bays at 5m center to center in Y-direction (20 x 25m plan area). It has 6 stories, the height of the ground one is 5 meters and all the others have a height of 3.5 meters. However changing the stories height is assumed vertical irregularity, but in the present work we assume it regular to differentiate it from setback irregularity. The irregular building in plan has the same spacing as the regular building but 2 bays in X-direction and 3 bays in Y-direction are removed. The irregular building in height also has the same spacing and dimensions, but 2 bays in X-direction and 3 bays in Y-direction are removed only from the last two stories. Figure 3 shows the modeling of the building in its 3 cases.



a- Regular building   b- irregular building in plan   c- irregular building in height

Figure 3: Buildings Dimensions

All slabs are 200mm thick; the rigid diaphragm option in the program is used to represent the slabs action. The foundation of the building is a raft with 80cm thickness (assumed fixed base in the modeling of the structures). Shear walls are not included in this work. Gravity load on the buildings are in addition to the self-weight a live load of 1.5kN/m2 uniformly distributed on the roof and 4.5kN/m2 on the other floors. In pushover analysis all the dead load plus 25% of the live load are assumed permanent on the buildings.
The details of the buildings members in dimensions and reinforcements are given in table 1.

Table 1:Details of Structural Members

Member	Dimension (cm)	Longitudinal Reinforcement
Beams (all)	30*60	6 #7 bars
Exterior Columns	40*70	10 # 8 bars
Internal column	50*50	8 # 8 bars

3.2. Material Properties

The material model used for the concrete is the Mander's model[17,18] as shown in figure 4. For steel reinforcement the Chai's strain hardening model [19] shown in figure 5 is used. The properties of steel and concrete used in this work are given in table 2.

Table 2: Material properties used in the analysis

Material	Property	Value
Steel reinforcement	Yield stress fy	420 MPa
	Modulus of Elasticity Es	200 GPa
	Tensile strength fsu	650 MPa
	Nominal Yield Strain εy	0.0021
	Ultimate Tensile Strain εsb	0.12
	Reduced Ultimate Tensile Strain εsu	0.087
	On Set Strain Hardening εsh	0.0115
	Poisson's Ratio	0.3
Concrete	Unconfined Compressive Strength fco	35 MPa
	Unconfined Compressive Strain at the Maximum Stress εco	0.002
	Unconfined Ultimate Compressive (Spalling) Strain εsp	0.005
	Poisson's Ratio	0.2
	Modulus of Elasticity Ec	30 GPa

IV. RESULTS AND DISCUSSION

A pushover analysisis applied on the three buildings using two codes International Building Code (IBC) & Iraqi Standard Code (ISC) for evaluating their performance for a design earthquake In Basrah Province lying in south of Iraq. The calculation of design earthquake is done according to the IBC 2012 where (Ss=1.3,S1 =0.7,Site class: D) and ISC where(Ss=0.3,S1 =0.1 ,Site class:D).Values of period time due to free vibrationanalysis of the three buildings were 0.574 second, 0.546 second and 0.522 second for the regular, irregular in plan and irregular in height buildings respectively.The analysis includedconcentrated plasticity in which the default plastic hinge built are assigned at the beginning and end of each column (P-M2-M3 hinge) and beam (M2 hinge)in the SAP2000 program.

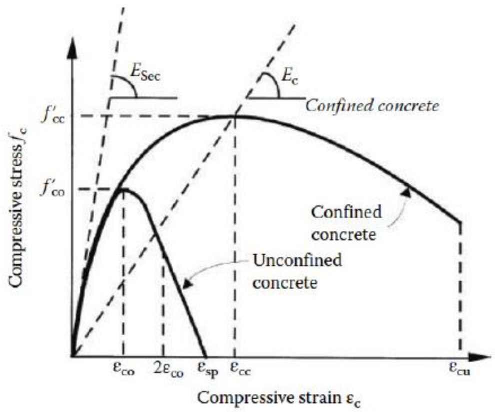


Figure 4: Stress-strain curve of concrete Mander model

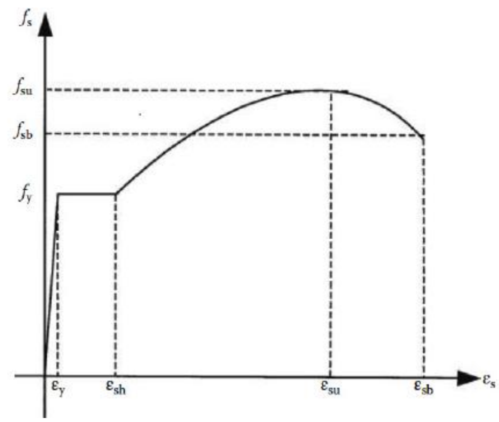


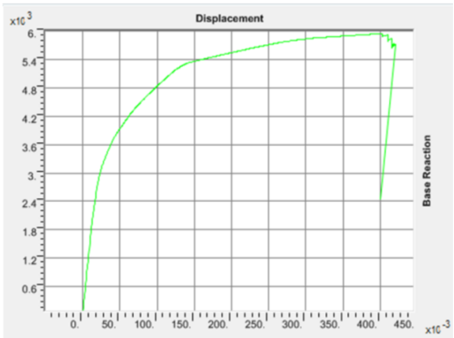
Figure 5: Stress-strain curve for steel reinforcement – Chai strain hardening model

Base shear, roof displacement, floor displacement, number and performance level of plastic hinges at the performance point of each building are given in table below.Table 3: Results of analysis according to FEMA356Coefficient Method for the three buildings.

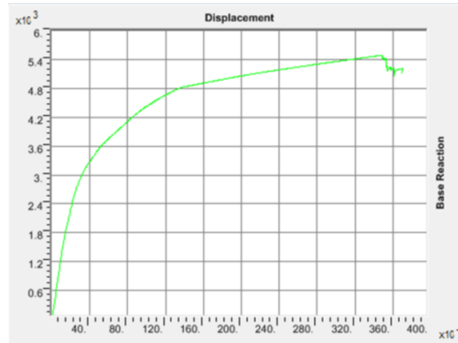
Table 3: Results of the analysis

CASE	IBC code							ISC code						
					No. of Plastic Hinges							No. of Plastic Hinges		
	Base Shear (kN)	Target Displace ment (cm)	Floor Displacement (cm)		(B-IO)	(IO-LS)	(LS-CP)	Base Shear (kN)	Target Displacemen t(cm)	Floor Displacemen t(cm)		(B-IO)	(IO-LS)	(LS - CP)
Regular	5108	34.0	U1	9.82	120	96	120	3506	7.7	U1	2.50	180	0	0
			U2	18.35						U2	4.66			
			U3	25.63						U3	6.17			
			U4	30.59						U4	7.02			
			U5	33.11						U5	7.48			
			U6	33.99						U6	7.71			
Irregular in Plan	4195	36.1	U1	10.30	96	78	96	2875	8.0	U1	2.54	144	0	0
			U2	19.23						U2	4.80			
			U3	26.90						U3	6.42			
			U4	32.23						U4	7.32			
			U5	35.04						U5	7.8			
			U6	36.07						U6	8.04			
Irregular in Height	5168	35.0	U1	10.23	105	102	117	3599	7.8	U1	2.58	180	0	0

Figure 6 shows the pushover curves in X and Y directions for the regular building



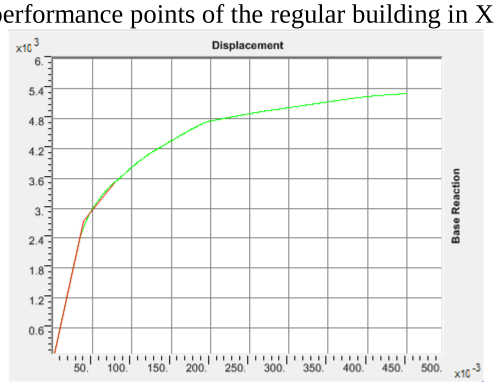
a- pushover curve in X direction



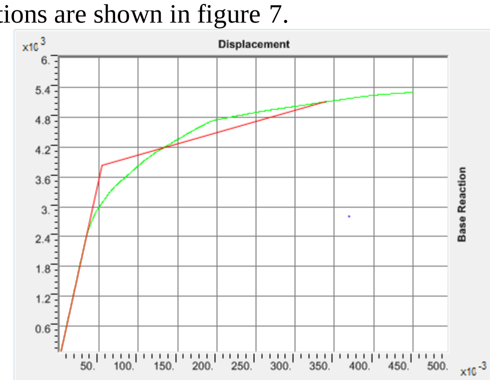
b- pushover curve in Y direction

Figure 6 pushover curve for regular building a- in X- direction and b- in Y- direction

The performance points of the regular building in X and Y directions are shown in figure 7.

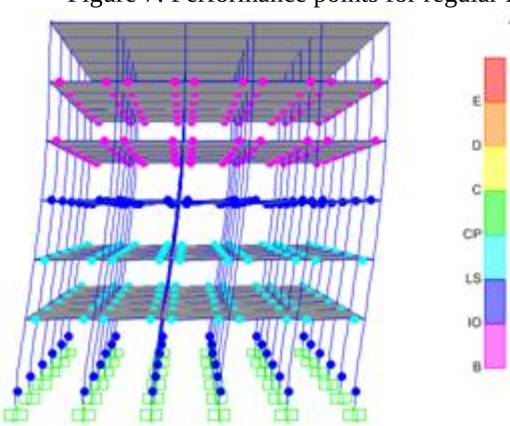


a- Using ISC code

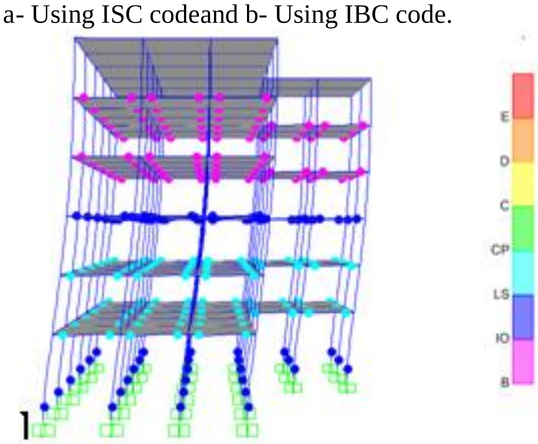


b- Using IBC code

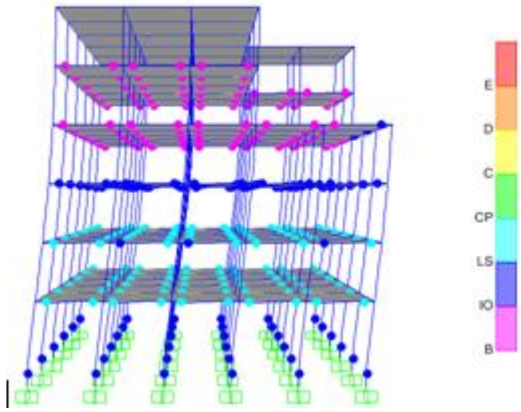
Figure 7: Performance points for regular Building a- Using ISC codeand b- Using IBC code.



a- regular in X



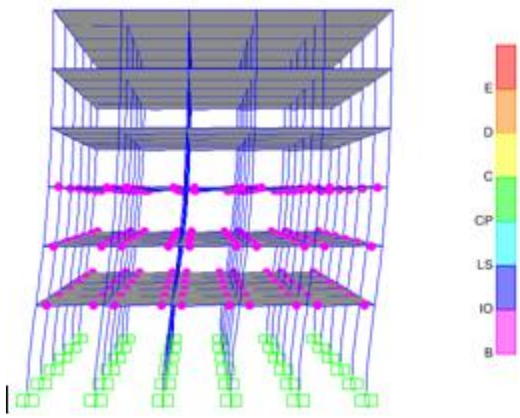
b- irregular in plan in X



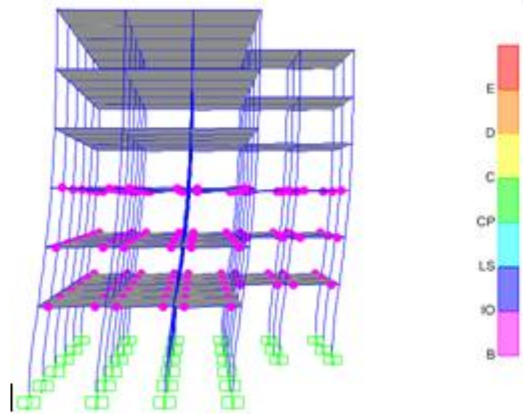
c- irregular in height in X

Figure 8 Performance levels of the plastic hinges in the three buildings Using IBC code

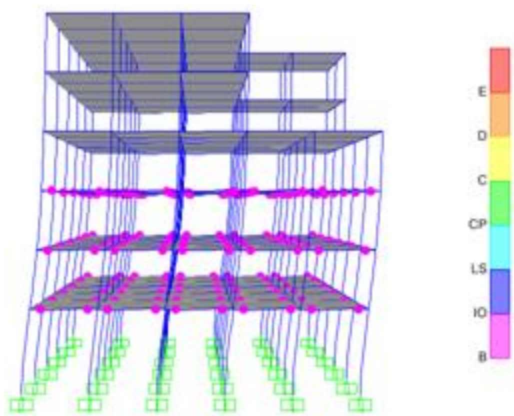
Performance levels of the plastic hinges in the three buildings Using ISC code are given in fig.9



a- regular in X



b- irregular in plan in X



c- irregular in height in X

Figure 9 Performance levels of the plastic hinges in the three buildings Using ISC code

Stories lateral displacements and drifts for the three buildings in both directions at the performance points are given in figures 10 and 11 respectively.

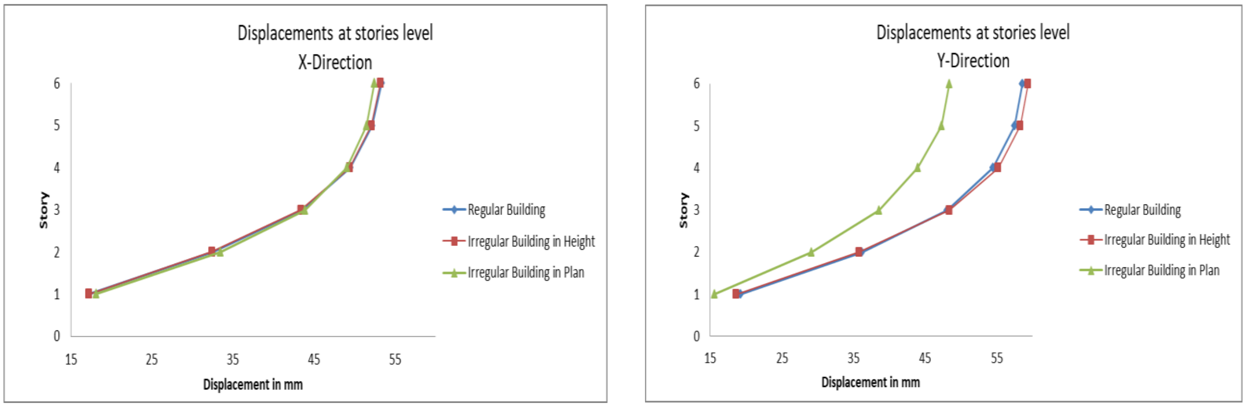


Figure 10: Lateral displacements at stories levels at the performance point

Results showed that the building in all its three cases for IBC2012 code is within life safety (L.S) performance level and this means that building has cracks and remains out of serviceability until rehabilitation is done but for ISC code the building is within immediate occupancy (IO) performance level and this means that building is still serviceable and it has minor cracks can beretrofitted rapidly. The base shear for all buildings when using IBC code are approximately 45% more than base shear values when using ISC code but the target displacement for all buildings when using ISC code are approximately 3.5 times the target displacement values when using IBC code.

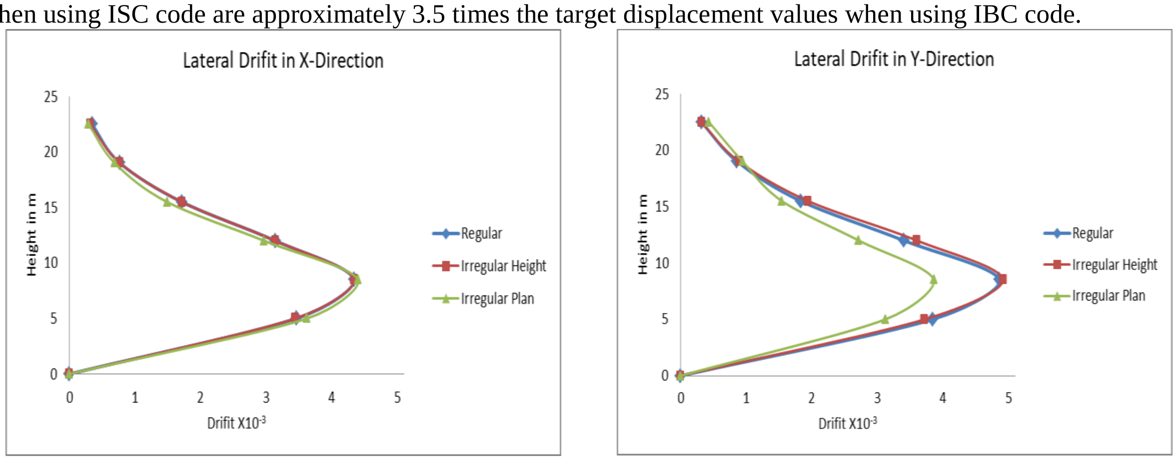


Figure 11: Inter-story drift at the performance point

V. CONCLUSINS

The following conclusions can be drawn from the results of analysis:-

1- The three buildings analyzed showed two performance levels: immediate occupancy (I.O) level when using ISC code and life safety (L.S) when using IBC code.

2- Irregularity in the building doesn’t affect the analysis results in terms of inter-story drift, structural drift or performance level since the stresses are close the elastic limit.

3- The most dangerous or less safety case is when building irregular in plan when using IBC code where base shear and target displacement values are 4195 kN and 36.1cm respectively.

4- The buildings in all its three cases and when using both codes ISC and IBC never arrive the collapse state.

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