International Journal of Engineering & Technology, 7 (4.20) (2018) 51-58

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Seismic Analysis of Reinforced Concrete Buildings in South of Iraq based on Different Codes

Samir A. B. Al-Jassim[1]*, Haider Abdul Kareem Raheem[2]

[1] *Basrah University- Engineering Collage – Civil Engineering Department*
[2] *Basrah University- Engineering Collage – Civil Engineering Department*
** Corresponding author E-mail: samiraljassim@gmail.com:*

Abstract

Buildings in south of Iraq were designed for gravity loads only. Recent studies showed that the Badra-Amarah fault at the Iraq-Iran boarder is an active fault and could suffer a major damage. Hence seismic evaluation of existing buildings is getting more importance. The objective of this paper is to assess the seismic performance of two reinforced concrete buildings with six floors each, one has a shear wall and the other has not. The concentrated plasticity with nonlinear time history is adopted for the analysis. The spectrum matching method is used to scale three time-acceleration records to the expected seismic level in the region. Three different codes are used for the analysis, the International building code-2012, the Uniform building code-1997 and the Iraqi seismic code-2017. Comparison of results showed that IBC-2012 gave the most conservative results in displacements, number and performance of plastic hinges and base shear. The Iraqi code gave the least values within 60% for the base shear and 18-50% for drifts. As a conclusion, the analyzed buildings are a little beyond the elastic level according to the Iraqi code, beyond the immediate occupancy level according to the UBC-1997 and near the collapse prevention level according to IBC-2012.

Keywords: *concentrated plasticity; nonlinear time history analysis; performance levels; SAP2000 program; spectrum matching.*

1. Introduction

The first Iraqi seismic code [1] was published in 1997 but it was neither include a probabilistic seismic hazard assessment for Iraq [2,3] nor mandated in the building industry, therefore most of the buildings in south of Iraq were designed without considering seismic forces. Recent seismological studies in Iraq showed that the eastern border of Iraq is a seismically active zone and represent part of the convergent plate between the Arabian, Anatolian and Iranian plates [4,5]. Abdulnaby et al 2016 [6] showed that the Badra-Amarah fault which is located at the south east and extend to the central east of Iraq 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 magnitude). The Badra-Amarah fault represents the boundary to the Mesopotamian zone in Iraq that has an alluvial thick sediment soil and can be susceptible to liquefaction during an earthquake shaking [5]. In 2017 the new Iraqi seismic code [7] was released, it is based on probabilistic seismic hazard assessment (PSHA) for Iraq but it is not mandated yet. In the last few years many seismic activities of different intensities were felt by the people in the south of Iraq some of them were strong enough to make the residents in multi stories buildings spent an overnight in the streets afraid from aftershock earthquakes. These events inspired engineers and landlords to evaluate the seismic performance of some important existing buildings, and to include the seismic loads in the design of new buildings.

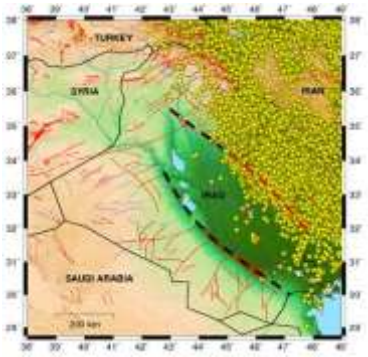


Figure 1: Seismicity of Iraq and adjacent areas taken from the Iranian Records of Seismic Catalogue IRSC (from 1/1/2006 to 1/10/2014) as given in ref.[5]

2. Nonlinear time history analysis for seismic evaluation of buildings

Buildings designed primarily for gravity loads may not perform well during earthquakes and represent a risk to life. Most of the new building codes include nonlinear analysis methods (either static or dynamic) for performance evaluation of existing buildings or design of new buildings [8]. The availability of fast computers and nonlinear structural analysis programs made it possible for engineers to employ nonlinear analysis methods for seismic evaluation of structures. In recent years, several nonlinear static and dynamic analysis methods based on performance based engineering have been developed and a greater attention to damage control has been paid. All these analysis methods involve some approximation to true behavior. Among all these methods, the

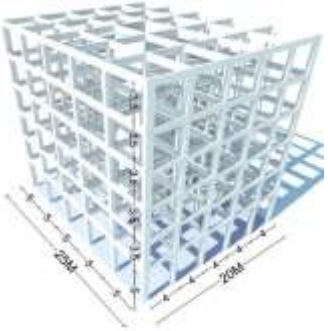
Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

most advanced and reliable method is the nonlinear response history analysis (NRHA) [9]. The method required the use of recorded acceleration-time histories as an input to represent the seismic loads on the structures. The acceleration-time histories to be employed for the analysis should be consistent with the seismicity of the building site and representative of the expected (design) earthquake [10] which is defined as a 10% (or 2%) probability of exceedance in 50 years depending on the importance of the building [11]. The seismicity of the building site includes earthquake magnitude, faulting mechanism, source to site distance and near fault directivity conditions [12]. Therefore the selection of a suitable acceleration-time history records that reflect all the aforementioned seismicity requirements is not an easy task and in some cases the records selection is more critical than the building modeling [13]. The available data bases of recorded acceleration-time histories are mostly for high seismicity zones and very rare records available for low to moderate seismicity zones as the case of Iraq especially in soft soils [14], which requires a scaling of the selected records to be consistent with the site characteristics. Many scaling procedures have been proposed, however the most suitable procedure is the spectrum scaling in which the acceleration-time record is scaled to be compatible with the design spectrum of the building [15,16,17,18]. In this work and due to the non-availability of recorded acceleration-time histories for the south of Iraq area, and based on the minimum requirement of ASCE7-10 [19] three motion records are selected from pacific earthquake engineering research center (PEER) [20] database to be used for the analysis. The selected records are then scaled to fulfil the seismicity in the region of south of Iraq using a seismomatch 2016 computer program [21]. A 5% damped linear spectrum from 3 different codes namely UBC-97 [22], IBC-2012 [23] and ISC-2017 [7] are used for matching to compare the difference in the codes evaluation of the seismicity in the region. Finally the nine records are input to the SAP2000 V18 program [24] for the analysis of two reinforced concrete similar buildings one with a shear wall and the other without.

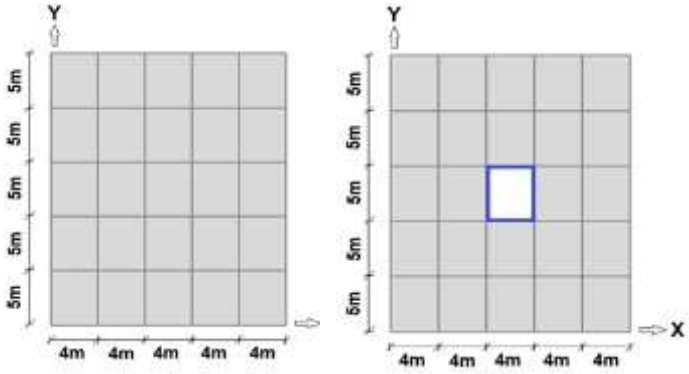
2. Description of the case study

3.1. Building description

A typical reinforced concrete building of six stories is used for the analysis and evaluation in this work. The building analyzed in two cases one with a shear wall and the other without. The 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). The height of the first floor is 5m and all the other floors have a height of 3.5m (22.5m total height). The shear wall location is around the perimeter of the central bay for the case of the building with a shear wall. A frame element is used for the modeling of the beams and columns while shell element is used for the modeling of the slabs and shear walls in the buildings. In addition to the self-weight of the building, 25% of the live load of 1.5kN/m^2 uniformly distributed over the roof and 4.5kN/m^2 uniformly distributed over the other floors are assumed permanent during the dynamic analysis. The foundations of the building in the two cases are raft and assumed fixed base in the analysis. Figure 2 shows the building details.



a- 3-dimensional model



b- plan without shear wall c- plan with shear wall

Figure 2: Building details

The dimensions and reinforcement details of the structural members of the buildings are given in table 1.

Table 1: Structural Members Details

Member	Dimension (cm)	Longitudinal Reinforcement	Transverse Reinforcement
Beams (all)	30*60	6 #7 bars	#3 stirrups at 100mm
Columns (all)	50*50	10 # 8 bars	#3 stirrups at 100mm
Shear wall	25 cm thick	# 8 bars at 20cm center to center in two layers	#3 bars at 20cm center to center

All slabs are 20cm thick; a rigid diaphragm option in the program is used to represent the slab action.

3.2. Material properties

The material model used for the concrete is the Mander's model [25,26] as shown in figure 3. For steel reinforcement the Chai's strain hardening model [27] shown in figure 4 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

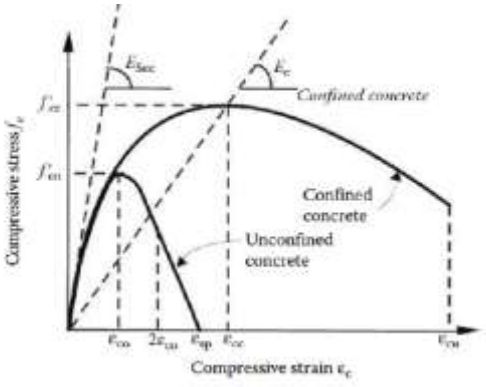


Figure 3: Stress-strain curve of concrete – Mander model as given in ref. [25,26]

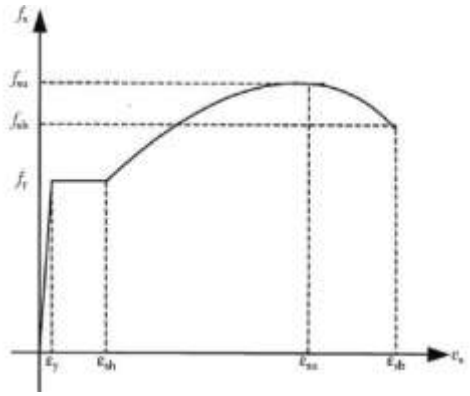


Figure 4: Stress-strain curve for steel reinforcement – Chai strain hardening model as given in ref. [27]

3.3. Plastic hinges and performance levels

The default plastic hinge description based on the applied technology council report ATC-40 [28] for reinforced concrete members available in the SAP2000 program is used and assigned at the beginning and end of each beam and column in the buildings. The description of the federal emergency management agency FEMA-356 [29] for the performance levels shown in figure 5 are used to evaluate the plastic hinges performance levels during the earthquake. Where IO stands for immediate occupancy, LS for life safety and CP for collapse prevention performance levels.

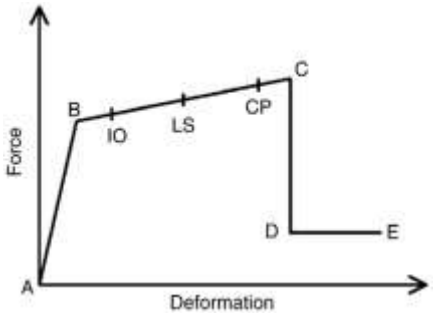


Figure 5: Force-deformation relationship for a typical plastic hinge

3.4. Codes and scaling of earthquake records.

Three actual acceleration-time records are selected from the PEER ground motion database in the horizontal direction and applied in both X and Y directions to the buildings. The details of the records are given in table 3.

Table 3: ground motion records information

Record	Event	Year	Station	Magnitude	Mechanism
1	Northern California-3	1954	Ferndale City Hall	6.5	Strike slip
2	Irpinia Italy-01	1980	Bisaccia	6.9	Normal
3	Imperial Valley-06	1979	El Centro Array #13	6.53	Strike slip

Each of the above records is scaled by spectrum matching method to represent the expected (design) earthquake at the south of Iraq with a probability of exceedance of 10% in 50 years (a return period of 475 years). a linear spectrum with 5% damping ratio from three different codes namely the UBC-97, the IBC-2012 and the ISC-2017 are input to the seismomatch 2016 program for the records matching process. The three spectrums are shown in figure 6. The records before and after matching to UBC-97, IBC-2012 and ISC-2017 are shown in figures 7, 8 and 9 respectively. The matched records are then input to the SAP2000 V18 program as seismic forces for the analysis of the two buildings.

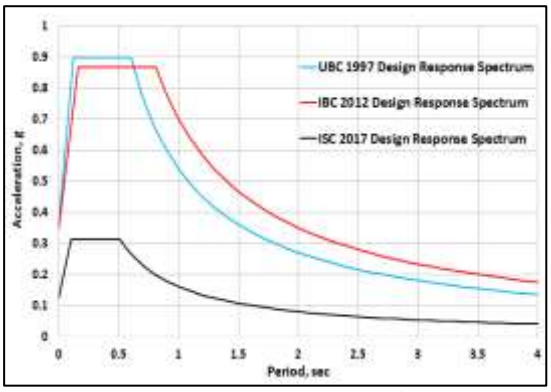


Figure 6: The 5% linear spectrums used for matching

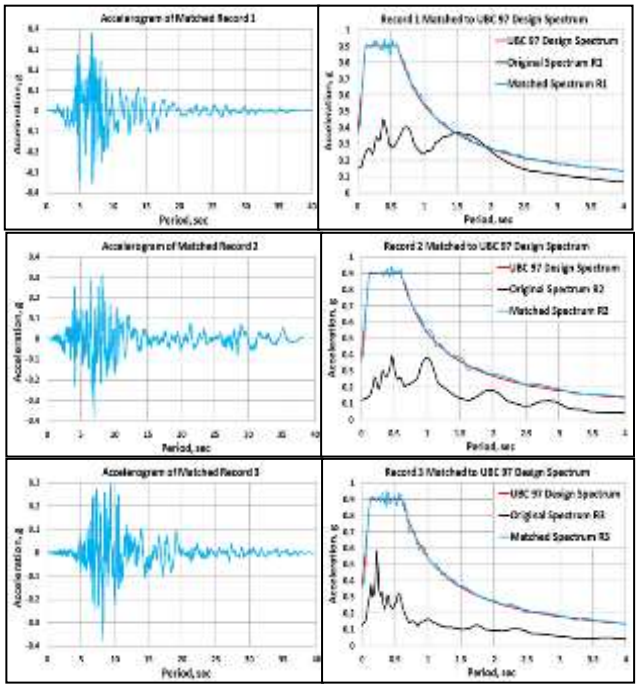


Figure 7: Records matching to UBC-97 code.

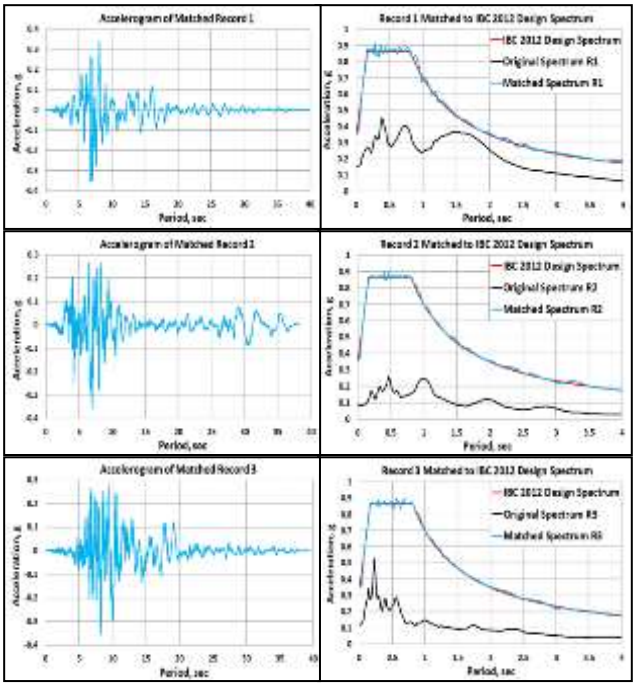


Figure 8: Records matching to IBC-2012 code.

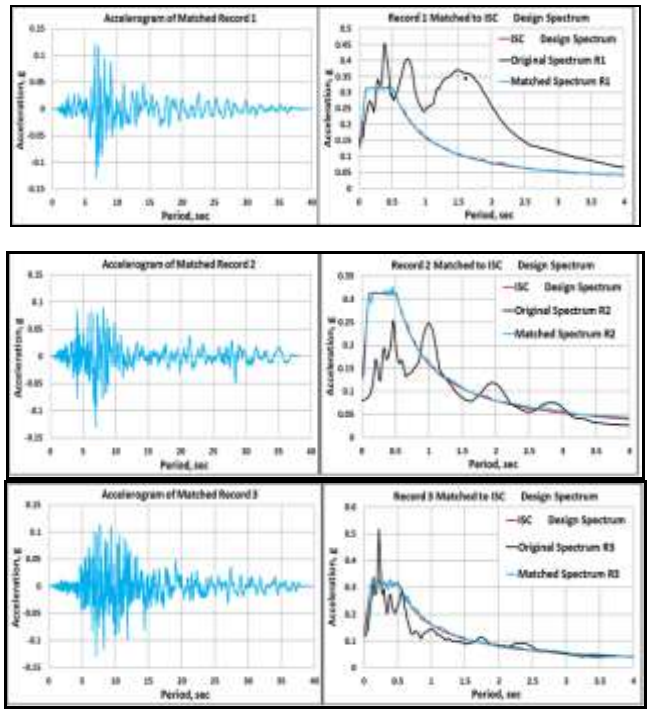


Figure 9: Records matching to ISC-2017 code.

4. Results and discussion

The main results of the case studied are given in the following:-

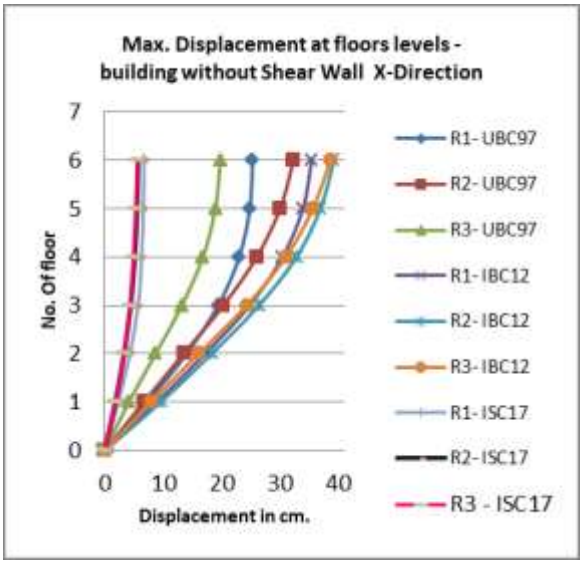
i. Maximum displacements at stories level in both directions X and Y for the two buildings are shown in figure 10.

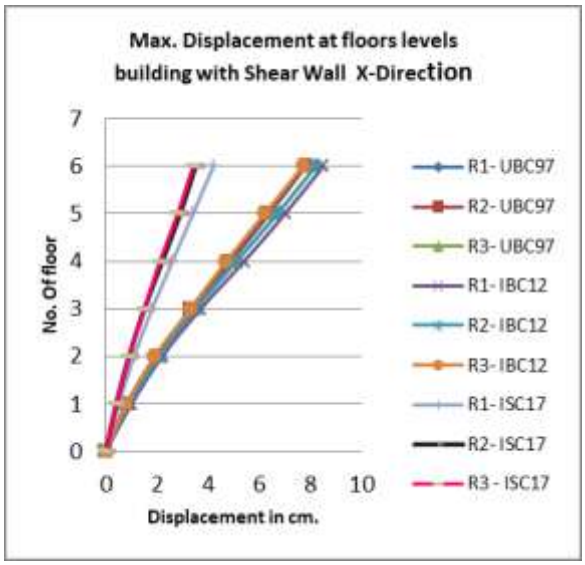
ii. Inter-story drift for the two buildings in both directions X and Y are shown in figure 11.

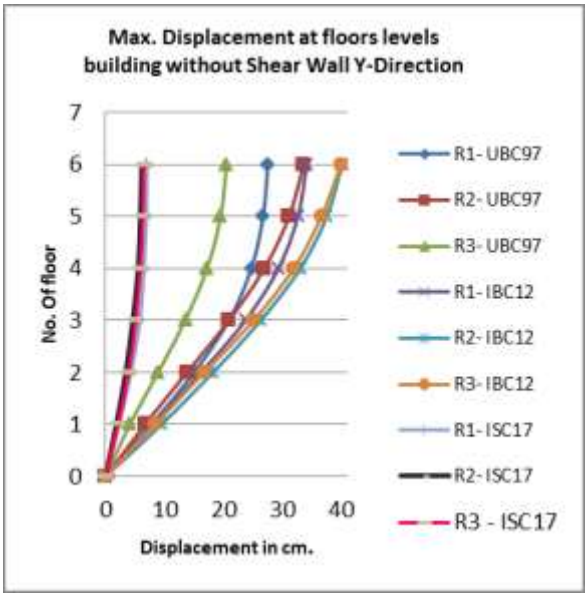
iii. Plastic hinges numbers, their performance levels, total base shear, maximum inter-story drift and maximum structural drift from three earthquake records and based on the three codes in X-direction are given in table 4.

iv. Plastic hinges numbers, their performance levels, total base shear, maximum inter-story drift and maximum structural drift from three earthquake records and based on the three codes in Y-direction are given in table 5.

v. Locations of the maximum plastic hinges performed in the buildings from the three earthquakes and their performance levels according to each code in X- direction are shown in figure 12.







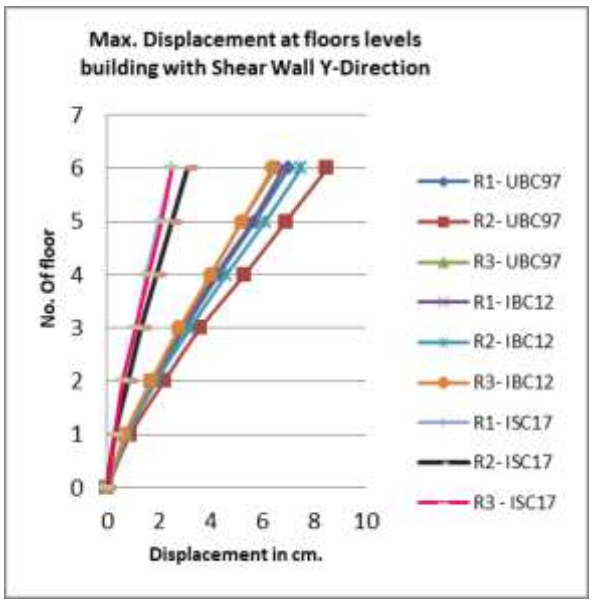


Figure 10: Maximum displacements at stories levels from 3 earthquakes records and based on the three codes for the two buildings in X and Y directions

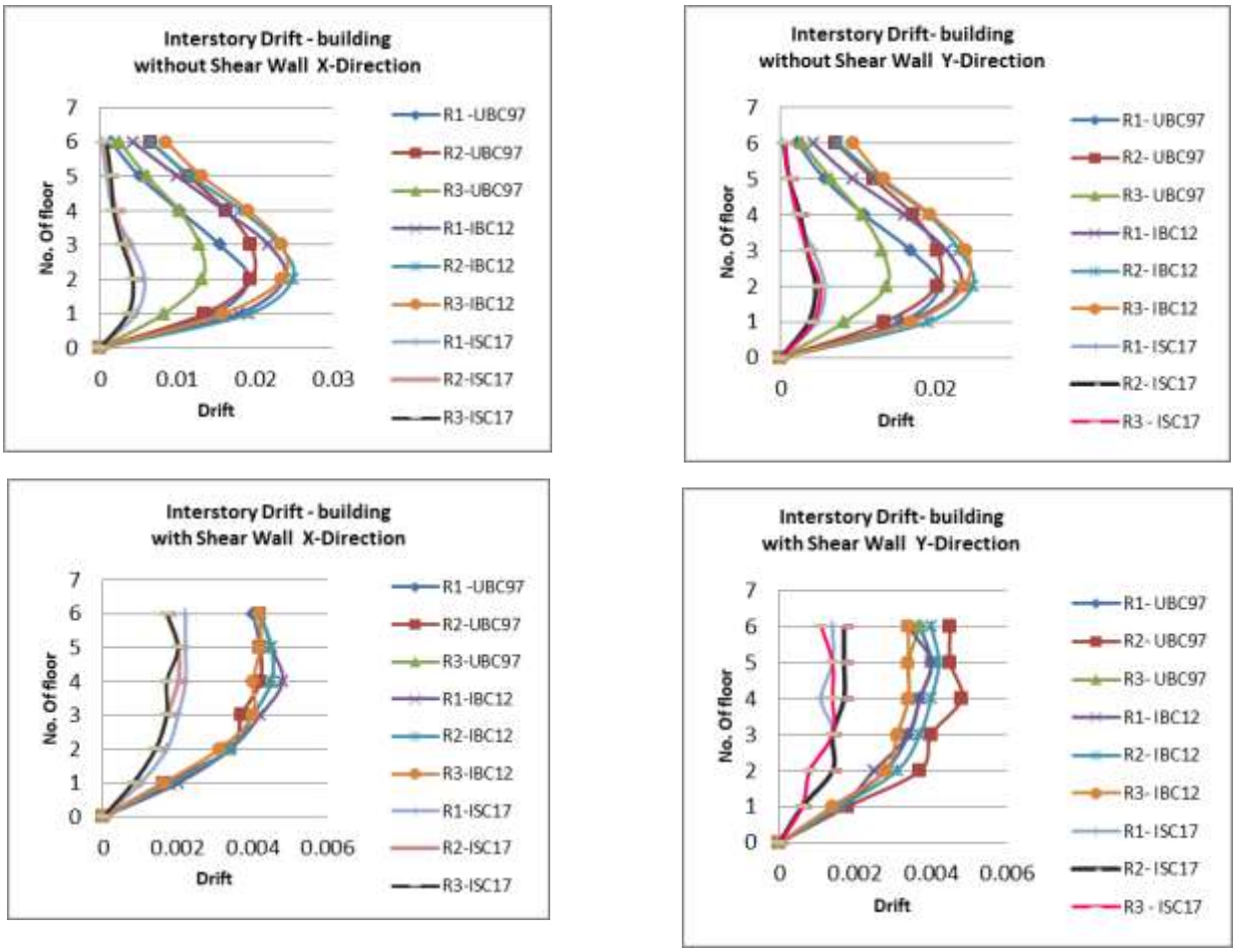


Figure 11: Inter-story drifts from 3 earthquake records and based on the three codes for the two buildings in X and Y directions.

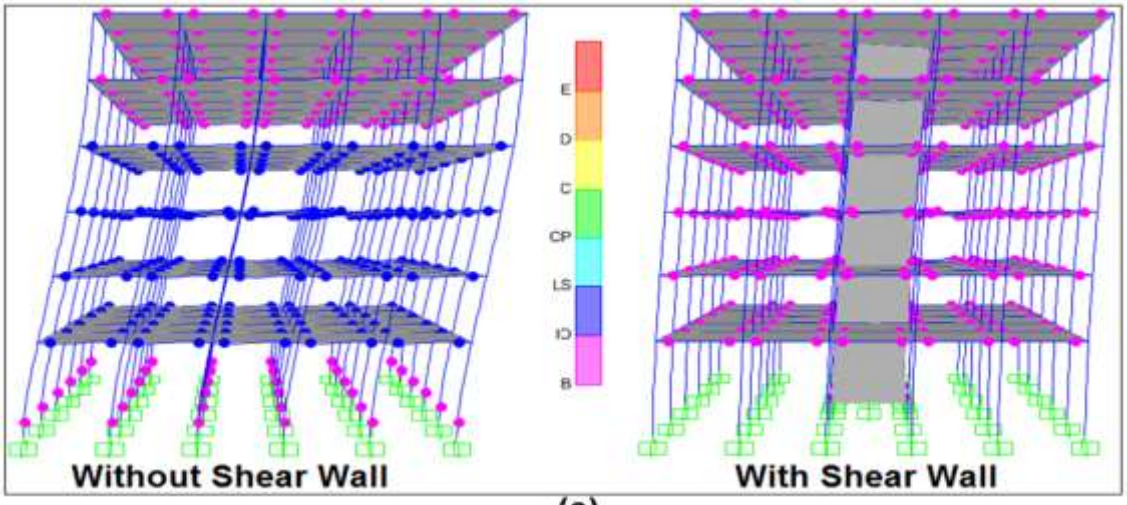
Table 4: Number and performance of plastic hinges, base shear, and maximum drift in X-direction.

Earthquake direction		X-Direction					
Shear wall		Without shear wall			With shear wall		
Record number		1	2	3	1	2	3
UBC 97	B-IO	130	156	174	350	352	352
	IO-LS	210	240	128	0	0	0
	LS-CP	0	0	0	0	0	0
	CP-E	0	0	0	0	0	0
	Total P.H	340	396	302	350	352	352
	Base Shear (kN)	5242	4924	4583	21988	18918	19341
	Inter-story Drift %	1.91	1.94	1.31	0.42	0.42	0.45
	Structural Drift %	1.12	1.44	0.9	0.35	0.35	0.36
IBC 2012	B-IO	96	120	60	352	352	352
	IO-LS	156	120	238	0	0	0
	LS-CP	120	156	96	0	0	0
	CP-E	0	0	0	0	0	0
	Total P.H	372	396	394	352	352	352
	Base Shear (kN)	5337	5186	5377	22442	19706	20801
	Inter-story Drift %	2.37	2.48	2.35	0.48	0.45	0.42
	Structural Drift %	1.57	1.74	1.71	0.38	0.36	0.34
ISC 2017	B-IO	180	166	174	100	42	38
	IO-LS	0	0	0	0	0	0
	LS-CP	0	0	0	0	0	0
	CP-E	0	0	0	0	0	0
	Total P.H	180	166	174	100	42	38
	Base Shear (kN)	3377	2946	3052	11520	9814	9547
	Inter-story Drift %	0.57	0.42	0.42	0.22	0.2	0.2
	Structural Drift %	0.3	0.25	0.25	0.19	0.16	0.15

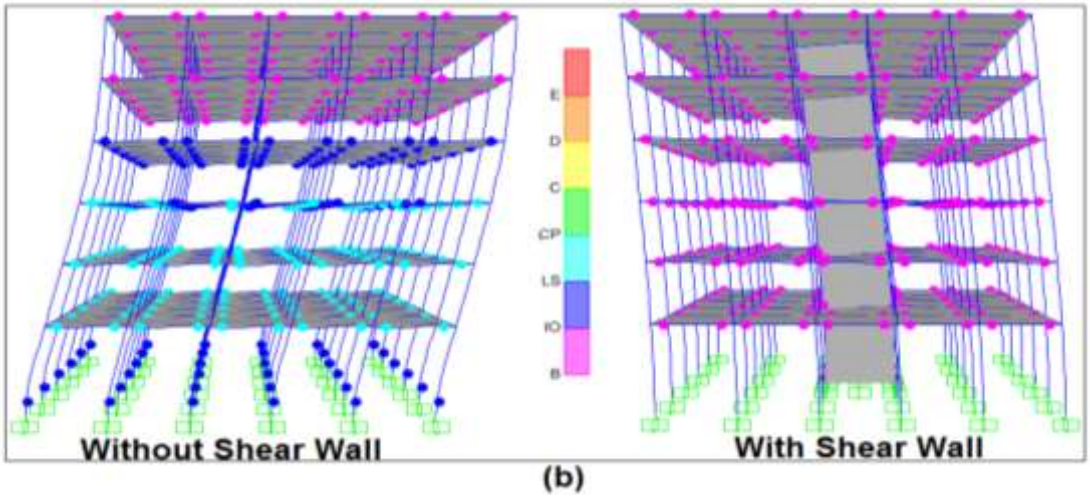
Table 5: Number and performance of plastic hinges, base shear, and maximum drift in Y-direction

Earthquake direction		Y-Direction					
Shear wall		Without shear wall			With shear wall		
Record number		1	2	3	1	2	3
	B-IO	126	156	180	298	388	284

UBC 97	IO-LS	212	240	120	0	0	0
	LS-CP	0	0	0	0	0	0
	CP-E	0	0	0	0	4	0
	Total P.H	338	396	300	298	392	284
	Base Shear (kN)	5009	4830	4442	23013	26730	22749
	Inter-story Drift %	2.05	2.02	1.37	0.4	0.48	0.34
	Structural Drift %	1.22	1.5	0.9	0.31	0.38	0.29
IBC 2012	B-IO	126	116	60	290	340	288
	IO-LS	210	128	226	0	0	0
	LS-CP	36	152	108	0	0	0
	CP-E	0	0	0	0	0	0
	Total P.H	372	396	394	270	340	288
	Base Shear (kN)	5382	5008	5395	23254	25109	22946
	Inter-story Drift %	2.31	2.48	2.4	0.4	0.42	0.34
	Structural Drift %	1.51	1.78	1.78	0.3	0.33	0.28
ISC 2017	B-IO	186	174	180	8	24	10
	IO-LS	0	0	0	0	0	0
	LS-CP	0	0	0	0	0	0
	CP-E	0	0	0	0	0	0
	Total P.H	186	174	180	8	24	10
	Base Shear (kN)	3254	2928	3102	8891	10952	9375
	Inter-story Drift %	0.57	0.45	0.51	0.14	0.17	0.14
	Structural Drift %	0.31	0.27	0.29	0.11	0.14	0.11



(a)



(b)

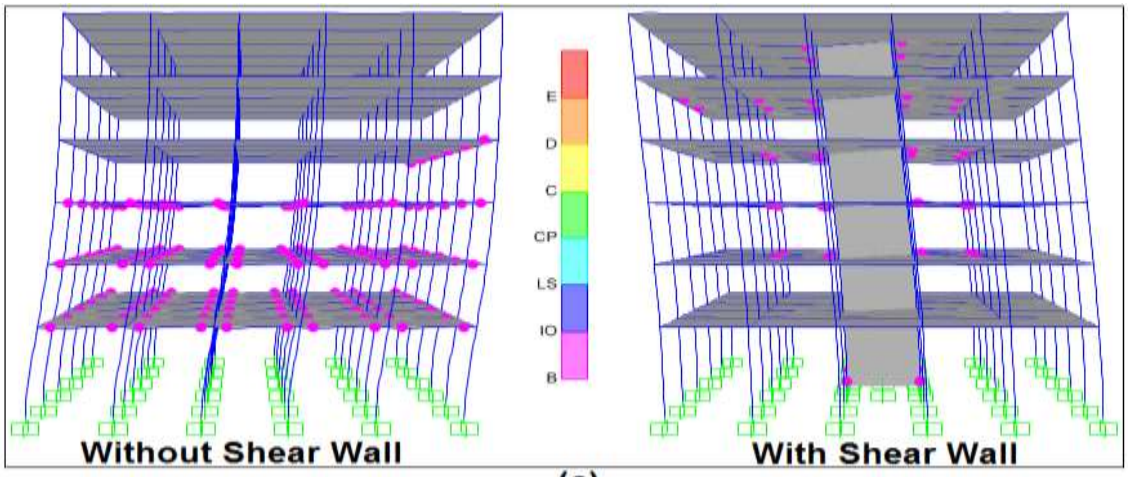


Figure 12: Locations and performance levels of maximum plastic hinges in the two buildings in X-Direction a- based on UBC97 code , b- based on IBC2012 code and c- based on ISC2017 code.

Results clearly show the large difference in evaluating the seismic response of the buildings between the Iraqi seismic code and the other two international codes. It looks like the Iraqi code is under-estimate the seismic forces in the region (the base shear are within 60%, the inter-story drift within 25% and the structural drift within 18% compared to the other codes for the building without shear wall and the base shear, inter-story drift and structural drift are within 50% for the building with shear wall compared to the other codes). Tables 4 and 5 show that the buildings respond differently to each earthquake record and the response of the building with shear wall in Y-direction is slightly higher based on the uniform building code than the international building code. The two buildings perform very well according to the Iraqi code (in both directions) as the inter-story drift and maximum drift are both below 1% which is the limit for immediate occupancy level according to ATC-40, this means that the buildings behave in nearly elastic behavior. The higher effects of the studied earthquakes were due to IBC2012 code. The building without shear wall is more affected than the one with shear wall, it has a considerable number of plastic hinges exceeded the immediate occupancy to the life safety level, but still its maximum structural drift is less than 2% which is the limit for life safety performance level according to ATC-40. Also figure 12 clarifies that both of the buildings behave in weak beams strong columns manner as the hinges started in the beams of the second, third and fourth floors where the inter-story drifts are higher, extended then to the beams of the higher floors and finally to the columns at the base . As a result, the building without shear wall will perform well under the expected earthquake according to the Iraqi seismic code while it requires retrofitting to increase its seismic resistance based on the UBC97 and IBC2012 codes. The building with the shear wall expected to perform well according to all codes.

5. Conclusion

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

i. The buildings respond differently to each earthquake records, which confirm the requirement of good selection and scaling of the records (the maximum results of 3 records or the average of 7 records as required by ASCE/SEI-7-10).

ii. The seismicity given by the IBC2012 code for the region is the highest while the given by the Iraqi seismic code ISC2017 is the lowest. In general, results based on the Iraqi seismic code are within 50-60% in the base shear and within 18-50% for the drift comparing to the two international codes. This requires more studies to check the efficiency of the Iraqi seismic code.

iii. Maximum base shear developed in the building without shear wall is about 20% in average of the maximum base shear developed in the building with shear wall.

iv. Both of the buildings behave in weak beams strong columns which is preferable during earthquakes.

v. The building with a shear wall responds well to the design earthquake in approximately linear behavior based on the three codes as its plastic hinges up to immediate occupancy level and its structural drift less than 1% of the immediate occupancy level.

vi. The building without shear wall is more fragile to earthquake especially based on the UBC-97 and IBC-2012. More than 60% of the plastic hinges developed in the building exceeding the immediate occupancy to the life safety level in both directions according to the UBC-97 code while about 40% of the plastic hinges developed exceeding the life safety level to the collapse prevention level according to the IBC-2012 code. No plastic hinges exceeded the immediate occupancy level according to the Iraqi seismic code ISC-2017.

vii. The building without shear wall need to be retrofitted if it is required to continue working after the expected earthquake based on the two international codes.

References

[1] ISCR (1997) "Iraqi seismic code requirements for buildings", Building research center, Ministry of Industry and minerals, republic of Iraq.

[2] Ameer A. S., Sharma M. L., Wason H. R., and Alsinawi S. A., (2005) "Probabilistic seismic hazard assessment for Iraq using complete earthquake catalogue files", Pure and applied geophysics, 162: pp951-966.

[3] Onur T., Gok R., Abdulnaby W., Shakir A., Mahdi H., Numan N., Al-Shukri H., Chalib H., Ameen T., and Abd N., (2016) "Probabilistic seismic hazard assessment for Iraq", Technical report to Lawrence Livermore national laboratory, LLNL-TR-691152.

[4] Abdulnaby W., Mahdi H., Numan N. and Al-Shukri H., (2014) " Seismotectonics of the Bitlis-Zagros fold and thrust belt in northern Iraq and surrounding regions from moment tensor analysis", Pure and applied geophysics, 171-7: pp1237-1250

[5] Abdulnaby W., Mahdi M., Al-Mohamed R. and Mahdi H., (2016) "seismotectonics of Badra-Amarah fault, Iraq-Iran border", journal of applied geology and geophysics, 4-3: pp27-33.

[6] Abdulnaby W., Al-Mohamed R. and Mahdi M., (2016) "Seismicity and recent stress regime of Diyala city Iraq-Iran border", Modeling earth system and environment, 2-3, Article no.142.

[7] ISC (2017) "Iraqi seismic code requirement for buildings", Ministry of housing and construction, Iraq.

[8] Paksoy M., Mola E. and Mola F., (2014) "A comparative study of Italian code-based seismic vulnerability assessment procedures for existing buildings", Second European conference on earthquake engineering and seismology, Istanbul, Turkey.

[9] Causevic M. and Mitrovic S., (2010) "Comparison between nonlinear dynamic and static seismic analysis of structures according to European and US provisions", Bulletin of earthquake engineering, 9-2,pp 467-489.

[10] Michaud D. and Leger P., (2014) "Ground motion selection and scaling for nonlinear dynamic analysis of structures located in eastern north America", Canadian journal of civil engineering, 41 pp232-244.
[11] Lee L. H., Lee H. H. and Han S. W., (2000) "Methods of selecting design earthquake ground motions for tall buildings", The structural design of tall buildings, 9 pp 201-213.
[12] Wang G., Youngs R., Power M. and Li Z., (2015) "Design ground motion library an interactive tool for selecting earthquake ground motions", Earthquake spectra, 31-2,pp 617-635.
[13] Katsanos E. I., Sextos A. G. and Monalis G. D., (2010) "selection of earthquake ground motion records a state of the art review from a structural engineering perspective", Soil dynamics and earthquake engineering, 30, pp 157-169.
[14] Catalan A., Climent A. B. and Cahis X., (2010) "Selection and scaling of earthquake records in assessment of structures in low to moderate seismicity zones", Soil dynamics and earthquake engineering, 30, pp 40-49.
[15] Georgioudakis M., Fragiadakis M. and Papadrakakis M., (2017) "Multi-criteria selection and scaling of ground motion records using evolutionary algorithms", Procedia engineering, 199 pp 3528-3533.
[16] Samanta A. and Huang Y. N., (2017) " Ground motion scaling for seismic performance assessment of high rise moment resisting frame building", Soil dynamics and earthquake engineering, 94, pp 125-135.
[17] Huang Y. N., Whittaker A. S., Nuco N. and Hamburger R. O., (2011) " Scaling earthquake ground motions for performance-based assessment of buildings", American society for civil engineers ASCE, Journal of structural engineering, 37, pp 311-321.
[18] Ozer B. and Akkar S., (2012) " A procedure on ground motion selection and scaling for nonlinear response of simple structural systems", Earthquake engineering and structural dynamics, 41-12, pp 198-213.
[19] American Society for Civil Engineers ASCE/SEI-7-10 (2010), "Minimum design loads for Buildings", Restone, VA.
[20] Pacific earthquake engineering research center (PEER), (2016) "Strong motion database", Berkeley, California.
[21] Earthquake engineering software solutions SeismoSoft, Seismomatch program (2016), Pavio, Italy.
[22] UBC (1997) "Uniform building code", International conference of building officials, Whittier, California, USA.
[23] IBC (2012) "International building code", International code council, Inc.
[24] SAP2000 V-18, "Integrated software for structural analysis and design", Computer and structures Inc., Berkeley, CA, USA.
[25] Mander J. B., Priestley M. and Park r., (1988a) "Theoretical stress-strain model for confined concrete", Journal of structural engineering, ASCE, 114-8: pp1804-1826.
[26] Mander J. B., Priestley M. and Park r., (1988b) "Observed stress-strain behavior of confined concrete", Journal of structural engineering, ASCE, 114-8: pp1827-1849.
[27] Chai Y. H., Priestley M. and Seible F., (1990) "Flexural retrofit of circular reinforced bridge columns by steel jacketing", Report no.SSRP-91-05, University of California, San Diego, CA, USA. Chai Y. H., Priestley M. by steel jacketing", Report no.SSRP-91-05, Uni

[28] ATC 40 (1996) "Seismic analysis and retrofit of concrete buildings", volume I, Applied technology council, Redwood city, CA, USA.
[29] FEMA-356, (2000) "Pre-standard and commentary for seismic rehabilitation of buildings", Federal Emergency Management Agency, Washington, DC..