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Seismic Performance Assessment of Reinforced Concrete Building in Basra and Baghdad: A Comparative Study

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***Abstract*—This paper aims to study the seismicity of Baghdad and Basra and compare the responses of structures in both cities. Basra and other Iraqi provinces or cities, mainly the cities that lie near or adjacent to the Iranian border to the east, experience light to moderate earthquakes from time to time. Therefore, the buildings and other structures should have enough resistance to the earthquake. This comparative study is important to know the impact of location on the structures. One of the analysis methods is called nonlinear static analysis (Pushover Analysis); in this method, the building is analyzed and then evaluated to know its performance against seismic force. In this work, pushover analysis depends on ATC 40 capacity spectrum to analyze and evaluate the G+5 floors RC building by choosing two different locations in Iraq, Basra, and Baghdad, which lie in zone 1 and zone 3, respectively, according to the UBC 70 code using SAP 2000 software. The results showed that the base shear of the building in Baghdad is 19% more than the base shear of the building in Basra whereas the target displacement of the building in Baghdad is 73% more than the target displacement of the building in Basra. The performance level of the building in Basra was immediate occupancy which means the building had light damage In contrast; the performance level of the building in Baghdad was life safety, which means the building had moderate damage. It is suggested to redo this work using another code to check how realistic these results are.**

Keywords*—*Nonlinear static analysis, Pushover analysis, Capacity spectrum, Reinforced concrete building, SAP 2000, Performance levels.

I. Introduction

Since 1900, Iraq has experienced around 104 quakes of magnitude (5- 7.2) , One quake had magnitude more than 7 degrees and 5 quakes between magnitude 6 and 7 degrees and 98 quakes between five and 6 degrees. A powerful earthquake along the Iraq-Iran border killed over 400 people in both countries on Nov. 13, 2017. Baghdad has experienced seven quakes of magnitude above 2 and 3.5 since 1970, whereas Basra has had 17 quakes of magnitudes above 2 and up to 4 since 2022[1]. Many years ago, buildings in the southern and central regions of Iraq were designed to resist only vertical loads. This was due to the absence of serious quakes and the lack of seismic codes at that time. The first Iraqi seismic code was published in 1997[2], and this code did not include seismic hazard assessment for Iraq[3,4]**.** Studies of seismology in Iraq recently stated that the Iraqi-Iranian border zone is an active seismically as it presents part of the convergent plate between the Arabian, Anatolian, and Iranian plates [5], [6,7] showed that the fault of (Badra-Amara) which is begun about (180km) to Basra north and extended to Badra (north of Kut). Structures lying in Earthquake –prone regions should satisfy the minimum requirements of seismic design codes so that to reduce the damages and prevent the collapse of structures by limiting the seismic risks and minimizing the loss of life. The provisions of seismic design codes are intended to ensure that buildings can resist seismic force sufficiently during strong earthquakes. One of the methods to evaluate the performance levels of the structures is nonlinear static analysis (Pushover Analysis). Structures can initially resist the seismic load elastically but when the applied load starts increasing beyond the elastic limit, the structure behaves nonlinearly, leading to many performance levels. The seismicity of the region and soil condition at the site affect the value of seismic lateral force; therefore, two locations are chosen in this work: zone 1which represents Basra city and zone 3 which represents Baghdad according to UBC 2017 code [8]. Kurdistan Region in Iraq, like Erbil and Duhok, also lie in zone 3. Figure 1 below states the seismicity of Iraq and adjacent locations. The Pushover analysis is a simple method if it is compared to time history analysis. Therefore, it is preferred to be used especially in buildings that have low or middle height. [9], [10]and[11]. Structures can be evaluated in the program by the colors of plastic hinges, which appear beyond the elastic range and the reach the plastic range [12].

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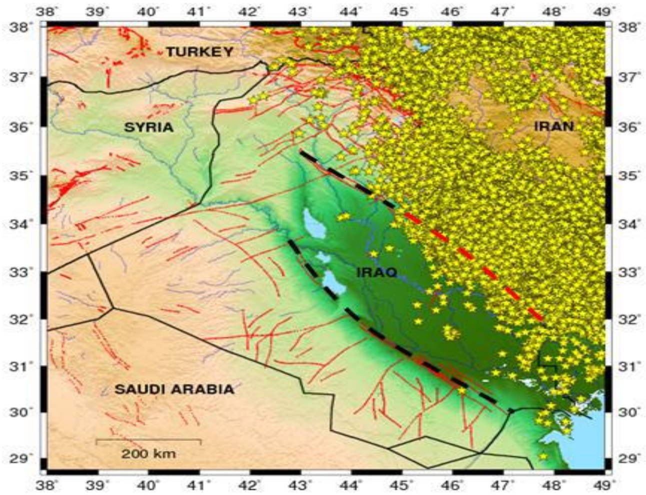

Fig. 1. The seismicity of Iraq and adjacent locations which is taken from the Iranian Records of Seismic Catalogue(IRSC)

II. PUSHOVER ANALYSIS

One of four analysis procedures (linear dynamic, linear static, nonlinear dynamic, nonlinear static) that are included in FEMA 356 and FEMA 440[13].

A. Pushover Curve

A pushover curve which produced from gradual increasing in lateral load (assumed as 100% dead load plus 25% live load) and taking many steps to develop that curve which represents the capacity of building, a pushover curve consists of a horizontal axis which represents top displacement and vertical axis which represents base shear as in figure 2 .

B. Response Spectrum curves

It is the plot between acceleration (a) and one of these quantities (frequency, displacement, period, velocity), and it depends on the sismicity of the region(Location), site class and damping ratio. SAP2000 can plot response spectrum curves when location, site class, and damping ratio are chosen.

C. Capacity Spectrum

After producing a pushover curve, which represents the capacity of structure and forming a demand curve which represents the seismic load, the two curves intersects producing performance point (target displacement, base shear) depending on capacity spectrum in (ATC40).The target displacement is when the structure is displaced due to the applied earthquake whereas the base shear represents the force due to that earthquake, as shown in Figure 3.

D. Performance Level of Building

The special thing in pushover analysis is describing the damage level or performance level of the structure where there are many levels B,IO, LS,CP, C,D and E according to ATC40, as shown in Table I.

III. SEISMIC ANALYSIS USING UBC-97 CODE

The seismic coefficients, C_v and C_a refer to ground acceleration, which is expected at the site. They can be found using tables in UBC-97 code to reflect regional seismicity and conditions of soil at the site. According to the UBC-97 code, Basra lies in zone 1, whereas Baghdad lies in zone 3, as shown in Table III. The seismic zone factor(z) for Basra is 0.075, whereas seismic zone factor (z) for Baghdad is 0.3, as shown in Table IV. Soil profile type for Basra is (S_E), therefore seismic coefficient C_a for Basra is 0.19 whereas seismic coefficient C_a for Baghdad is 0.36 as shown in table V. Seismic coefficient $C_v$for Basra is 0.26 whereas seismic coefficient C_v for Baghdad is 0.54 as shown in table VI. in other meaning two locations, of Iraq, different in the seismicity between low for Basra to moderately high for Baghdad are chosen to represent two levels of ground motions . It is important to describe the seismicity of Iraq. Kurdistan regions like Erbil and Duhoklie as Baghdad in zone 3.Table II below summarizes the seismic factors and coefficients for Basra and Baghdad.

IV. MODELING OF THE BUILDING

The building dimensions are shown in Table VII and Figure 4. Table VIII shows the slab thickness and the value of vertical loads (dead and live loads) which applied to the slab. The building has a raft foundation with a depth of 80 cm, but in modeling it is assumed to be a fixed support . The load on slabs is shown in Table VIII, but in pushover analysis procedures 100% of the dead load on slab and 25% of the live load are taken to produce a pushover curve. The details of the buildings members in dimensions and reinforcements are given in table VIII. Building has been modeled using SAP2000 software [15], as shown in Figure 5 then analyzed using the ATC40 capacity spectrum method and choosing seismic coefficients according to UBC97 for two locations Basra and Baghdad. Figure 5 shows a 3-D model of the building, which is modeled in SAP2000 software. The material model used for the concrete is the Mander's model [15,16] .

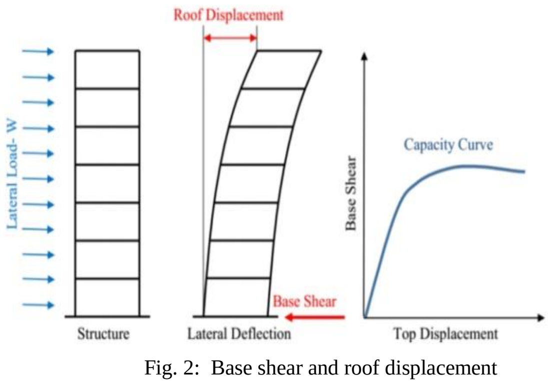

Fig. 2: Base shear and roof displacement

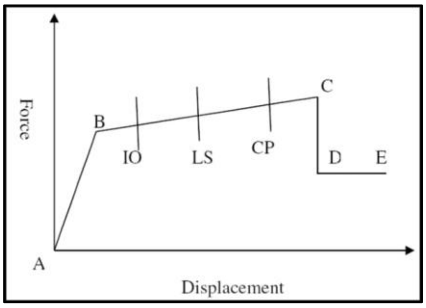

Fig. 3. Performance level of structure

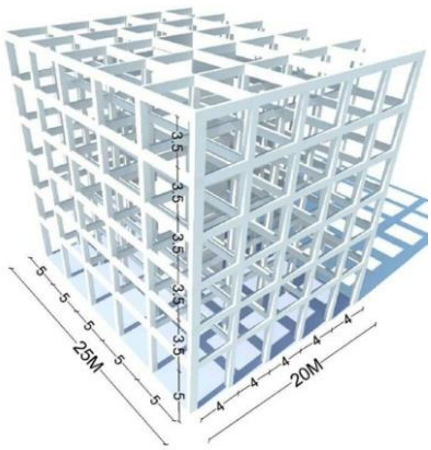

Fig. 4. Building dimensions

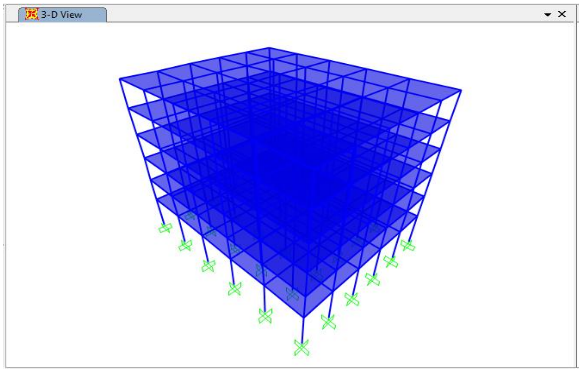

Fig. 5. 3D model

TABLE I: PERFORMANCE LEVEL AND DESCRIPTION

Level	Description
Operational	Negligible impact on building
Immediate Occupancy	Building is safe to occupy but probably not useful until repair has occurred
Life Safety	Building is safe during the event but probably not afterward
Collapse Prevention	Building is on verge of collapse, probable total loss

TABLE II. SEISMIC FACTORS AND COEFFICIENTS FOR BASRA AND BAGHDAD

city	Seismi c zone	Seismic zone factor(z)	Soil Profile Type	C_a	C_v
Basra	1	0.075	S_E	0.19	0.26
Baghdad	3	0.3	S_D	0.36	0.54

TABLE III. SEISMIC ZONE FOR SOME LOCATIONS OF THE WORLD ACCORDING TO UBC-97

Location	Seismi c Zone	Location	Seismic Zone
Manama(Bahrain)	0	Baghdad(Iraq)	3
Beijing (China)	4	Basra(Iraq)	1
Tokyo (Japan)	4	Amman(Jordan)	3
Riyadh(KSA)	0	Kuwait (Kuwait)	1
Tehran (Iran)	4	Damascus (Syria)	3
Ankara (Turkey)	2A	New Delhi (India)	3

TABLE IV. SEISMIC ZONE AND SEISMIC ZONE FACTOR

Zone	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

TABLE V. SEISMIC COEFFICIENT C_A

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR,Z				
	Z=0.075	Z=0.15	Z=0.2	Z=0.3	Z=0.4
S_A	0.06	0.12	0.16	0.24	$0.32N_a$
S_B	0.08	0.15	0.20	0.30	$0.40\ N_a$
S_C	0.09	0.18	0.24	0.33	$0.40\ N_a$
S_D	0.12	0.22	0.28	0.36	$0.44\ N_a$
S_E	0.19	0.30	0.34	0.36	$0.36\ N_a$
S_F	See Footnote I				

TABLE VI. SEISMIC COEFFICIENT C_V

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR,Z				
	Z=0.075	Z=0.15	Z=0.2	Z=0.3	Z=0.4
S_A	0.06	0.12	0.16	0.24	$0.32N_v$
S_B	0.08	0.15	0.20	0.30	$0.40\ N_v$
S_C	0.13	0.25	0.32	0.45	$0.56\ N_v$
S_D	0.18	0.32	0.40	0.54	$0.64\ N_v$
S_E	0.26	0.50	0.64	0.84	$0.96\ N_v$
S_F	See Footnote I				

TABLE VII. DIMENSIONS OF THE BUILDING IN ALL DIRECTIONS

Direction	No. of bays/ Floors	Dimension (m)
x	5 bays	4 m for each bays
y	5 bays	5 m for each bay
z	6 floors	5 m for the 1st floor and 3.5 m for other five floors.

TABLE VIII: LOAD ON SLAB AND SLAB THICKNESS

Slab Thickness(mm)	Dead Load on Slab	Dead Load on Slab
200 mm	Self-weight only	1.5 kN/m^2 on roof and 4.5 kN/m^2 on the other floors

TABLE IX. DIMENSIONS and REINFORCEMENT OF STRUCTURAL MEMBERS

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

V. RESULTS AND DISCUSSION

The result showed that the building had a ductility (the ratio between ultimate displacement to yield displacement[17]) more than 10 and that clear in pushover curve in Figure 6 [18]**.** Figure 7 and Figure 8 show the capacity spectrum curves in Basra and Baghdad respectively whereas Figures 9 and 10 show the performance level of the building in Basra. Figures 11and12 show the Performance level of the building in Baghdad. The severely collapsed performance level of the building is shown in Figure13.

The results of the analysis in Basra and Baghdad are shown in Table IX while in case of beyond collapse limit, the displacement of the building reaches 45 cm forming 100 plastic hinges in (C-D) performance level, pushover curve starts linear path (elastic), then the reaches nonlinear behavior forming plastic hinges.

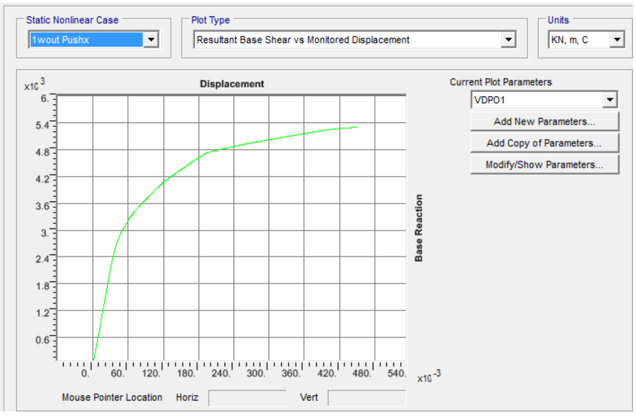

Fig. 6. Pushover curve of the building

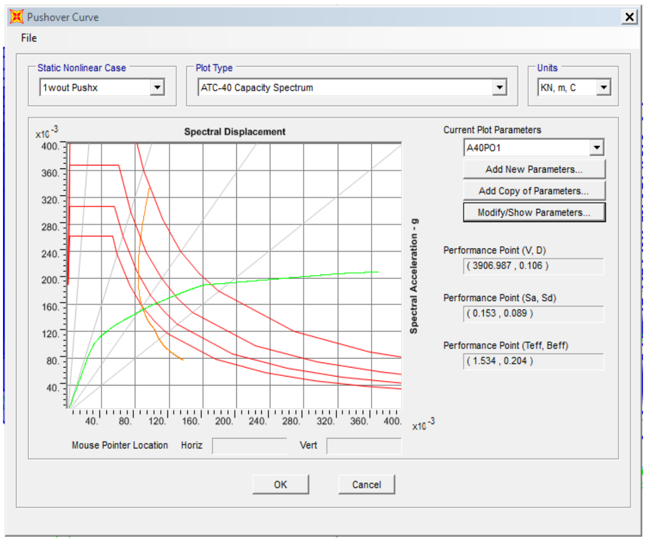

Fig. 7. Capacity spectrum curves in Basra

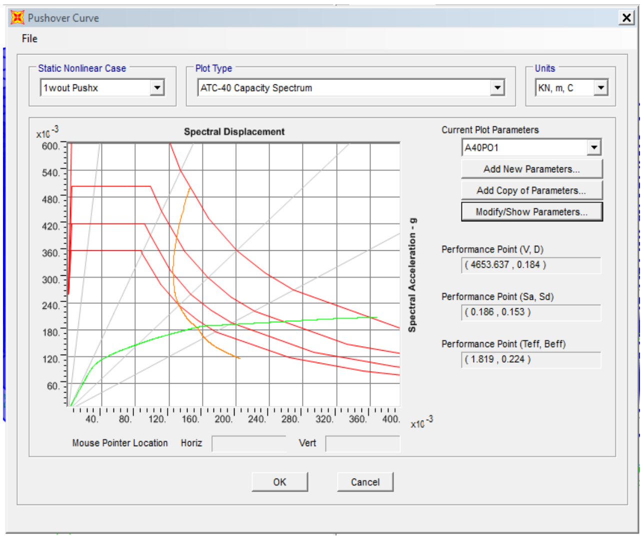

Fig. 8. Capacity spectrum curves in Baghdad

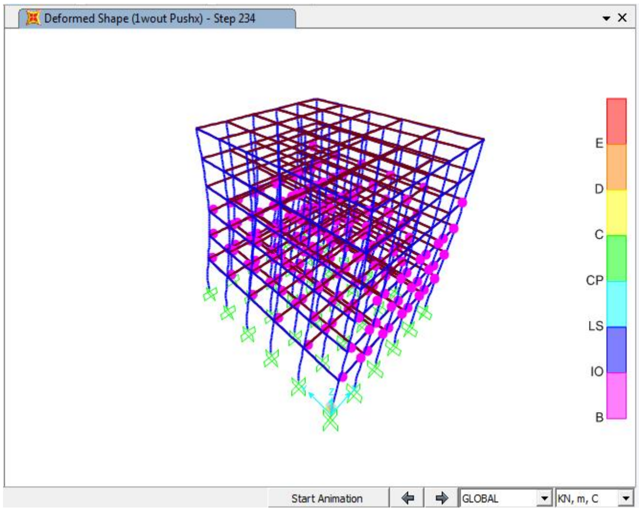

Fig. 9. Performance level of the building in Basra (3D)

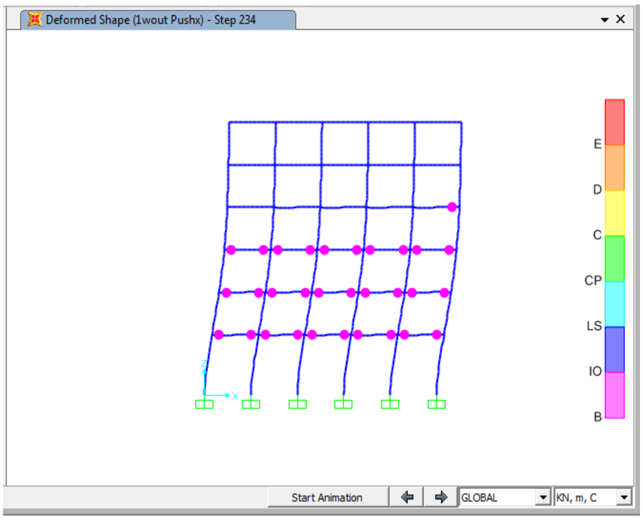

Fig. 10. Performance level of the building in Basra (2D)

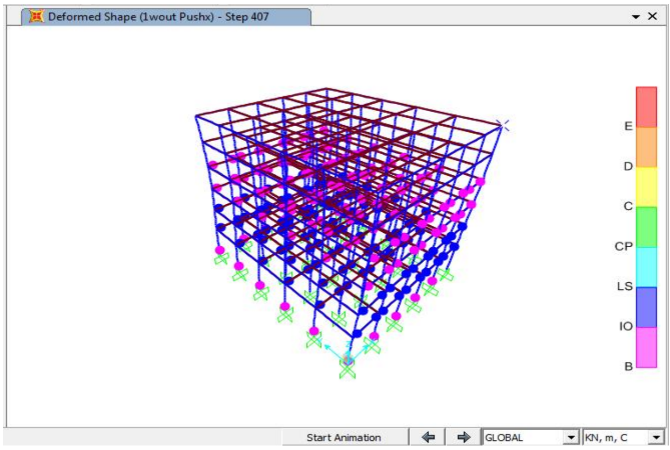

Fig.11. Performance level of the building(3D) in Baghdad

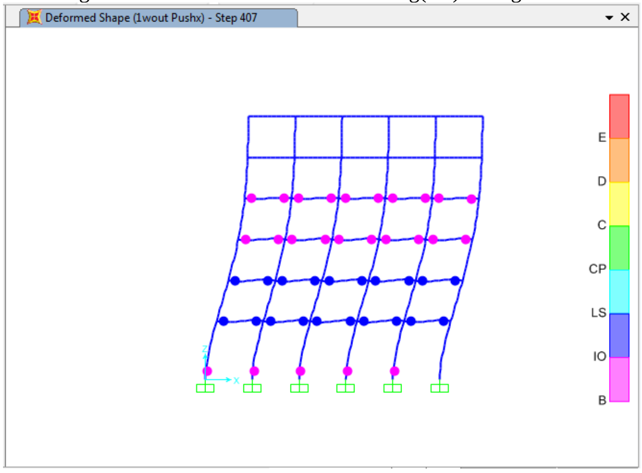

Fig.12. Performance level of the building in Basra (2D or Plane)

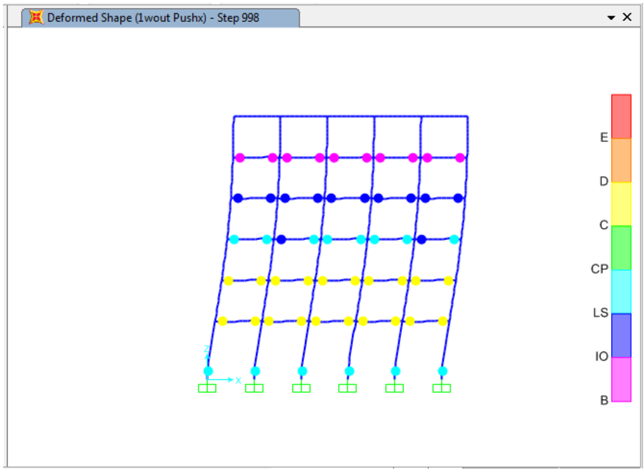

Fig.13. Severely collapsed performance level of the building

TABLE IX. RESULT OF THE ANALYSIS IN BASRA AND BAGHDAD

City	Target Displacement(cm)	Base Shear(kN)	Spectral Displacement (cm)	Spectral Acceleration (m/s^2)
Basra	10.6	3907	8.9	0.153
Baghdad	18.4	4654	15.3	0.186

TABLE X. RESULT OF THE ANALYSIS IN BASRA AND BAGHDAD

City	Step	No. of P.H	
		(B-IO)	(IO-LS)
Basra	234	164	0
Baghdad	407	134	120

VI. CONCLUSIONS

The following conclusions, which were noticed from the results of analysis that the building analyzed, showed that there is a ductility within Ten. This means there is a sufficient plastic path where the ultimate displacement is 10 times the yielding displacement.

As known, base shear represents the maximum lateral force on the base of the structure due to seismic activity, whereas target displacement represents the top displacement of the building when exposed to the design earthquake excitation, so reducing base shear and target displacement enhances structural safety, design efficiency, and overall building performance.

The base shear of the building in Baghdad is 19% more than the base shear of the building in Basra, while the target displacement of the building in Baghdad is 73% more than the target displacement of the building in Basra.

The performance level of the building in Basra was immediate occupancy performance level which means the building had light damage and needed only simple retrofitting, whereas the performance level of the building in Baghdad was life safety performance level which means the building had moderately damaged where the damage reached parts of the building leading to be out of serviceability and needed rehabilitation to be operational again.

Buildings in both cities need retrofitting in case subjecting to more severe earthquake in the future to improve their efficiency and performance.

VII. RECOMMENDATION

Further Studies on the change of seismicity of the Iraqi cities and exploring the evolution of seismic hazard and risk assessment of structures in Basra and Bagdad using recent codes.

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CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

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