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ANALYSIS OF MASONRY BUILDINGS EXPOSED TO EARTHQUAKE WITHIN IRAQI ZONES

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By

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

وَعِندَهُ مَفَاتِحُ الْغَيْبِ لَا يَعْلَمُهَا إِلَّا هُوَ وَيَعْلَمُ مَا فِي الْبَرِّ وَالْبَحْرِ وَمَا تَسْقُطُ مِن وَرَقَةٍ
إِلَّا يَعْلَمُهَا وَلَا حَبَّةٍ فِي ظُلُمَاتِ الْأَرْضِ وَلَا رَطْبٍ وَلَا يَابِسٍ إِلَّا فِي كِتَابٍ مُّبِينٍ

صَدَقَ اللَّهُ الْعَلِيُّ الْعَظِيمُ

سورة الأنعام / ٥٩

DEDICATION

To who had taught me the patience and success, my ***father***

To my ***mother*** *with my endless love and fidelity*

To my best companion and inspiration   my ***wife***

To my support my ***brothers*** *and* ***sisters***

To my life flowers my ***children***

To my ***teachers*** *who had taught me*

To all those who taught me and encouraged me

To the homeland of the brave and the source of men ***Iraq***

Maan Hatam Saeed

2017

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In the name of ***Allah****, the most gracious, the most merciful. I thank* ***Allah*** *before anyone, who enabled me to achieve this research.*

To who led the message and advised the nation to the Prophet of Mercy and the light of the worlds Prophet ***Muhammad****, peace be upon him.*

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Maan Hatam Saeed

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ABSTRACT

ANALYSIS OF MASONRY BUILDINGS EXPOSED TO EARTHQUAKE WITHIN IRAQI ZONES

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Masonry is considered as the oldest construction material still being used in nowadays construction. However, masonry building shows great sensitivity to the impact of earthquakes. Since most of the typical residential houses buildings in Iraq were designed using outdated building codes that did not account for horizontal seismic loads where only vertical loads were considered, it became necessary to introduce earthquake loads in the designs of these buildings. Due to the increase in seismic impact on Iraq in recent times, so it is important to study the behavior of the masonry building under the influence of earthquakes in order to assess the seismic performance and identify the weakness of this type of construction. This study focuses on assessing the seismic performance of residential buildings scattered throughout Iraq, which is subjected to seismic action.

In this research a three-dimensional finite element model using ABAQUS 6-13 program was developed to represent, simulation and analysis of residential masonry buildings generally constructed in Iraq cities. The verification is carried out with two experimental models. The first verification done to select the best technique for modeling the masonry wall is by representing it in three techniques(micro modeling, simplified micro modeling, and macro modeling) where the macro modeling has proved its efficiency to modeling large models. The second verification is done with masonry room under the dynamic load was adopting macro modeling which has also close convergence for the simulation results to the

experimental data. In this study, a single room and three typical houses are simulated with the total dimension (5 x 20 m,10 x 10 m,10 x 18 m) for one and two stories depends on the nonlinear behavior of the material and the nonlinear dynamic procedure (time history) in the analysis. The compressive strength of the masonry wall f_m and nonlinear properties of the materials that are used in this study were obtained by testing samples in the laboratory which are used as an input data in the ABAQUS 6-13 program. Through the results of the prism tests of the masonry wall models, an equation is concluded to find the compressive strength of the masonry wall consisted of Iraqi building materials by using Artificial Neural Network (AAN).

The design spectral responses acceleration parameters of the earthquake are adopted as 0.5g according to Iraqi zone. Two different acceleration is implemented, separately. El Centro earthquake happened in Southern California in1940 with a magnitude of Mw=5.4(peak ground acceleration PGA=3.50 m/sec^2) and Ali Al- Garbi earthquake happened in Maysan Province south of Iraq in 2012 with a magnitude Mw=4.9 (peak ground acceleration PGA=1.04 m/sec^2) are used as the input ground motion in this study. The involved result parameters are the maximum displacement, drift, and base shear which are compared with the requirements of seismic demand by the preliminary draft of Iraqi code and ASCE Standard ASCE/SEI 7-10. The results show that the models prove efficiency and stability against the effect of earthquakes, especially when the load is applied in the Z (long direction) more than the load applied in the X (short direction) for all models. On the other hand, when the EL Centro earthquake load is applied on the models, the maximum displacement increased by 6-12%, drift increased by 22-29% and base shear increased by 29-32.96% more than when the Ali Al-Garbi earthquake load is applied on the models.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS	DEFINITION
$\{a\}$	The nodal displacements vector.
$[B]$	Strain displacement matrix.
$[C]$	Damping matrix.
C_s	Seismic response coefficient.
$[D]$	Constitutive matrix.
d	Vector of displacements in B due to the initial strains and stresses.
d_t	Tensile cohesion stresses (MPa).
d_c	Compressive cohesion stresses (MPa).
E	The Young's modulus (MPa).
E_0	The initial (undamaged) elastic stiffness of the material (MPa).
E_m	Modulus of elasticity of masonry (MPa).
E_b	Modulus of elasticity of brick (MPa).
E_j	Modulus of elasticity of mortar (MPa).
Es	Modulus of elasticity of steel(MPa).
F	External load vector (kN).
f_b	Ultimate compressive strengths of brick in (MPa).
f_m	Ultimate compressive strength of a masonry prisms in (MPa) .
f'_m	Ultimate compressive strength of a masonry prisms in horizontal direction in (MPa) .
f_j	Ultimate compressive strength of mortar in (MPa).
f_s	Yield stress of steel in (MPa).
f_t	The tensile strength of masonry in (MPa).
f_a	Site coefficients.
f_D	The damping force (kN).
f_I	The inertia force (kN).
f_s	The elastic resisting forced (kN).
G_b	Shear modulus's of brick (MPa).
G_j	Shear modulus's of mortar (MPa).
g	Ground accelerations (m/sec^2)
H	Height of building (mm).
h_n	Height of story (mm).
h_{sx}	The story height below the Level X (mm).
I_E	Seismic importance factor
[J]	Jacobian matrix.
[K]	Stiffness matrix.
$[K]^e$	Element stiffness matrix.
k_c	Ratio of second stress invariant
k_n, k_s, k_t	Normal and shear direction .
k	Constant .
L	Love wave.
[M]	Mass matrix.
m	Mass (kg).
[N]	Shape functions matrix.
N_i	Shape function at the i-th node.
P	Longitudinal wave.
R	Rayleigh wave.
R	Response modification factor.
S	Transverse wave.
S_s	Mapped maximum considered earthquake spectral accelerations for short periods determined for seismic map for Iraq.

S_{Ds}	Design spectral response acceleration parameter for short period.
S_{Ms}	Mapped maximum considered earthquake spectral accelerations for short periods adjusted for site class effect.
S_{D1}	The design spectral response acceleration at 1-second period
T	The fundamental period of the building (sec).
t	Time(sec).
t_m	Thickness of mortar bed joint (mm).
u	The inter-floor (or relative) displacement (mm).
$\dot{u}$	The relative velocity (m/sec).
$\ddot{u}$	The relative accelerations (m/sec^2)
u,v,w	Displacement components in x,y and z coordinates.
W	Effective seismic weight (kN).
V	Seismic base shear (kN)..
X,Y,Z	Global coordinate.
GREEK SYMBOL	
σ	Stress (MPa).
σ_t	Tensile strength (MPa).
σ_c	Compressive strength (MPa).
ε	Strain.
$\varepsilon_t^{\sim pl}$, $\varepsilon_c^{\sim pl}$	Tension and Compression equivalent plastic strains
$\dot{\varepsilon}_t^{\sim pl}$, $\dot{\varepsilon}_c^{\sim pl}$	Tension and Compression equivalent plastic strain rates
γ	Shear strain.
μ_o	The viscosity parameter
υ	Poisson ratio.
ϵ	The flow potential eccentricity.
ψ	The dilation angle.
β	Constant.
α	Constant.
ξ, η, ζ	The natural coordinates.

ABBREVIATIONS	DEFINITION
ASCE	American Society of Civil Engineers.
ASTM	American Society for Testing and Materials.
NDL	Nonlinear Dynamic Load.
NSL	Nonlinear Static Load.
LDL	Linear Dynamic Load .
LSL	Linear Static Load.
URM	Unreinforced masonry.
FEM	Finite element method.
MW	Masonry wall.
PGA	Peak ground acceleration.
UNW	Unreinforced masonry wall.
CDP	Concrete damage plasticity.
ANN	Artificial Neural Network .
FEA	The finite element analysis.
LSP	linear static procedure.
NSP	Nonlinear static procedure.
LDP	linear dynamic procedure.
NDP	Nonlinear dynamic procedure.

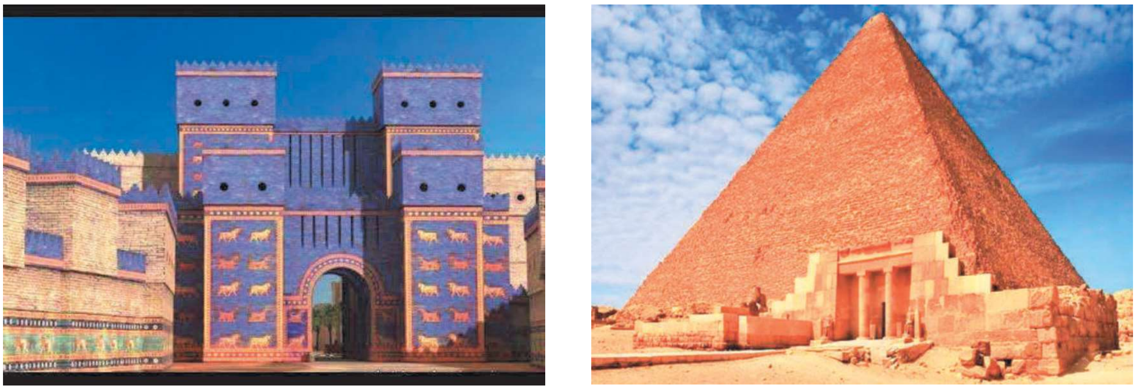
MHS1	Masonry house structure with 10m x 10m plan.
MHS2	Masonry house structure with 5m x 20m plan.
MHS3	Masonry house structure with 10m x 18m plan.

INTRODUCTION

1.1 General

The type of construction that consists of the constructional units and mortar as the joining material is known as (masonry), furthermore, the constructional units may be bricks, concrete blocks, stones , granites, marbles. The mortar is a mixture of water and any bound material like (sand, cement), gypsum and clay.

Masonry is considered the oldest construction material type that still to be used in constructions until these days. In the old ages, stone , clay brick and sliced stone were used as the masonry units ,as in the ancient city of Babylon (Iraq) and Great Pyramid of Giza (Egypt) as shown in Figure (1-1). All these old constructions built in the old ages and still stand in nowadays after several natural disasters as devastating earthquakes. However, many of those old buildings subjected to the earthquakes over the past years unable to withstand seismic excitation, such Iskenderun Lighthouse and old citadel of Bam **(Costa,2007)**.



a)Babylon(Iraq) b) Great Pyramid of Giza (Egypt)

Figure (1-1) Oldest masonry construction cities**(Costa,2007)**.

The most important properties of masonry construction building are plains. The skills and materials which are required to build masonry are great available. Therefore, it is possible to begin masonry work almost instantly. The other substantial characteristic is the acceptable appearance, strength, toughness, low repair cost, sound absorption, versatility and fire resistance. The examples of buildings that resist wind and seismic loads are bearing walls of a building having few stories, the masonry wall system demonstrates competitive performance with other building systems like steel and concrete frame. However, the use of masonry construction hampered by the development of design rules compared with other systems such as concrete and steel. A few models in the literature illustrates the complex interaction behavior of masonry components dictates lack of insightfulness of the system **(Lourenço,1997)**.

During the recent years, the attention is focused on masonry increasingly due to the development of modern technologies of research and software engineering and the growing knowledge of the behavior request, especially regarding earthquakes. The wide spread of masonry buildings, the heritage buildings, residential buildings and government buildings such as schools, hospitals, etc., especially in countries with seismic action dictates to expand the scope of knowledge in theoretical, numerical and experiential research to evaluate the seismic performance of masonry buildings and to diagnose the weakness of masonry buildings for processing. A series of analytical programs and methods are used exclusively for concrete and steel structures for several years used now to analyze masonry building structures **(Parisi, 2010)**.

1.2 Types of masonry walls

Masonry wall is a construction composed of individual units of construction and connecting with each other by mortar. The strength of the masonry wall can be affected by several factors, such as the type of the masonry units, the strength of the masonry units, type of the masonry units connected, the thickness of the masonry wall and the strength of the mortar. Masonry walls are mainly classified into two categories (Rana ,2008):

1- Bearing masonry walls:- There are walls designed to transport the dead and live loads to the base(foundation) and can be external or internal walls .
2- Non-Bearing masonry walls:- There are walls designed to carry its weight and the weight of cladding attached, its used as internal partitions or architectural walls .

1.3 Masonry brick walls in Iraq

Advantages of masonry such as to decrease cost, the speed of delivery, date of heritage masonry building use in Iraq and many others advantages dictate to spread this system of construction in residential houses, government buildings, schools and hospitals, where mostly used as bearing masonry walls in residential homes, hospitals, government buildings and in one or two floors where using as non-bearing walls on the internal partitions and external wall without direct loads with frame concrete in multi-story buildings is limited. The use of bearing masonry walls in all of Iraq's provinces, especially in residential buildings forms a large proportion up to more than 80% with the presence of seismic action dilation with time in Iraq dictates the great importance of this study which identifies the behavior of the walls under the influence of earthquakes**(Oti,2009)**.

1.4 Earthquake and Hazard Consideration in Iraq

1.4.1 Earthquake

Earthquakes are natural phenomena that shake the surface of the earth resulting from the sudden release of the energy in the rocks of the soles earth where this energy creates seismic waves spreading from the ground or in a sense from the center of the earthquake (focus) to the surface of the earth and these waves are spread in all directions to the surface. The point vertically above the focus on the surface of earth is epicenter, the distance between the focus and epicenter called focal depth as shown in Figure (1-2) the focal depth of the earthquake is important to determine the potential of the earthquake as most of the earthquakes have a focal depth of less than 70 km More harmful. Earth affected by the focus of earthquake is called the focal zone. Foreshocks are defined as shocks occurs before the earthquake (main shock). Aftershocks are those that occurs after the main shock **(Dhanaji,2011)**.

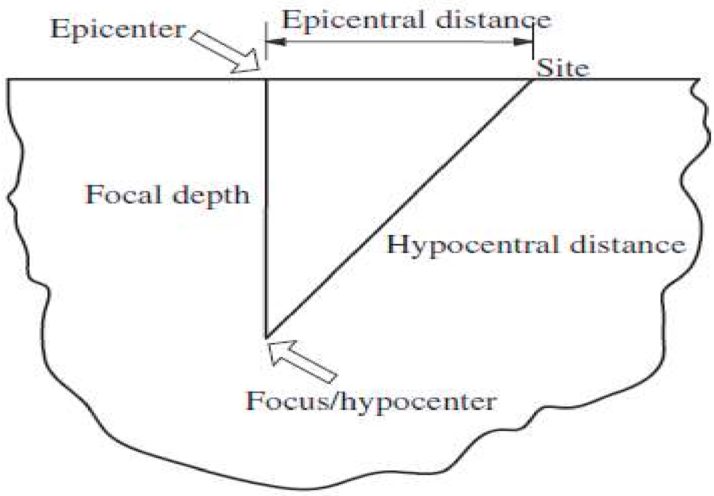


Figure (1-2) Definitions focus and epicenter pointes**(Dhanaji ,2011)**

Seismic waves propagate in all directions from the center of the earthquake, the energy carrier from one point to another through the layers and finally carry the energy to surface , during the transmission of waves within the layers of the earth it is called body waves and when they reach the surface of the earth it is called surface waves . Body waves , which is of two types P and S wave, where P are longitudinal waves in the direction of particle movement or the opposite direction as shown in Figure (1-3). The S waves are transverse in which the motion of the particles is vertically in the wave propagation direction as shown in Figure (1-3) **(Dhanaji ,2011)**.

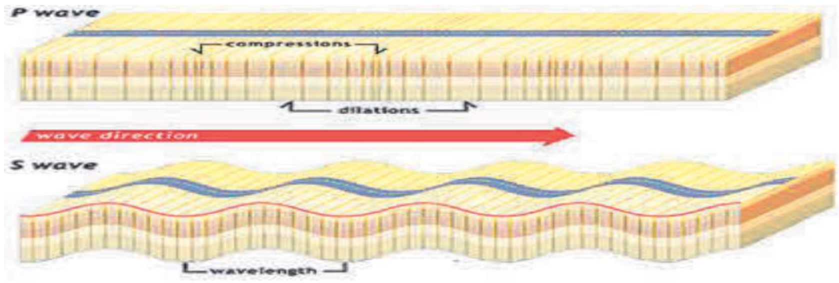


Figure (1-3) P &S waves **(Datta,2010)**

Surface waves are spread on the surface of the earth and are classified on two types L and R waves. L waves (Love waves), it is characterized by particle movement at the horizontal plane and to be transverse to the direction of propagation as shown in Figure (1-4) , L wave faster than R as it is the first seismic wave arriving on the monitoring station. R waves (Rayleigh waves), it is characterized by particle movement in a vertical plane and traces an elliptical path, which is retrograde to the direction of waves propagation as shown in Figure (1-4) **(Datta,2010)**.

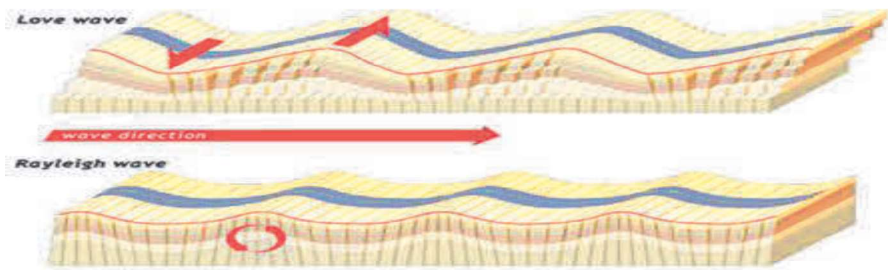


Figure (1-4) L&R waves **(Datta,2010)**

1.4.2 Hazard Earthquake in Iraq

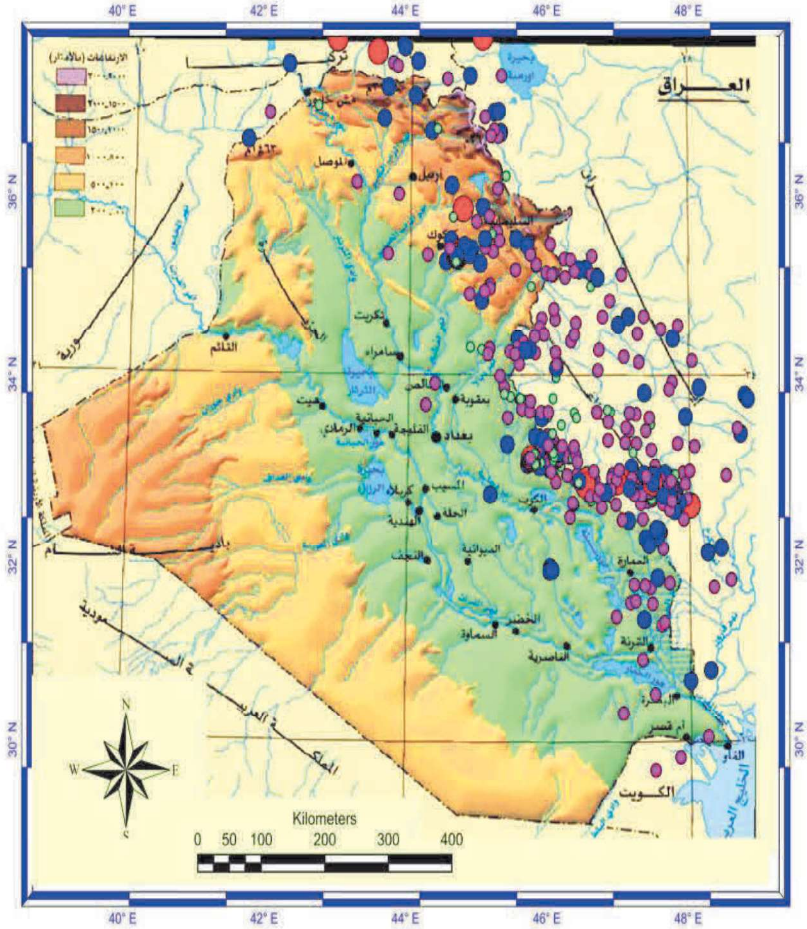
Many of seismic and seismic - tectonic studies in Iraq indicate that seismic effect is moderate to high in the northern and north-eastern borders, and low in the south and south-west direction **(Alsinawi,2002)**. Seismic effect in Iraq is directly related to the general trend in the alpine belt seismic activity on the global scale. While the seismic activity locally crosses the line from the epicenter often associated with the structures observed easily intercept the North-West direction from the orientation area Zagross, and is associated with major faults trending north in areas north latitude 34° N. The depth of foci for most of the shocks recorded in Iraq range between 5 -50 km. This means that most of the events with depth (h < 20 km) originated in the upper crust which is characterized by large fracturing and heterogeneity **(Alridha,2013)**.

After 1900, the earthquakes in Iraq were well known and magnitudes ranged from Mw=2.6 to Mw=7.1 in the geo-seismic map of Iraq's borders. the earthquake center suffered shocks suffered by Iraq after 1900, as follows **(Alridha,2013)**:-

1- At 17/10/1946, 1/ 1/1950 and March 1956 Baghdad stroked by strong earthquakes causing significant property damage.
2- In 1992, the village Kasimiyah. 50 km east of Arbil earthquakes destroyed dozens of homes but did not record any deaths.
3- August 2004, earthquakes stroked southern Iraq in the district AL - Rafaee has many houses collapsed Figure (1-5)**(ISN,2004)**.
4- In 2012 earthquakes stroked district Ali al-Gharbi, north of Al-Amara governorate which affected strongly by Mw=4.9 on the Richter scale, its data are used in this study **(ISN,2016)**.

Figure(1-5) Collapse of main walls and roof masonry house in AL Rafaee, Iraq in 2004)**(ISN,2004)**.

Iraq meteorological organizational and Seismology recorded (552) earthquakes in 2015 in Iraq and its neighboring areas as shown in Figure (1-6) ,thereof (120) shake inside of Iraq and (432) in border areas of neighboring countries and has some parts of Iraq witnessed seismically active noticeable during this period was the number of ground tremors, some of which were significant(10) and other were insignificant **(ISN,2016)**.



552 events of 2015			
Magnitude			
1≤M<2	2≤M<3	3≤M<4	4≤M<5
96	307	134	15

Figure(1-6) Earthquakes of 2015 in Iraq and neighboring areas**(ISN,2016)**

1.5 Research Importance

The importance of the study is concentrated on the following :-

1- Since most of the Iraqi buildings are considered masonry construction which is accounted up 80% of the buildings at last, it is necessary to study their behavior under the influence of earthquakes.
2- Increase the impact of earthquakes on Iraq in the recent years generated, great importance to studying this topic.
3- The lack of studies concerned with the impact of earthquakes in Iraq in in encourages researcher to cover this topic.

1.6 Aim and Scope of Study

The main objective of this study is to investigate and evaluate the seismic performance of masonry wall buildings behavior in Iraq under the earthquak load.The 3D finite element method is used for the modeling and analysis. The nonlinear material and nonlinear dynamic analysis (Time-History) are conducted by using the computer program ABQUS 6.13. In this study various models of residential masonry building including one room, one storey and two stories house with different plans. The study considered two earthquakes action in X-axis and Z-axis of every models with different intensity earthquake load.

1.7 Layout of the Thesis

This thesis consists of six chapters :-

1- Chapter one contains an introduction to the history of masonry wall and the hazard of earthquakes on masonry wall in Iraq.
2- Chapter two contains a brief review of experimental and analytical studies carried out on masonry wall under seismic loads.
3- Chapter three shows the finite element modeling used ABAQUS program of the masonry wall and the nonlinear solution techniques.

4- Chapter Four deals with experimental tests of the comparessive strength of the masonry wall and its component materials (brick, mortar).
5- Chapter Five presents the applications, results, and discussion.
6- Chapter Six gives the main conclusions and recommendation for future work.