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EVALUATION OF SAFETY FACTOR OF SELECTED ANCIENT BUILDINGS IN IRAQ AGAINST EARTHQUAKE LOADS

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Evaluation of Safety Factor of Selected Ancient Buildings in Iraq Against Earthquake Loads

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Supervisor

Assoc. Prof. Dr. Amjad KHABAZ

By

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Ahmed Hakim Oudah ALWANI

ABSTRACT

EVALUATION OF SAFETY FACTOR OF SELECTED ANCIENT BUILDINGS IN IRAQ AGAINST EARTHQUAKE LOADS

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Environmental factors are affecting most of the archaeological sites in countries, and may sometimes lead to the demolition and destruction of these buildings, especially countries that lie on a seismic line. Therefore, it has become necessary to study the factors that help sustain and extend the life of these buildings. One of the most important of these factors is the safety factor, through which we obtain important information about the strength of archaeological buildings due to environmental loads such as earthquakes, winds, etc.

The archaeological sites in Iraq and in the ancient city of Babylon were visited exclusively. We will start with a study (Babylonian Theatre, Ishtar Gate and Natmakh Temple) and the building materials and the bonding mortar were seen, as well as the measurements, dimensions and height for each site separately**.**

It is no secret to anyone that the walls and ceilings of archaeological buildings in past and ancient countries and civilizations do not contain reconstituted or unreinforced concrete walls**.**

Accordingly, this thesis focused on the study of the safety factor for the walls and ceilings of the site, as well as the bonding mortar between the building bricks by knowing the moment of overturning of the walls and their resistance to wall volatility, in addition to knowing the seismic shear force and the amount of resistance force of the bonding force against shear**.**

On this basis, the information for each site was modeled using computer programs such as Etabs, and then the shear force was found, on which all engineering calculations focus to find the safety factor for each archaeological site**.** The results showed high resistance of bonding materials against the provided seismic shear loads and the safety factor was high for all these buildings.

Key words: Ancient buildings, masonry, safety factor, bond strength, finite element modeling (FEM).

ÖZET

IRAK'TAKİ BELİRLİ TARİHİ BİNLARIN DEPREM KUVVETLERİNE KARŞI GÜVENLİK FAKTÖRLERİNİN DEĞERLENDİRİLMESİ

ALWANI , Ahmed

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Çevresel faktörler ülkelerdeki arkeolojik alanların büyük bir çoğunluğunu etkilemektedir ve özellikle sismik hat üzerinde bulunan ülkelerde bu binaların göçmesine ve zarar görmesine neden olmaktadır. Bu durumdan ötürü bu binaların ayakta kalmasına ve ömrünün uzamasına yardımcı olacak faktörleri çalışmak gerekli hale gelmiştir. Bu önemli faktörlerden bir tanesi, sayesinde depremler, rüzgarlar gibi çevresel yüklerden kaynaklı arkeolojik binaların dayanımı hakkında önemli bilgiler elde ettiğimiz, güvenlik faktörüdür.

Çalışma için özellikle Irak'taki arkeolojik alanlar ve Babil'deki tarihi şehir ziyaret edilmiştir. (Babilli Tiyatrosu, Ishtar Kapısı ve Natmakh Tapınağı) ile çalışmaya başlanmıştır ve her alan için boyutlar ve yüksekliklerinin ölçümlerine ek olarak yapı malzemeleri ve bağlayıcı harçlar incelenmiştir.

Eski ve tarihi ülkelerdeki arkeolojik binaların duvar ve döşemelerinin yeniden yapılandırılmış veya donatılı beton içermediği herkes tarafından bilinmektedir.

Bu doğrultuda, bu tez çalışması arkeolojik alanların duvar ve döşemelerinin güvelik faktörünü, bunun yanında duvarların devrilme momentini, dirençlerindeki istikrarsızlığı ve ek olarak sismik kesme kuvveti ve kesmeye karşı bağ kuvvetinin direncinin miktarını dikkate alarak bina tuğlaları arasındaki bağlayıcı harcı çalışmaya, odaklanmıştır.

Bu bağlamda, her alana ait bilgiler Etabs gibi bilgisayar yazılımları kullanarak modellenmiştir ve her bir arkeolojik alanın güvenlik faktörünü bulmak için bütün mühendislik hesaplarının üzerine esas kılındığı kesme kuvvetleri tespit edilmiştir. Sonuçlar harç malzemelerinin sismik yüklere karşı yüksek direncinin olduğunu ve güvenlik faktörünün bütün bu binalar için yüksek olduğunu göstermiştir.

Anahtar Kelimeler: Tarihi binalar, yığma, güvenlik faktörü, bağ dayanımı, sonlu eleman modellemesi (SEM).

THE DEDICATION

Praise be to Allah , whose grace good deeds are accomplished. Praise be to God that I completed this thesis, which I hope will benefit the country to preserve their ancient history. I dedicate this thesis to my deceased parents (may Allah have mercy on them) and to all my brothers and sisters.

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LIST OF SYMBOL AND ABBREVIATIONS

FoS	Factor of Safety.
Vs	Shear wave Velocity.
Fa	Site parameter.
S_{Ds}	The design value of the spectral acceleration of earthquake motion at short periods.
S_{D1}	The design value of the spectral acceleration of earthquake motion at 1 sec.
S_{MS}	The modified values for the site at short periods.
S_{M1}	The modified values for the site at 1 sec.
I	The moment of inert.
UNESCO	The United National Educational ,Scientific and Culture Organization.

CHAPTER 1

INTRODUCTION

The architectural and cultural ancient , and others of its various types and forms, is a source of pride for nations and a proof of their nobility and originality. Today, this ancient does not belong to any particular nation, but is the property of humanity. Many traces of ancient civilizations have survived as witnesses and indicators of the depth of thought and creativity in architecture and the arts that distinguished her sons.

The duty to preserve archaeological sites from tampering and vandalism is one of the first and most important duties, and this duty is not entrusted to a specific party without the other parties, as it falls on everyone.

Archaeological sites are defined as any location that contains archaeological evidence that is studied and examined by archaeologists in order to be used later in a variety of fields, with archaeological sites primarily benefiting in identifying the behavior of the people who lived there. One day at the research site, study site, or those who have benefited from it in their daily lives, which aids in identifying the nature of life that prevailed in the past.

Archeology can also provide insight into ancient historical eras, their form and nature, as well as the nature of the lives of the generations who lived during them. Is the urban ancient , which connects the past to the present and helps to introduce people to their ancestors' civilization and history, resulting in a strong bond between the homeland and the citizen, and helps to introduce all citizens to their history and preserve it through generational transmission**.**

The economic importance of archaeological sites

The economic effects are significant because they are a major contributor to the economy's support, whether directly or indirectly. The provision of job opportunities and community support in terms of reducing unemployment is one of the most prominent economic aspects to which the effects contribute. Where investments in antiquities and various archaeological sites - particularly in remote regions, governorates, cities, and villages - result in the creation of functional economic roles for young people in those areas. This strategy achieves population stability while providing assistance to low-income families. Also archaeological sites play a critical role in attracting tourists and, as a result, in improving countries' economies.

Because people of all kinds and types have different constructive and mutualistic ideas, and they are mutually compatible, tourism is an important, vital, and effective source of income in various societies and countries - especially in areas with many important and vital archaeological monuments - tourism is an important, vital, and effective source of income in various societies and countries. Which are stimulating economic activity in the countries they visit; where many job opportunities abound and commercial activity is brisk during tourist seasons.

The Social significance of archaeological sites

Archeology plays an important social role; As its social status and importance lies in the role it plays in shaping the identity of the citizen, and introducing him to his history, civilization, ancestral values and ways of life; This is reflected positively on the citizens' increased belonging to their country and their civilization, and contributes to bringing them closer to the history of their homeland. It also enhances the instillation of national values, and consolidates pride in the homeland, which results in strong cohesion among the people. Preserving antiquities helps preserve history; as a main source for preserving the history of the country and the history of the peoples who lived in it and it reflects the authentic civilization that has existed in it since antiquity.

Impact factors on ancient sites, includes

1. Earthquakes.
2. Effect of loads and stresses.
3. Humidity, which includes rainwater, groundwater, and condensation.
4. Biological damage.
5. Change in temperature.
6. The wind.

7. The human factor.

The loads and their effect on the damage to the archaeological sites

Archaeological buildings are exposed to loads and include two types of loads: vertical loads, including permanent (dead) and live loads, and the second type is horizontal loads, including wind loads and earthquake loads.

1. **Vertical loads**

A. **Permanent (dead) loads**

It is the set of fixed and permanent loads, including self-weights of the element or fixed weights carried by that load-bearing element. This definition includes the weight of floors, load-bearing walls and fixtures.

B. **Live loads**

They are the variable and moving loads to which any part of the structure is exposed, including distributed and concentrated loads, shock loads, vibrations and inertia. They include the loads and weights of the persons using the structure.

2**. Horizontal loads**

A. **Wind loads**

They are the loads resulting from the exposure of the structure to the forces resulting from gusts of wind, which can be in the form of pressure or drag.

B. **Earthquake**

Because buildings differ in their design, location, building materials used, and the soil on which they are built, earthquakes are one of the most dangerous factors of mechanical damage to buildings, and many buildings and cities have been reduced to ruins and ruins as a result of them. Given that buildings differ in their design, location, building materials used, and the soil on which they are built, each building has certain sensitivity to earthquakes. Earthquakes cause severe damage to historical and archaeological buildings, such as loosening, cracking, and sometimes collapse. This process is proportional to the earthquakes' intensity and duration.

They are the loads that the structure is exposed to when earthquakes occur, and they are one of the most common types of loads affecting archaeological buildings due to their nature, which is characterized by great heights, as it can be subjected to severe damage as a result of the ground movement of the soil bearing the archaeological buildings as a result of the earthquake movement.

Damage resulting from earthquakes is related to the amount of energy released from it and the region in the form of vibration waves. The resulting effects vary according to the intensity of the earthquake, the depth of the seismic focus, the nature of the region and its geological and topographic composition, which can lead to amplification of soil vibration if its nature is sandy, for example, or to the extinction of vibrations if the earthquakes encounter rocky areas as well. The shapes of architectural elements and their structural properties affect the amount of damage caused to them by seismic loads.

The proposed research efforts focused on earthquakes and their effects on Iraqi ancient structures. There will be a historical look at the earthquakes that hit Iraq. The safety factor will be assessed and the outcome will be decided.

In the future, all engineering projects built in Iraq should pay close attention to the effects of earthquakes on soil foundations.

When earthquakes strike crowded areas in both rural and urban environments, they have been shown to be the cause of significant human–made disasters. Because man-made structures can be affected by earthquake-induced shaking, the majority of hazards and dangers that people must deal with come from these structures.

Millions of people have died as a result of destructive earthquakes, and billions of dollars have been lost in economic losses over the years.

For civil buildings, under the influence of an earthquake, both linear and nonlinear time history analyses were performed, as well as a nonlinear static (pushover) analysis, taking into account the effects of including the infill panels in both types of analyses. The effects of different types of lateral load distribution patterns on the response of the building, with fixed and isolated bases, were investigated in the pushover analysis.

According to Indian Standard IS code, inverted triangular load according to Iraqi code, and load distribution according to FEMA 440 code, these load patterns are uniform, mode shape, inverted triangular load.

The building will be analyses by using software ETABS or SAP 2000.

The effects of base isolation on the dynamic response of the building will be investigated for specific buildings within some Iraqi cities using linear and nonlinear time history analysis. The following are some of the time history analysis parameters that were discussed.

1. The structure's natural time periods.
2. Changes in the lateral displacement of the roof over time.
3. Roof acceleration as a function of time.
4. Changes in base shear over time.

Preserving the civilization and ancient of nations is one of the important matters that must be taken into consideration. In recent years, seismic activity has increased and its impact has become more dangerous. There are many ancient buildings in Iraq. These buildings suffer from accumulated neglect, which requires conducting a seismic risk assessment on these buildings in order to take appropriate measures to mitigate the effects.

Generally, Preserving ancient buildings and sites is extremely important; these structures are a record of history's memory, with their cultural and historical significance. As a result, it was necessary to work on the development and restoration of these sites; because they contain architectural and urban elements, they depict the way of life of the people who lived there.

The present study focused on three ancient buildings in Iraq against earthquake loads, and these are the following buildings:-

1. **Babylonian theater**
2. **Ishtar Gate**
3. **Natmakh temple**

CHAPTER 2

LITERATURE REVIEW

Ancient buildings and sites are considered economic vessels, and the archaeological building in itself represents an economic value because it is only an archaeological building.

Ancient buildings and areas with historical value are considered a national treasure and existing resources that are easy for investment and economic exploitation, which increases their historical value.

2.1 Natural disasters and the damage they cause to cultural ancient

The ability to assess the measures that have been designed, adopted, and implemented on a national or international scale to prevent, reduce, and repair the effects of natural disasters requires knowledge of the characteristics and impacts of natural disasters that threaten cultural ancient . The most common types of natural disasters are described below, with recent examples of typical problems in relation to cultural ancient (Baker, 2005)**.**

Natural disasters pose a significant risk to cultural ancient . Floods, earthquakes, fires, environmental fatigue, and other long-term climate effects can damage cultural ancient irreversibly or completely destroy entire areas of cultural ancient , both movable and immovable. Many ancient objects are further harmed by insufficient emergency interventions, as urgent responses to basic needs can lead to emergency measures as well as recovery planning and rehabilitation schemes that are insensitive to cultural ancient (Jirásek, 2003).

Except in a few countries, the issue of protecting cultural ancient from natural hazards and disasters has not been adequately addressed in EU legislation or national laws, by-laws, and other documents, according to an evaluation of consultants' team experience, targeted questionnaire campaigns and interviews, and the accompanying literature survey. This is due to a number of factors:-

1. Many well-designed and well-functioning preventative and emergency measures that save lives completely fail to protect cultural ancient assets.

2. Because of a lack of understanding of the assets, failure to calculate the true cost of loss and damage, and the difficulty of putting a value on the non-market nature of many cultural ancient values, effective risk management of cultural assets is rare. There have been significant inadequacies and mistakes in hydrological predictions in recent major floods, and knowledge of cultural ancient at risk and its state and conditions has proven to be insufficient.

3. Thirdly, poor maintenance of old buildings and materials has increased the extent of damage caused by other disasters, such as windstorms, earthquakes, and heavy snowfall (Justo et al., 2005; Marek, 2006).

Natural disasters generate loads that engineers are unfamiliar with, and in many cases, the induced forces act in opposition to gravity loads (e.g., uplifting and suction), horizontal forces (horizontal movement, moisture expansion of most building materials), or dynamic forces (flow, shocks, impacts). Maintenance methods aren't always properly accounted for in design standards and recommendations, and professionals aren't always well informed. As a result, they are ill-equipped to devise and implement protective or mitigation strategies (Taboroff, 2000 ; Sassa et al., 2000; Nadim, 2005).

Cultural ancient is frequently overshadowed by environmental issues, which garner more political attention due to their close ties to health and environmental preservation. Cultural ancient's importance is not always well articulated, and it receives little media support. However, as we will see in the report, there is a very strong and solid foundation of knowledge and experience that can be used to achieve the objectives for which this report was written (SNCO, 2002).

In most European countries, cultural ancient protection is a minor concern for politicians and governments. Cultural ancient is frequently overshadowed by environmental issues, which garner more political attention due to their close ties to health and environmental preservation. Cultural ancient 's importance is not always well articulated, and it receives little media support. However, as the report reveals, there is a very strong and solid background of knowledge and experience that can be used to achieve the objectives for which this report was written. Large single-event fires and climate change effects are also examples of natural disasters (Taboroff, 2001; Toledo, 2003).

One of the most important features of archaeological buildings is that they are green

buildings because they are built from environmentally friendly natural materials (bricks, clay) and that the walls of archaeological buildings are often thick, and this in itself is useful for thermal insulation and reduces heat transfer between the external and internal environment.

Green buildings aim to promote the positive role of buildings in the community service, and to reduce the negative impact of buildings on the natural environment, as well as to support the national economy (Khabaz, 2018).

2.1.1 Earthquakes and Tsunamis

Thousands of cultural artifacts are at risk due to seismic activity. Actions caused by an earthquake can severely affect the stability of historic buildings, particularly masonry buildings, causing heavy crack patterns and damaging facades, corners, roofs, and floors, leading to partial and total collapse both within and outside the plane of seismic activity. When a building hasn't been maintained in years, it's especially vulnerable. This is common in the case of vernacular or minor historic structures that aren't protected by Ancient Offices.

When the next earthquake strikes, invasive incompatible repair techniques may cause major damage instead of protecting the buildings. Movable cultural ancient inside damaged buildings (for example, in churches and museums) can be lost not only during the earthquake, but also when they are improperly removed and transported away from the structures (Schmuckle, 2006; Maxwell, 2006).

Monumental structures, such as the parish church of Herkenbosch and the Minderbroeders Church in Redmond, both in the province of Limburg, were severely damaged by seismic shocks. On the Richter scale, the Roermond earthquake of April 13th, 1992 had a magnitude of 5.8. The river floods of February 1995 made international headlines, forcing more than 200,000 people to flee their homes. The rising water posed a serious threat to monuments and collections, including a museum depot in the Tielerwaard of the Arnhem Open Air Museum. Examples like these demonstrate the need for a high level of continuous alertness (Taboroff, 2001).

The Italian CNR encouraged research on masonry building prevention and repair after the 1976 earthquake in Friuli and the 1980 earthquake in Irpinia. The National Group for Defense against Earthquakes (CNR-GNDT) was formed as a special research group. It coordinates structural engineering research in the areas of protection, prevention, and repair of steel, concrete, and masonry structures. A study of masonry buildings, not necessarily monuments, as well as minor architecture in the tissue of historic centers, as well as new masonry buildings, was funded as part of the research (SNCO, 2002).

Seismology and volcanic eruptions are studied by another institute, the National Institute of Geophysics and Volcanology. For a long time, the two groups worked together. The findings of the research have been published on the websites of GNDT and INGV.

The Civil Protection Department provided funding for a three-year GNDT research program from 2003 to 2005. The study of the earthquake vulnerability of historic cities was funded through specific research projects. On the GNDT website, the research findings are available as books, papers, and reports (Stuive, 2003).

Since 2006, the Department of Civil Protection has been directly funding a three-year research program called RELUIS (Rete dei Laboratori Universitari di Ingegneria Sismica (Network of University Laboratories of Seismic Engineering), with a total budget of €15 million. The project's goal is to fund the construction of shaking tables for advanced experimental research on steel, concrete, timber, and masonry structures, including existing and historical structures, as well as to collect, homogenize, and digitize the vast amount of research in various fields that already exists. After the first year of the program, researchers and professionals (architects and engineers) were given access to a website where all of the publications and research results could be found (Toledo, 2003; Secours, 2005).

Following the devastating earthquakes in 1976 and 1980 that devastated the regions of Friuli and Irpinia, as well as their historic centers, the first Italian Seismic Code was drafted, but it did not take cultural ancient into account. In the case of historic masonry building repairs, it was suggested that the old masonry structures be treated as new structures in order to establish safety coefficients in seismic structural analysis. Under the hypotheses of stiff connections between the walls and between the floors and the walls, and stiff behavior of the floors in their plane, "box" behavior for masonry structures was assumed. These assumptions necessitated the replacement of timber floors and roofs with concrete ones, as well as the stiffening of masonry walls with grout injections and reinforced injections (Tommasi, 1997; Wiseman, 1999).

The earthquake in Umbria and Marche in 1997 struck areas where the Code had been applied and the type of intervention described above had been carried out following a previous earthquake in 1979. Building collapses were primarily caused by a lack of maintenance and incompatibility of the techniques used for repair work, according to observations made in four historic centers in Umbria and, for comparison, in two historic centers in Liguria. Heavy concrete beams smashed the walls, tie beams inserted into the walls caused them to partially collapse, and injections failed due to the walls' inability to be injected (see Annex 5). In an extensive survey that included the historic centers of Campi, Castlluccio, Montesanto, and Roccanolfi in Umbria, this phenomenon was documented by L. Binda and other universities (Padua, Genova, etc.). Other organizations focused on the vulnerability of historic centers and buildings that are part of the cultural patrimony (Sassa, 1998 & 2000).

Seismic hazards pose a threat to Iraq. Earthquakes are likely to occur, and they can cause significant damage. After the most recent earthquake in November 2017, such hazards occurred and were recorded (Halabjah earthquake). Unfortunately, there is a scarcity of research on the assessment of earthquake hazard on Iraqi soil. Figure 1 showed the damages to various structures in Iraq as a result of the Halabjah earthquake. shown figure 2.1.

Figure 2.1 Damages to various structures in Iraq as a result of the Halabjah

2.1.1.1 Examples of earthquakes that occurred in the Middle East and had damage to archaeological sites

1. Egypt

Egypt witnessed a devastating earthquake on October 12, 1992, and its intensity was 5.8 on the Richter scale, and antiquities had a share of this destruction, especially the historic buildings of Cairo, registered as a world ancient since 1979. 210 monuments were affected and damaged in the 1992 earthquake out of 560 impacts. A large block fell from the Great Pyramid in Giza, which had previously been subjected to falling stones in the earthquake of the sixties of the last century, and the 1992 earthquake caused the fall of a stone block in the Temple of Hatshepsut and the Temple of Kom Ombo in Aswan, and the destructive force of the earthquake was vertically, which made the statues in temples Luxor is buried in the ground for a distance of 4 meters, and most of the buried statues represented the goddess Sekhmet, the goddess of war. There were also a number of earthquakes that occurred in the Dahshur region and led to the destruction of the small pyramids and their transformation into simple rocks. Able to absorb earthquake waves. Islamic monuments were also among the most damaged monuments as a result of the 1992 AD earthquake. A large number of historical Islamic monuments were damaged; including a large number of mosques and ancient minarets, including; the minaret of Al-Hanafi Mosque, which fell completely. As for the cultural buildings that were damaged as a result of the 1992 earthquake, it included about 17 houses and culture palaces, including Al-Jawhara Palace, Al-Amr Beshtak Palace, Prince Taz Palace, which exposed many of its pillars and columns to great damage, and Al-Sinary House in Sayyida Zainab. It was much damaged before it was restored later shown figure 2.2.

Figure 2.2 Damages of Egypt earthquake , 1992

2. Lebanon

The devastating August 4, 2020 earthquake caused damage to thousands of buildings of varying degrees, whether newly built or those whose construction dates back more than 150 years. The number of damaged buildings is estimated at tens of thousands, of which 650 are antiquities, some of which date back to the eighteenth or nineteenth century, and most of them were concentrated in the regions of Gemmayzeh, Mar Mikhael, Ashrafieh and Jeitaoui. Shown figure 2.3.


Figure 2.3 Damages of Lebanon earthquake

3. Syria

In the twelfth century AD, the Great Aleppo earthquake occurred, which is considered the fourth largest earthquake causing deaths in history, in which most of the city of Aleppo and a number of surrounding towns were destroyed. Among them are the citadel of Aleppo, the citadel of al-Atareb, and a citadel built by the Crusaders in Harem, as well as the destruction of the Hamam of Adzmar, and the successive earthquakes of Aleppo in the Levant, which extended to the island and Iraq, which resulted in the destruction of the Baalbek citadel and its walls and the destruction of the walls of Aleppo and its mosques. The Hamam of Adzmar was destroyed, and the successive earthquakes of Aleppo in the Levant, which extended to the island and Iraq, resulted in the destruction of the Baalbek Citadel and its walls and the collapse of the walls and mosques of Aleppo. Shown figure 2.4.


Figure 2.4 Damages of Syria

4 – Iraq

Seismic hazards pose a danger to Iraq. Earthquakes are likely to occur, and they have the potential to cause significant damage. After the most recent earthquake in November 2017, such hazards were observed and recorded (Halabjah earthquake), its intensity was 7.3 on the Richter scale.

Unfortunately, studies on the assessment of earthquake hazard on Iraqi soil are lacking. The proposed research efforts focused on earthquakes and their effects on Iraqi ancient structures. There will be a historical look at the earthquakes that hit Iraq. The safety factor will be assessed and the outcome will be decided.

2.1.2 Landslides

Avalanches, mud flows, debris flows, and rock falls are all examples of natural disasters that result in the loss of historic objects and architectural ancient . They have a wide-ranging impact, with the majority of the damage being irreversible. The object or structure has been displaced from its original location, severely distorted, and, in many cases, partially overturned. Floods are frequently accompanied by landslides, which are triggered by the same heavy rains that cause flood. Landslides are caused by earthquakes, which are the second most common cause. Erosion (e.g., by river or sea) and human activities are also important triggering factors (excavations at the bottom of a slope or surcharge at the top of a slope). Landslides can happen at a variety of speeds. Unlike other natural disasters, which strike suddenly and almost without warning, some landslides are gradual and can occur over many years. Although such landslides can be destructive, there is more time for emergency measures to be taken. Landslide hazards are common throughout Europe from a territorial standpoint, but the real threats are localized and affect areas that are relatively predictable (Nadim et al., 2005; Maxwell, 2006).

2.1.3 Winds, storms and hurricanes

Wind primarily damages structures by loading them and causing mechanical damage, but it can also change the chemical action of water and gases on cultural ancient objects. The flow around structures has a significant impact on pollutant deposition, biological corrosion, drying and wetting cycles, as well as mechanical wear of the attacked surfaces. Water, salts, dust, and gases can either be carried to or away from an object by wind. The effects of air flow on historical structures or sculptures in the open air are obvious. In order to provide a systematic description of their negative consequences in order to anticipate hypothetical risks, we can divide possible failures into two groups, each of which has fundamentally different causal relationships. To begin, wind erosion damages must be taken into account. Wind and weather have an abrasive impact on building materials, and over time, this abrasive impact can cause significant changes to all exterior parts of structures. Preventive maintenance and monitoring of weather conditions and changes can help you save a lot of money in the long run. The second category of damages occurs when wind loading significantly exceeds the bearing capacity of the construction materials, particularly when combined with rain, as is frequently the case. Localized mechanical damage can result from an abrupt increase in material stress, and structures can even collapse in extreme events (windstorms, hurricanes). This occurs frequently and unexpectedly, making preventative measures much more difficult to implement. Both cultural and natural ancient are harmed and destroyed by strong winds and storms. High buildings, high or light roofs, and released or slender building elements are particularly vulnerable to windstorms. When large trees fall down or heavy boughs break off of them in the vicinity of valuable buildings or sculptural monuments, they can cause significant damage. Winds can sweep across vast swaths of land in multiple countries, bringing with them floods, hail, snow, and sandstorms. Regional storms are the leading cause of financial and insured losses in Europe, according to the Munich Reinsurance Company. Storm surges, floods, avalanches, landslides, high seas and waves, excessive snow loads and rain pressure, and coastal erosion are all possible effects of winter storms. They are difficult to predict, and there is no way to reduce the number of times they occur in Europe (Baker, 2005; Graham and Spennemann, 2006).

2.1.4 Floods

Floods are the most common natural disaster, with a growing negative impact in urbanized areas. They range in size and duration from small inland or coastal floods with only a local impact to catastrophic events affecting large areas and multiple countries. Static and dynamic loads (water pressure, water flow, uplift forces), impacts from floating objects, wetting of building materials (which is difficult to treat), and the effects of soluble salts, chemical pollutants, and biological infection all contribute to damage and failure. Despite the fact that floods are usually short-lived, the aftermath can take a long time to repair and requires enormous effort. Floods can wreak havoc on historic structures, infrastructure, cultural landscapes and gardens, and, in many cases, moveable cultural ancient (see Annex 2 & 5).

Salt transport can cause long-term damage to masonry materials, with few options for repair or protection (Berz, 1994 & 1997).

2.1.5 Natural disasters of various kinds

Natural disasters of various types also pose a threat to cultural ancient . Large areas in the vicinity of volcanic eruptions are destroyed. Houses are frequently built on the sides of volcanoes, even near the crater, especially after the volcano has been dormant for a long time (e.g. the built environment on Mount Vesuvius is so heavy that 600,000 people would have to be evacuated in the event of an eruption). Another type of natural disaster that threatens cultural ancient is land subsidence caused by karst effects, water pumping, or historical mining. The historic cities of Oppenheim (Germany), Norwich (UK), and Ravenna (Italy) are all examples of places where historical monuments are threatened by unexpected ground loss or large-scale settlement. Because of the possibility of flying objects, overloading, icing, and other sudden effects, hailstorms, snowstorms, and sandstorms can be disastrous. Drought and desertification are two phenomena that should be considered in the context of the cultural landscape and archaeological sites (European Research on Cultural Heritage, 2004).

All major disasters and their consequences have been documented and evaluated in national and international documents and reports in recent decades. These are a basic source of data for the protection of cultural ancient , covering technological, procedural, and operational issues. Many well-designed and well-functioning prevention and emergency measures that save human lives completely fail to protect cultural ancient assets, as is well known (Thieken et al., 2005).

Natural disasters generate loads that engineers are unfamiliar with, and in many cases, the induced forces act in opposition to gravity loads (e.g., uplifting and suction), horizontal forces (horizontal movement, moisture expansion of most building materials), or dynamic forces (flow, shocks, impacts) (Drdácký & Slížková, 2005), they aren't always taken into account in design standards and recommendations, and professionals aren't always well-informed. Professionals have not received the necessary training to design and implement protective or mitigation measures.

The majority of these fatalities have occurred in developing countries as a result of shoddy construction (Khalfan, 2013).

For example, in 2003, the Iranian city of Bam was struck by an earthquake with a magnitude of 6.6 on the Richter scale (Richter, 1935), the collapse of many (approximately 60%) unreinforced masonry (URM) buildings in that area resulted in the deaths of more than 43,000 people and the displacement of more than 60,000 people, resulting in the deaths of more than 43,000 people and the displacement of more than 60,000 people (Nasrabadi et al., 2007).

As a result, learning from previous earthquakes and expanding our understanding of earthquakes, including their impact, are essential requirements for developing procedures that must be followed in the future to mitigate these devastating effects and protect communities. Unreinforced masonry and ancient buildings represent the greatest vulnerability (Grunthal, 1998).

The ensemble could be a critical component of a business if original historic properties, or their cultural contents, are deemed to be of significant or unique societal value, even if a realistic financial value cannot be placed on them. In many cases, a disaster resulting in the loss of these objects' components would also result in the loss of the business. As a result, no amount of insurance will be able to adequately replace the business if the original authentic value is lost. The question is how companies should express the various levels of risk that can occur, as well as how they should fully disclose these risks in their financial statements. Many cultural ancient stakeholders are unprepared for such an event (Drdácký, 2005; Drdácký et al., 2006).

Currently, the applicable regulations only require private companies to disclose their risk readiness in their publicly available financial statements. It may be possible to enact a similar regulation in the future to require all European public institutions responsible for extraordinarily valuable buildings and collections (museums, archives, monuments, historic structures, and so on) to follow suit. Because this initiative would encompass such a broad range of European cultural ancient , the European Parliament may wish to consider taking such action (Marek, 2006; Maxwell, 2006).

In order to comply with existing EU documents and recommendations, the following topics would need to be considered on a local or territorial level during this process:-

1. Making Use of Relevant Databases.
2. Planning for risk management and being aware of risk are two important aspects of risk management.
3. Planning for Damage Limitation (including maintenance planning).
4. Planning for Business Continuity.
5. Liaison with Fire Departments and Other Government Agencies (including feedback reporting).
6. Management and Staff Training.

This must be backed up by strong ties between ministries in charge of cultural ancient and civil protection agencies (Nasrabadi et al., 2007).

2.2 Factor of Safety

A factor of safety (FoS), also known as (and used interchangeably with) safety factor (SF), is a term used in engineering to describe how much stronger a system is than it needs to be for the load it is intended to carry. The safety factor is an important parameter to consider when assessing the slope's stability. The safety factor can be calculated accurately using the pseudo-static method based on limit equilibrium and the numerical simulation method, but the velocity at which the result is obtained is slow. If we can establish a relationship between the safety factor and some other parameters, we can calculate the safety factor more quickly by employing the relationship. A safety factor improves people's safety while lowering the chance of a product failing. The factor of safety is extremely important when it comes to fall protection and safety equipment. There is a risk of injury and death if a structure fails, as well as financial loss for the company.

The Factor of Safety is primarily used to ensure that no unexpected failures, deformations, or defects occur during the structural design process. The lower the Factor of Safety, the more likely the design was to fail. As a result, the design is both inefficient and unusable.

To avoid failure under static permanent loads, the factor of safety (FoS) against any type of failure, denoted hereafter as FS, must be kept above 1 (actually "well" above 1 to cover uncertainties). FoS is a function of time when there is seismic shaking.

2.2.1 Factors affecting on factor of safety

1. The consequences of failure.
2. Component materials.
3. Loads types.
4. The degree of precision with which forces are applied.
5. Machine component dependability.
6. The cost of the elements.
7. Manufacturing quality.
8. Machine element testing**.**

The application of the safety factor is no longer limited to modern facilities, but has become an important factor in preserving the integrity of ancient buildings with standards that take into account the different types of loads that these buildings are exposed to, and many studies have been conducted to preserve ancient and archaeological buildings in many countries of the world, but mostly It did not set a specific limit for safety, but the safety coefficient ranged within a certain range according to each type of loads as the following:-

1. For use with highly reliable materials in non-severe loading and environmental conditions, and where weight is a major factor, Safety factor ranged from (1.3 – 1.5).

2. When loading and environmental conditions aren't too harsh, use with dependable materials, Safety factor ranged from (1.5 – 2).

Below, we will present the results of some studies concerned with the application of a safety factor to protect archaeological areas and ancient buildings in some countries of the world:-

1. In Egypt

A. The tomb of Tutankhamen in Egypt

A safety factor was applied to protect the tomb of Tutankhamen in Egypt In order to protect the colorful cemetery inscriptions from fungi, and the impact of dust and carbon dioxide resulting from the increased tourist influx on the place. Preserving the colorful cemetery inscriptions from the effects of climatic factors, as the number of tourists inside the cemetery was determined for a specific period of time for each tourist group, in addition to equipping the cemetery with modern devices for ventilation, lighting, and temperature and humidity measurements. The effects of the tourists on the cemetery were very clear because these visits increase the humidity, the proportion of carbon dioxide in the atmosphere, in addition to the dust, in order to reduce the moving and changing loads and their impact on the material of the components. As, these visits lead to a kind of climate change inside the cemeteries and changes in temperature and humidity, in addition to the behavior of visitors, it constitutes one of the most important and most dangerous factors that threaten the region and its physical and cultural continuity, which severely affects the murals drawings and their erosion or fall, and of course there are new requirements to serve those Visits include interventions in the nature and infrastructure of cemeteries, as there is a need to install lighting and ventilation works, and to establish entrances equipped for the movement of visitors (Hemeda, 2019).

B. Giza Pyramids

Different types of structural damage, as well as decay and disintegration of construction materials, plagued the pyramid complex. Nature, time, and man-made factors are all factors that contribute to this degradation. Rising groundwater levels caused by water infiltration from the suburbs, irrigation canals, and mass urbanization surrounding the Giza plateau have posed a threat to the great pyramids and the Great Sphinx in recent years.

Previous earthquakes caused shear forces on the pyramid complex's walls; vertical cracks and cracks with a direction of about 35–45 degrees above the horizontal show the corresponding failure mechanism. As shown in the illustration, some cracks affect specific elements such as opening thresholds, doors, and foundation stones (figure 2.5 a, b). Due to overloading, material decay, and strength regression, the backing limestone blocks cracked, affecting the great pyramid's stability. On the surfaces of the backing limestone blocks, the honeycomb (differential) weathering effects are visible. The outer-facing limestone blocks go completely unnoticed.

Figure 2.5. a, b Cracking and splitting of backing limestone blocks at Giza

A total of 45 samples of fallen fragments from various locations around the three pyramids were chosen to investigate the above questions. The chosen samples are from the back layers and facades, and they show typical building material characteristics (Lehmer and Hawass, 2017; Hemeda and Pitilakis, 2010).

C. Historic Mosques

Historic mosques in Cairo are considered among the most ancient facilities that are subject to various internal and external damage processes of all kinds, physical and chemical, and the impact of many loads and pressures such as moisture, rainwater, subsurface water and condensation. One of the most important studies conducted to study the safety factor in this field is a study conducted on the Al-Rifai Mosque in Cairo. The study concluded, through the results of those examinations, analysis, and various tests of damaged samples of limestone taken from different places of the study case, that they suffer from deterioration and erosion in calcite crystals, loss of the bonding material, and the presence of cracks and micro cracks in the mineral crystals of the stone as a result of the internal stresses resulting from blooming. The salts on the surface are Efflorescence, below the surface, and within the components of the Crypto florescence stone as a result of the rise of salt solutions from contaminated soil in the building materials used in the walls of the mosque. It was found through physical properties tests that there is a decrease in the density of limestone and an increase in its porosity and its ability to absorb water, as shown by the During the mechanical properties tests, a slight decrease in the resistance of limestone to compressive and tensile stresses due to the influence of various wear factors (El-Arabi et al., 2013).

2. In Syria. (**Umayyad Mosque)**

The Umayyad Mosque – Shown at figure 2.6. – was subjected to a severe state of deterioration in the eighties of the last century. An example of safety factor application studies. It was also found through the mechanical properties tests and various analysis that there was a significant deterioration in the resistance of limestone to pressure and tensile stresses as a result of the presence of cracks and cracks in the stone as a result of the internal stresses resulting from the blooming of salts on the surface Efflorescence and under the surface sub-florescence and within the stone components Crypto florescence as a result of the rise of salt solutions in Building materials used in the walls of the mosque. In the eighties and early nineties of the last century, a large-scale renovation of the mosque was carried out. The restorations included the western minaret of the mosque (the minaret of Qaitbay), the western facade of the mosque, and the northern wall of the mosque overlooking the tomb of Salah al-Din. The western entrance to the mosque was also re-paved, the floors were renewed and the damaged stone bases of the columns were replaced. Treating damaged wood, restoring and repairing the halls, re-establishing and installing a dome inside the courtyard of the mosque (Mostafa, 2009).

Figure 2.6 Umayyad Mosque in Damascus

Therefore, it has become necessary to restore the archaeological buildings and strengthen the weakly bonded mortar by reinforcing the concrete mixtures with mineral fibers and adding them in the weak places of the walls and foundations in accordance with the rules of UNESCO (Khabaz, 2014).

3. In Iran

Iran is considered the country with the most ancient sites on the World Ancient List, as it owns 23 sites, and the first sites selected by UNESCO were in Iran, where UNESCO chose (Takht Jamshid, Naqsh- Jahan Square, Chaga Zanbeel) followed by Syria, but most Its sites are on the list of endangered sites. Every year, the World Ancient Committee adds new sites to the list, or removes sites that no longer meet the criteria. Moisture in its various forms, especially rain and torrential rains, is one of the most damaging factors that threaten the ancient areas in Iran, in addition to exposure to cracking due to seismic activity in many Iranian cities, and this calls for a more evaluation of the safety factor. Iran to be removed from UNESCO's list of endangered sites as the site of "Bam and its Cultural Landscape" in Iran was removed from the List of World Ancient in Danger as a result of improvements in the management and maintenance of the site (Salman, 2007).

4. In Iraq

Iraq includes many ancient archaeological and ancient monuments, dating back thousands of years, such as the ziggurat of Ur, the remains of Babylon, and the Citadel of Erbil in its north. It also includes the most important religious shrines and Islamic shrines, as well as a group of palaces, castles and museums from all historical eras, and interest has increased in applying the safety factor in preserving ancient sites after exposure to many devastating earthquakes, which affected the overall structure of archaeological sites in some areas and It has become necessary to conduct accurate studies of the totality, especially the wind loads, earthquakes, and the stress to which the soil bearing the effects is exposed (Emam, 2011).

5. In Morocco

Morocco is at the forefront of African countries in terms of the number of archaeological sites that are considered a global human ancient , as it includes ancient archaeological sites, including: Volubilis, Tavogalt, Lixus, Mogador, and the Moroccan ancient descends from the mixture of several tributaries, including: African, Berber, Saharan, Arab, and Andalusian and this is what makes the character of diversity overshadow its very rich ancient . The Kingdom of Morocco is considered one of the world’s most respected countries in preserving ancient sites, and it is concerned with applying safety measures to address the deterioration of these sites. Weather factors such as rain and wind represent the bulk of the loads on Moroccan archaeological sites. The interest in evaluating the safety factor led to a significant growth of the sector. Moroccan tourist (Emam, 2011).

2.2.2 Evaluation of safety factor against earthquake loads in Iraq

As a magnitude 7.3 earthquake occurred between Iraq and Iran, causing the entire Iraqi-Iranian border to be affected, but the epicenter was in Iran near Izgil, there was a need to study the impact of seismic activity on Iraq and reassess the seismic risk in this region, as a magnitude 7.3 earthquake occurred between Iraq and Iran, causing the need to study the impact of seismic activity on Iraq and reassess the seismic risk in this region. The last earthquake was used to assess the liquefaction susceptibility of poorly graded sand in the southwest of Baghdad, Iraq. The liquefaction susceptibility of soil was assessed using the NCEER workshop procedure from 1997, which used shear wave velocity. At various earthquake magnitudes and accelerations, the variation of the safety factor with depth was investigated. When exposed to earthquake magnitudes within the ranges that hit Iraq in November 2017, the soil had a high tendency to liquefy, according to the study. In the future, all engineering projects built in Iraq should pay close attention to the effects of earthquakes on soil foundations (Abbas, 2019).

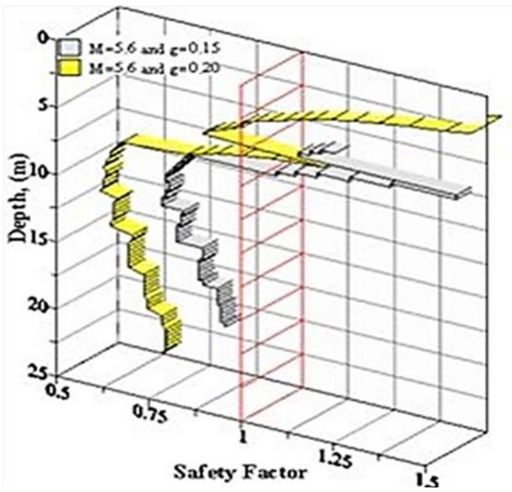


Figure 2.7 Variation of the safety factor with depth at various acceleration values

Table 2.1 showed the ranges of safety factor values and application of each range and table 2.2 showed equipment of safety factor.

Table 2.1 Ranges of safety factor values and application of each range

FoS	APPLICATION
1.25 - 1.5	Material properties are well-known. The operating conditions are well-known. Loads, as well as the stresses and strains that result, are known with a high degree of certainty. Regular inspection and maintenance, as well as material test certificates and proof loading. Designing for low weight is crucial.
1.5 - 2	Under relatively constant environmental conditions, known materials with certification are subjected to loads and stresses that can be determined using qualified design procedures. Proofing, inspection, and maintenance are all required.
2 - 2.5	Materials obtained from reputable suppliers in accordance with relevant standards, operated in normal conditions, and subjected to loads and stresses that can be calculated using checked calculations.
2.5 - 3	Under average conditions of environment, load, and stress, for less tried materials or brittle materials.
3 - 4	When using untested materials under typical environmental, load, and stress conditions.
3 - 4	When using materials that have not been tested under typical environmental, load, and stress conditions.

Table 2.2 Equipment of safety factor

Equipment	FoS
Components of aircraft.	1.5 - 2.5
Boilers.	3.5 - 6
Bolts.	8.5
Wheels made of cast iron.	20
Components of the engine.	6 - 8
Shafting with a lot of strength.	10 - 12
Hooks are a type of lifting equipment.	8 - 9
Vessels under pressure.	3.5 - 6
Components of a turbine – static.	6 - 8
Components of a turbine – rotating.	2 - 3
Large, heavy-duty spring.	4.5
Buildings with structural steel work.	4 - 6
In bridges, structural steelwork is used.	5 - 7
Ropes made of wire.	8 - 9

2.3 The stock of European cultural ancient is in jeopardy

Any future decision on strategies and measures to protect cultural ancient from natural disasters must be based on reasonably reliable knowledge of the European cultural ancient stock at risk. Individual European countries' situations vary significantly in this area, and are highly dependent on the level of national information systems and technology. There are a few examples of national efforts to map endangered cultural ancient (e.g. Italy 9 and Norway). In Slovakia, there is a list of 52 mediaeval castles that covers the entire country. Every castle has a geological map that shows the geo-hazards that affect the cultural site. Even these databases, however, are fragmented and incomplete, lacking some data necessary for natural hazard risk assessment processes and risk management approaches and tools.

Immovable cultural ancient has been listed and recorded in inventories without a systematic geographic location, a technical description of the materials and structures used, and, in most cases, no information about its current state and health, all of which are crucial for its vulnerability to adverse natural forces and action (European Research on Cultural Heritage, 2004).

Building a variety of local and regional databases on cultural ancient stock, particularly in cities, has taken a significant amount of time and effort. The databases, on the other hand, are not standardized, let alone harmonized and coordinated for effective use in the face of natural (and man-made) disasters.

2.4 Protecting cultural ancient with specific tools

Guidelines and national action plans for dealing with various types of natural and man-made disasters have been issued by national governmental bodies.

Guidelines and action plans for dealing with various natural and man-made disasters have been issued by international organizations and bodies. ICOM, ICCROM, the Council of Europe, and the ICBS, as well as the ICOMOS Charters, IFLA, and ICA documents, have issued the most important documents. They don't always directly aid in the coordination of international efforts to protect cultural ancient from natural disasters, but they do encourage collaboration and are useful for training and public awareness campaigns (Federal Insurance and Mitigation Administration, 2002).

In the recent "Hyogo Declaration"26 and specifically in "The Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters"27 adopted at the World Conference on Disaster Reduction in Kobe, the United Nations International Strategy for Disaster Reduction (UN/ISDR) issued documents calling for the protection of cultural ancient (2005). The Hyogo Framework for Action calls for greater international cooperation and joint action (Federal Insurance and Mitigation Administration, 2002).

A proposal for the establishment of an "Intergovernmental Platform under the Aegis of UNESCO for Cooperation on Earthquake Risk Reduction in the Balkan Region" has been proposed by UNESCO (SNCO, 2002).

The earthquakes are the most common types of natural hazards impact on archaeological sites and be dangerous, according to its degrees, time and duration, according to also the nature of the impact, and the method of construction and design, location, building material, but they often destructive and cause a lot of damage to buildings archaeological and may destroy it in Complete or partial, and the archaeological ancient is still exposed in many countries of the world that fall within the scope of the earthquakes to the destruction, rather such earthquakes have led to the destruction of entire cities and settlements, causing the many natural outbreaks to ripple the effects of the ravages of the country. Of the preventive measures to protect archaeological sites, in order to face the negative effects of these factors, but due to the dynamic nature of nature with its various components and changing climatic conditions, It can be said that the most important challenge in the process of interacting with these circumstances is how to reduce as much as possible their negative effects on the various components of the archaeological ancient . Although it is not possible to fully control these factors, it is possible to work to reduce their risks, by including issues of archaeological ancient protection, preservation and maintenance within the framework of the management plans (European Research on Cultural Heritage, 2004).

2.5 Ancient buildings, the subject of the study

The current study focused on three ancient buildings in Iraq against earthquake loads, and these are the following buildings:-

1. Babylonian Theater

The construction of the Babylonian theater is one of the distinctive buildings, whose foundations have remained steadfast in the face of geographical changes, soil erosion, and groundwater that threatened all traces of Babylon. shown figure 2.8.

Figure 2.8 Babylonian theater

2. Natmakh Temple

It is a cuneiform cylinder with an inscription by King Nebuchadnezzar II describing the rebuilding of the temple of the mother goddess Natmakh, and it is the temple of women. shown figure 2.9.

Figure 2.9 Natmakh temple

3. Ishtar Gate

That gate, which was built in 575 BC, was the first to meet a visitor to Babylon. It was constructed using polished stones similar to ceramic, which bear the colors cobalt blue and sea green. These stones are decorated with carvings depicting 575 dragons and bulls shown figure 2.10.

Figure 2.10 Ishtar Gate.

2.5.1 Reasons for conducting the presented study

Many archaeological sites in Iraq suffer from deterioration and exposure to collapse in the absence of essential studies for the application of safety factors, especially in open areas as a result of the exposure of many lands of Iraq to earthquakes and the consequent stress of the soil on which the archaeological sites are located and its instability in front of loads, whether horizontal loads It includes wind loads, earthquakes, inertia and vibrations, as winds are one of the factors that damage archaeological installations, as they carry fine sand, dust and air pollutants. Wind and air currents are also one of the most important factors of erosion and are one of the main reasons for the demolition and erosion of many mud buildings. Vertical loads, including the weight of floors, load-bearing walls, fixtures, and the weights of people using the facilities.

Since the beginning of this century, the phenomenon of damage and its manifestations that appear on the exposed stone archaeological buildings, which can affect the impact permanently, is considered one of the major multi.angle problems and the subject of research activities in recent years, which proved that the resistance of stones to various damage factors and the stability of inscriptions and decorations The cohesion of the building materials between the stones depends on the surrounding conditions and the extent of human activity encroachment on the archaeological areas besides the mechanical and physical properties of the stones and the diversity and difference of the stones that make up the archaeological buildings, which vary between granite, sandstone and limestone.

The external factors whose activity is concentrated in the environment surrounding the archaeological buildings, which cause damage to their building materials, may deform or disintegrate the stones themselves or what is between them from the moon and bonding materials, and this disintegration may arise as a result of excessive loads on the different building layers in Absence of safety factor application or as a result of moisture and ground vibrations or as a result of unregulated heat spread and other physical manifestations.

2.5.2 Shortcomings in the study of the causes of the collapse of archaeological sites

1. The lack of scientific documents to guide them in dealing with ancient sites according to the nature and privacy of each site.
2. Neglecting to perform periodic maintenance and monitoring infringements on public sites.
3. Conflicting competencies between the authorities responsible for protecting archaeological sites.
4. Lack of analytical studies that deal with the importance of the role of the safety factor in protecting archaeological sites and the absence of records for each archaeological site to determine the deterioration or previous treatments it has been exposed to and evaluate previous studies.

CHAPTER 3

THE RELATIONSHIP BETWEEN SAFETY COEFFICIENTS AND LOADS AFFECTING OF ANCIENT BUILDINGS

In this chapter, all the information about the archaeological sites selected in this study is clarified: Ishtar Gate, Babylonian theater, Natmakh temple, and these archaeological sites are located in the Iraqi city of Babylon, south of the capital, Baghdad.

Iraq is located between latitudes 29 ^{o} and 37 ^{o} north of the equator, and between longitudes 38 ^{o} and 48 ^{o} east of Greenwich. The geographical coordinates of the port of Babylon: It is located at latitude 32°32′30″ N and longitude 44°41′32″ E.

Babylon is distinguished by the diversity of its archaeological sites that belong to the prehistoric era and represent the exploits of many successive ancient civilizations.

One of the most important motives for conducting this study is the encroachments to which the archaeological sites in Babylon are exposed, which may lead to their extinction and their exclusion from the World Ancient List and the British archaeologist Richard Dumbriel warned of the repercussions of this work on the survival of the archaeological sites in the city, the ancient city of Babylon became more vulnerable to attack and destruction now, especially when the Babylon Governorate decided to dig a road between Ishtar Gate to the great ziggurat.

The results of the analytical studies that were conducted on many archaeological sites in the city of Babylon - including the sites selected in this study - in order to determine the best method for their maintenance and restoration in line with the nature of their construction, indicated that they are made of bricks and asphalt taken from the ancient city of Hit. Located about 170 km from Baghdad, the city of Hit is famous for its springs, as it is widely known for its asphalt, which was used as a building material in ancient civilizations. In many areas, it was noticed that the residents stole a lot of bricks from archaeological sites in the area to build and support their poor homes.

3.1 Ishtar Gate

Ishtar Gate The eighth gate of the inner city of Babylon, which was built by Nebuchadnezzar in 575 BC in the north of the city as a dedication to Ishtar, the Babylonian gods. The Germans found the original Ishtar Gate in the days of the Ottoman Empire, and it was transferred to Germany and placed in the Pergamon Museum in Berlin and is still in the museum to the present time. The gate, which is part of the city walls of Babylon, was considered one of the Seven Wonders of the World until the 6th century. Replacing it with the Lighthouse of Alexandria. The Ishtar Gate with the towers is fifty meters high and eight meters wide.

The Ishtar Gate's facade is adorned with glazed bricks carved with dragons and bulls in successive rows. The animal carvings are made out of yellow or brown bricks, with blue bricks surrounding them. The blue-coated brick is thought to be made of lapis lazuli, but this has not been confirmed. Figure 3.1 (a, b, c). showed some pictures of Ishtar Gate during different historical periods.

Figure 3.1 a A picture of the ruins of Ishtar gate from the excavations of 1930

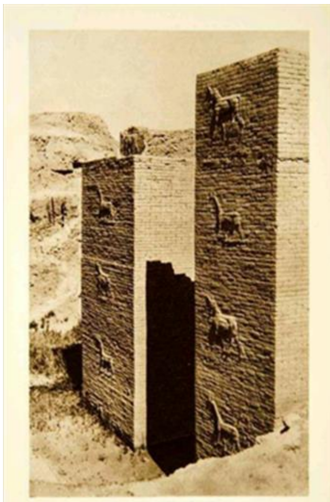


Figure 3.1 b Photo of Ishtar Gate (1938)

Figure 3.1 c Ishtar Gate in Babylon at the end of 2011

Figure 3.2 Ishtar Gate

Figure 3.3 Ishtar Gate (3DS MAX 2021)

3.2 Natmakh Temple

It is considered one of the four most important temples of the ancient Babylonian state, in addition to the temple of Asigila, which was dedicated to the worship of Marduk, the temple of Ishtar and the temple of Nabu. This temple is for women only, and this temple was built from mud, which is the main material used in construction in the old city, because of many advantages, the most important of which is that it dries quickly and makes the place cool in summer and warm in winter. On this basis, the temple consists of a courtyard surrounded by several rooms, including a holy room, the sanctuaries in which religious hymns were held, and in which statues of the goddess were also placed. The walls of the Natmakh temple are exposed to recklessness at the present time, as they are considered a deer due to the excavation work below the area in which the temple is located shown figures 3.4a-i.

Figure 3.4 a Natmakh Temple 2021

Figure 3.4 b Natmakh Temple 2021

Figure 3.4 c Natmakh Temple 2021

Figure 3.4 d Natmakh Temple 2021

Figure 3.4 e Natmakh Temple 2021

Figure 3.4 f Natmakh Temple 2021

Figure 3.4 g Natmakh Temple 2021

Figure 3.4 h Natmakh Temple 2021

Figure 3.4 i Natmakh Temple 2021

3.4 Babylonian theater

This theater was built during the time of the African King Alexander the Great and was built from the bricks of the Tower of Babel (331 BC) and continued throughout the ages and ages to perform all the activities and activities at that time. This building was built in the northern part of the city of Babylon over a group of hills known as Al-Hira, attributed to the red color of its soil. It takes the form of a semi-circular theater, and through these stands there are nine stairs to go up and down. These terraces consisted of three stages, the first stage included six seating, the second stage was nine, and the third stage was twelve seating areas, and a walkway (1-9 meters) wide was prepared between each stage and the other. The internal facade of the theater was decorated with stucco relief, and in the front of the theater in front of the stands there was a row of twelve columns constructed with bricks and plaster.

Figure 3.5 a Babylonian Theater 2021

Figure 3.5 b Babylonian Theater 2021

Figure 3.5 c Babylonian Theater 2021

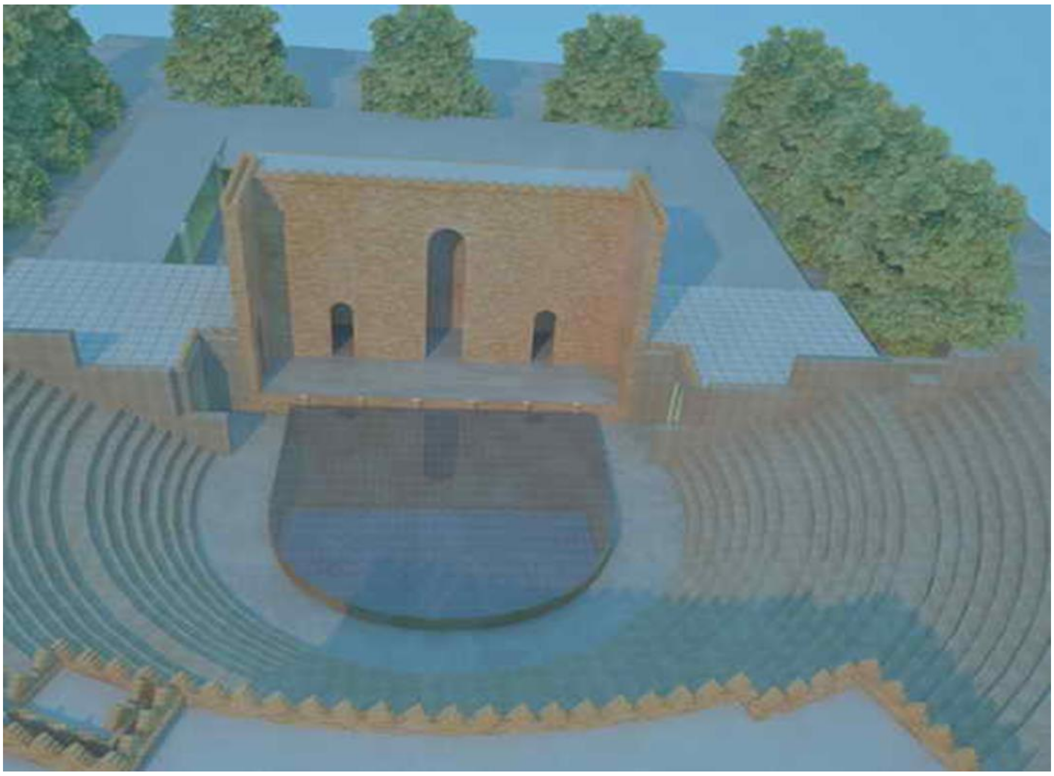


Figure 3.5 d Babylonian Theater 2021

3.4 The scientific concept of earthquakes and their dynamic nature

The word earthquake is derived from the Greek: Σεισμός, the scientific concept of earthquake, how it happened, and what caused it remained a mystery until the beginning of the twentieth century, when seismology emerged, able to answer all of the nagging questions about this phenomenon. Vibrational vibrations caused by movement in the earth's crust, usually caused by the movement of the earth's plates or a fracture in the crust.

3.4.1 Definition of earthquake

Thus, an earthquake can be defined as any sudden shaking of the earth caused by the passage of seismic waves through the rocky plates located beneath the surface of the earth when they move, as this movement produces a large amount of energy that causes the production of those destructive waves, and the planet has witnessed many earthquakes that have occurred throughout history and in various parts of it, geologists believe that there is no place on the surface of the earth where an earthquake will not occur, thousands of earthquakes occur every day, but some have a minor effect while others can be destructive and powerful, resulting in the death of people and the destruction of property and infrastructure. According to statistics, earthquakes killed over one million people in the twentieth century (Ramirez et al., 2015; Preciado et al., 2016b).

3.4.2 How do earthquakes occur?

An earthquake is caused by the movement of the tectonic plates that make up the earth's crust, and this movement releases a large amount of energy, resulting in seismic waves that cause the earth's surface to vibrate. The plates themselves remain motionless, and as a result of the pressure generated by the thrust, a portion of the rocks that make up these plates begin to collapse, resulting in an earthquake, and the tectonic plates begin to move during and after the earthquake, and the epicenter of the earthquake is located underground, while the epicenter is located above the earth's surface.

Rockslides that occur as a result of tectonic plate collisions are not the only cause of earthquakes; such collapses may occur by humans during the construction of some works, such as digging tunnels for roads or railways, or even as a result of detonating mines while carrying out such works, and these rock falls may occur as a result of the collapse of mines dug in the ground while some human activities may produce imperceptible seismic waves, others, such as conducting military tests for nuclear weapons, may have a large and enormous impact similar to large natural earthquakes. The conduct of such experiments has been prohibited, much like the use of bombs in the ground, because of the grave dangers that must result from the occurrence of large seismic waves (Preciado et al., 2016a).

3.4.2.1 Natural earthquakes

Natural earthquakes occur as a result of a sudden fracture of rocks beneath the earth's crust, and on long stretches where this fracture leads to rockslides, the rocks move towards each other and scramble without moving from their place, and after a period of accumulation of rocks, pressure increases on them, they suddenly break, and plates and rock blocks begin to move, forming the earthquake, and these plates or rocks continue to move until they reach a place where it lands, and these plates or rocks continue to move until, earthquakes are classified according to the depth of epicenter of the earthquake into:

A. Shallow earthquakes: occur when the depth of the focus is less than 100 km.

B. Medium earthquakes: occur at depths of 100 km to 300 km.

C. Deep earthquakes: Deep earthquakes occur at depths between 300 and 720 km (Preciado et al., 2015b).

3.4.2.2 Artificial earthquakes

Unnatural factors such as explosions made with the goal of breaking rocks while building roads, tunnels, railways, or detonating mines can cause earthquakes, but these types of earthquakes usually have weak, non-destructive seismic waves that may not be felt at all, and sometimes others cause mine collapses to cause seismic waves that people feel near the place of the explosion, while the explosions resulting from nuclear warheads cause seismic waves that people feel near the place of the explosion. As a result, nuclear warhead testing on the ground has been prohibited because it is impossible to test on the ground without causing destructive seismic waves (Preciado et al., 2015a).

3.4.3 Types of earthquakes

The following are the types of earthquakes that can be classified based on their magnitude:

1. Tectonic earthquakes: These earthquakes are caused by the movement of tectonic plates, and they happen at plate boundaries.
2. Volcanic earthquakes: These earthquakes are linked to volcanic activity and the eruption of molten rock materials from the ground to the surface, such as the eruption of the Hawaiian Islands' volcanoes following a powerful and violent earthquake. The Krakatoa volcano in Indonesia erupted in a massive eruption that wreaked havoc.
3. Destructive earthquakes: They are small earthquakes that occur in caves and underground mines are caused by seismic waves resulting from the explosion of rocks on the earth's surface, and these explosions can be nuclear or chemical.

4. Plutonic earthquakes: Plutonian earthquakes are named after the planet Pluto, whose center is located at a great depth below the surface of the earth (Sperbeck, 2009).

3.4.4 Types and characteristics of seismic waves

(Preciado et al., 2016) studied the seismic waves, like all other types of waves, transfer energy from one place to another, and the types of seismic waves vary in their types and characteristics. Some are known as primary waves, which are characterized by their speed of arrival and are abbreviated (P), while others are known as secondary waves. They are slow waves with the abbreviation (S), and these two types of waves can be combined to produce surface waves, which have a significant impact on causing damage from earthquakes such as demolishing buildings. And we explain the following types of seismic waves and their characteristics:

A. Primary or longitudinal waves

Speed: 5-7 km/sec across the Earth's crust. 1.5 km/sec across the water. 0.3 km/sec through the air.

Characteristics: Fast waves are the first types of waves to be detected by seismographs because they travel faster through materials and can travel through solid, liquid, and gaseous media. Surface waves are smaller than primary waves, and primary waves have higher frequencies. It travels in the form of compression as it reaches the earth's surface perpendicularly. Pressure waves are another name for them.

B. Waves Love

Its speed: 4.5-2 km/sec across the earth, depending on the frequency of wave's propagation.

Characteristics: It's a particular type of surface wave. The speed and depth of a wave are determined by its frequency, so they are scattered waves. It moves horizontally and transversely and travels parallel to the earth's surface. Long waves are another name for them.

C. Rayleigh waves

Speed: 4.5-2 km/s.

Characteristics: It's a different kind of surface wave. The waves are spread out in an elliptical pattern. Its capacity decreases as the earth's depth increases. They move at a slower pace than Love waves. Its depth is determined by how frequently it occurs (Mistler, 2006).

3.4.5 Earthquake strength gauges

Earthquake vibrations are measured using a seismograph (or seismogram), a device that records a graph resulting from the vibrations caused by seismic waves travelling through the earth. There are several scales by which earthquake strength can be measured, including:

1. The Richter scale is a numerical system that is based on a logarithmic basis. An increase of one degree on the Richter scale corresponds to a tenfold increase in the amplitude of waves generated by the previous degree. The Richter scale works on the principle of measuring the amplitude of seismic waves that result from the movement of the earth in addition to using the information provided by the seismograph, and an earthquake with a magnitude of five on the Richter scale means the emergence of a force ten times greater than an earthquake with a magnitude of four on the same scale (Johnson and Harrison, 1990).
2. Momentum scale: The moment magnitude scale, like the Richter scale, measures the strength of an earthquake in terms of the amount of energy released from it, and it is based on a logarithmic system that is 32 times greater than the amount of energy released at each degree than its predecessor.
3. Mercalli scale: The Mercalli intensity scale is used to determine the severity of earthquake effects that may occur in the future, based on a variety of factors such as the geological nature of the area, building design, previous earthquakes in the area, and the amount of damage caused (Desroches and Smith, 2003; Dougherty et al., 2012; Lourenco et al., 2014).

Damage caused by earthquakes varies according to their strength on the seismic scale, as follows:

1. Less than 2.5 degrees: An earthquake with a magnitude of 2.5 or less is ineffective and imperceptible to humans, but it can be detected by a seismograph, and this type of earthquake occurs frequently around the world, with approximately 900,000 earthquakes of this magnitude occurring annually.
2. 2.5 to 5.4 degrees: The occurrence of earthquakes with strengths falling within this range of degrees causes them to be felt in many cases, but they only cause minor damage, and the number of earthquakes with strengths falling within this range is 30,000 per year.
3. 1 to 6.9 degrees: Every year, about 100 earthquakes with magnitudes of 6.1 to 6.9 strikes densely populated areas, causing extensive damage.
4. 7 to 7.9 degrees: If the intensity of an earthquake is between 7 and 7.9 on the Richter scale, it causes severe and severe damage, and about twenty earthquakes of this magnitude occur each year.
5. More than 8 degrees: This type of earthquake occurs once every decade or half-decade, wreaking havoc on all areas nears its epicenter (D'Ayala, 2000; Castellano, 2001).

3.4.6 Earthquakes hazards

According to (Fugazza, 2003) and (Mistler, 2006), there are many risks that may be caused by earthquakes, including the following:-

1. Earthquakes: As a result of the movement of seismic waves across the surface of the earth, earthquakes are considered to have the most effects, and the intensity of the impact varies depending on the duration of the earthquake, as in earthquakes that last for a long time, buildings and facilities are vulnerable to destruction and ruin, as well as the interruption of public life in terms of movement and other activities, as occurred in the 1946 Alaska earthquake, where the resulting earthquakes lasted for seven minutes continuously, and on the other hand, some earthquakes may be light in earthquakes of small strength.

2. Ground ruptures: Earthquakes result in fractures, cracks, and cracks on the earth's surface, which is referred to as ground cracks or ground ruptures. The occurrence of large-scale ground ruptures is uncommon, but when it does, it causes extensive damage to the infrastructure of the affected areas, including the destruction of tunnels, water channels, and roads. Pipelines and railroads run beneath the ground.
3. Landslides: Other side effects of earthquakes, such as landslides or earthquakes can cause landslides. Landslides can destroy property and buildings, cut off roads and railways, and even cause damage to buildings on potentially collapsing hills.
4. Tsunami: Tsunami waves are generated by a series of water waves produced when an earthquake occurs at the bottom of the seas and oceans. It can travel at speeds of more than 700 km per hour to cover large distances in a short amount of time, and when it reaches coastal areas, it can reach heights of more than 27 meters.
5. Fires: Earthquakes can destroy natural gas pipelines, which can contribute to fires, as well as power lines, pouring flammable materials, and other things that an earthquake can cause and cause fires, and earthquakes can destroy water pipes and other things that can hinder efforts to control burning fires.
6. Damage to the soil: Earthquakes can result in soil liquefaction, which is caused by the saturation of the soil with water, causing it to lose its strength. Groundwater may be released to the surface of the earth as a result of earthquakes, resulting in the formation of mud and water mixed with dust, as well as access to buildings, roads, and infrastructure.

3.4.7 The area's most prone to earthquakes

The areas located along the fault line or fault is thought to be the most vulnerable to earthquakes. Because these areas are located on the edges of the earth's tectonic plates, where the movement of these plates towards or away from each other causes earthquakes, ninety percent of large earthquakes occur in those areas while areas far from these plate boundaries are less vulnerable to such large and powerful earthquakes, the term seismic is used to refer to earthquake frequency and distribution across the earth, where earthquakes that occur at these locations are more powerful. The fault line is split into earthquakes with focal depths of less than 70 km and earthquakes with focal depths of 75 to 700 km (Orduña et al., 2008; Foraboschi, and Vanin, 2013b).

3.4.8 The dynamic movement of the earthquake

The earth's dynamic system is constantly evolving, and it can be understood by knowing that the outer part of the solid layer of the earth is made up of a group of small plates that move relative to one another, creating a new solid layer in the surrounding hummock systems, while the old solid areas fade in the areas of flexion or one of these plates slipping over the other creates a tremendous effort in the rocks, when the effort exceeds the strength of the rocks, the rocks collapse and the stored energy is released in the form of earthquakes.

When a structure is subjected to a force as a result of the ground on which it is built moving (static force), the structure generates three internal forces (dynamic forces) whose sum equals the external forces.

These three internal forces (dynamic forces) are:-

1. The inertia force is equal to the mass of the building multiplied by the acceleration of the building's movement (not the acceleration of the ground beneath the building).
2. The damping force is equal to the speed at which the building moves multiplied by the coefficient of friction between the vertical elements of columns, shear walls, and ceilings.
3. The elastic force is defined as the amount of displacement that the building moves multiplied by the rigidity of the building, figure 3.6 illustrated the dynamic motion of earthquakes (Preciado, 2011).

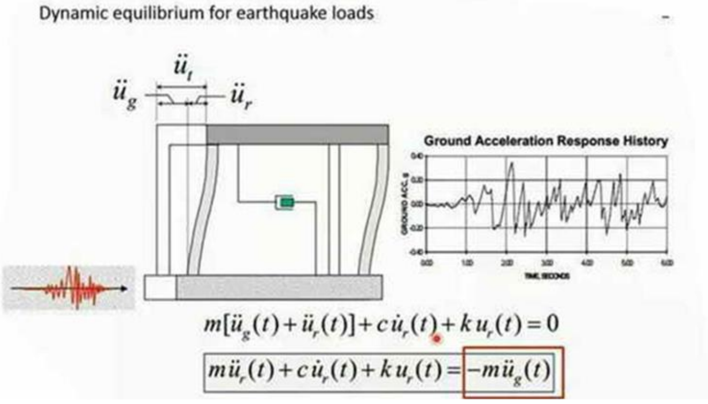


Figure 3.6 An illustration of the dynamic motion of an earthquake

3.4.9 The effect of earthquakes on ancient buildings

The impact of earthquakes on archaeological buildings and ancient facilities varies according to the different type of soil on which these facilities are built in terms of being clay or sandy, as well as building materials and materials that make up the walls in terms of being of mud bricks or stones. Clay soils have a much higher intensity of seismic waves than sandy soils, also walls made of clay materials are weak to the impact of earthquakes, in addition to the presence of other elements that help increase the impact of those strong on buildings such as soil and the presence of errors in the implementation of the building or the use of specifications for inappropriate building materials and the behavior of impact-bearing soil and groundwater that have an impact as for the stones, they are more tolerant to shocks and vibrations caused by earthquakes, but stones and foundations are vulnerable to damage and erosion of the materials responsible for their cohesion due to weather and water erosion factors caused by wind and moisture resulting from rainwater and groundwater, and this damage paves the way for easy damage to those Buildings when earthquakes occur at a later stage, meaning that the damage to ancient buildings is the result of the integration between earthquakes and the weather factors, or it can be described as an interaction between geological factors and physicochemical factors, as they represent an imbalance in the static equilibrium of the facilities as a result of a subsidence in the soil, especially the soil that contains clay minerals that can expand and contract or marshy soil that can creep (Meli, 1998).

The impact of earthquakes on ancient buildings can be summarized as follows:-

1. Earthquakes cause the most serious types of mechanical damage, such as the total collapse of an archaeological structure, depending on the strength and severity of the earthquake, which is caused by the generation of horizontal forces (shear forces), which are sudden and have a significant impact on archaeological structures.
2. Deep cracks are created by earthquakes, which could lead to the archaeological structure collapsing in the future.

3. Earthquakes and vibrations cause the soil on which the archaeological structure is constructed, whether clay or sandy soil, to become more compacted.
4. Vibrations cause a separation and dislocation in the layers that make up the walls of the archaeological building and the materials bearing them, resulting in a bulge and its complete separation over time.
5. The vulnerability to earthquakes increases due to the proximity of the building to a potential seismic source that may generate great intensity in the site and horizontal vibrations lead to micro-cracking of the supporting walls and may lead to partial or complete collapse in the event of a strong earthquake. The structural vulnerability of cultural ancient buildings is further increased by the sheer mass of these monuments and the massive openings that characterize them. In the event of an earthquake, the level of inertial forces is proportional to the mass, which leads to strong vibration in the different parts of the building and most of the stresses are concentrated in the big holes.

And because clay soils are larger in seismic waves, the seismic intensity increases at the surface of this soil, and if such areas are exposed to an earthquake, they are subjected to tensile forces that they cannot bear, resulting in the appearance of cracks or variations in width, or the structures shrinking or collapsing, and thus the damages resulting from earthquakes range from total or partial collapse to cracks, When loose soil is subjected to earthquakes, it may shrink in size in a short period of time, causing an increase in internal water pressure in the soil's interspaces, as well as the continuation of pressure vibrations in the voids, resulting in pressure in the soil and the collapse of buildings and mud houses (Orduña et al., 2008).

3.4.9.1 The effect of earthquakes on foundations and walls

These damages are inferred from the general tendency of structural elements (walls and columns) starting from the base, and refer to the crushing of foundations and lower courses, as well as subsidence of the ground beneath the foundations and ruptures. Even if no subsequent tremors occur, the damaged foundations raise the risk of horizon collapse; the effects of earthquakes on buildings appear in the following forms:

A. The wooden ceilings that make up the structure are prone to failure.

B. Construction and mortar layers are falling to the ground.

C. Longitudinal cracks and top-of-wall cracks.

D. The inclination, cracking, and rotation of buildings, as well as the collapse of faults (Preciado et al., 2015a).

Therefore, it has become necessary introduce and equip to the engineer to have the knowledge of engineering public works in general and special conditions, to have a knowledge of specifications of building materials as per codes provisions, and to study quantities surveying of civil engineering projects(Khabaz, 2016c).

3.4.10 The effect of loads and stresses on buildings

The ability to resist loads and stresses is defined as mechanical endurance, and the resistance of adobe samples to stresses and loads is determined by a number of factors, the most important of which are the following:

1. Building materials

Mud buildings, without a doubt, are more vulnerable to damage and do not bear the harmful effects of various damage factors that stone buildings do, because mud buildings are built with blocks of mud bricks that contain heterogeneous materials in their characteristics and multiple sources, and are not characterized by strong natural interdependence such as the bonding that connects components. As a result, many mud-brick building ruins were severely damaged when they were discovered in archaeological sites, as the mud-brick components could not withstand the drastic difference in environmental conditions between before and after the discovery. The most significant destructors are those that cause the evaporation of water contained within the mud brick components where the resistance of bricks to loads and stresses depends on their organic and inorganic components, as it has been observed that the pressure resistance of adobe bricks increases with an increase in the percentage of minerals in it, and the various damage factors greatly affected the strength of adobe in terms of its ability to resist loads and pressures, and moisture is taken into account One of the most important of these is that increasing the water content of mud bricks reduces their resistance to pressure by a significant amount In most types of mud bricks, however, tensile forces are considered to be extremely low. Because most types of mud bricks crack after drying, it's difficult to make a precise estimate.

2 . The effect of loads by increasing pressure on the soil

The percentage of loads on the soil beneath the foundations rises as the pressure on it rises, which is represented by the vertical thrust, which is not always equal to the horizontal thrust. The organic pollutants and harmful salt solutions that these waters carry on the surface or below the surface, as well as where they settle beneath the surface. The water then moves by capillary action from the foundations to the walls. When it comes to the movement of sticky water in the soil, it determines and estimates the value of the external pressure caused by an excessive load that causes a horizontal movement in a mud brick building (Mistler, 2006; Orduña et al., 2008).

3.5 The economic feasibility and investment opportunities expected from preserving the archaeological sites selected in this study

The area under study, with its unique antiquities unparalleled in many countries of the world, can, when maintained and preserved, become one of the most important tourist attractions and create multiple investment opportunities, as specialists and tourists from the countries of the world are eager to visit these unparalleled archaeological sites in the area.

Perhaps because of the important role historical assets and ancient sites can play in promoting tourism and increasing economic opportunities, the preservation and development of historical assets and ancient sites is becoming a priority in the policies of the international community and local governments today, in addition to sustainable development in the long term.

Archaeological sites play a critical role in attracting tourists and, as a result, improving countries' economies. Because people of all kinds and types have different constructive and mutualistic ideas and are mutually compatible with each other, tourism is an important, vital, and effective source of income in various societies and countries - especially in areas with many important and vital archaeological monuments - tourism is an important, vital, and effective source of income in the countries they visit; There are many job opportunities, and the commercial movement is active during tourist seasons, in addition to tourist demand for various tourist facilities, resulting in large sums of money being injected into tourist countries.

The policies for preserving archaeological sites are divided into:-

A. Preserving archaeological sites

It aims to maintain these sites and their continuity for the longest possible period, and to preserve our ancient history, in addition to preserving the general character and value of the area, protecting archaeological and historical buildings, and developing and developing the surrounding area, which ultimately leads to the protection of these sites from damage, deterioration and their continuity. As an important tourist attraction

B. Reusing neglected archaeological sites

By setting plans and policies that restore these sites their value and status, and preserve their historical value by highlighting their originality and status, placing them within the tourism programs and using them as a unique attraction.

CHAPTER 4

MODELING AND DYNAMIC ANALYSIS OF THE STUDIED ANCIENT BUILDINGS

4.1 Aims and procedures

The introduction to this chapter discusses the main objectives and purpose of preparing this thesis, and also explains the method of working to reach the actual results. These objectives include:

1. Modeling of the three ancient buildings using the Etabs program.
2. Extracting the values of shear moments as a result of the seismic loads of the three archaeological buildings from the above modeling results using the ETABS program.
3. Finding the safety factor for the archaeological buildings against the seismic load.
4. Finding the safety factor of the bonding mortar in the walls of the three buildings against the seismic load
5. Evaluation of the safety factor for each building separately against the seismic load.

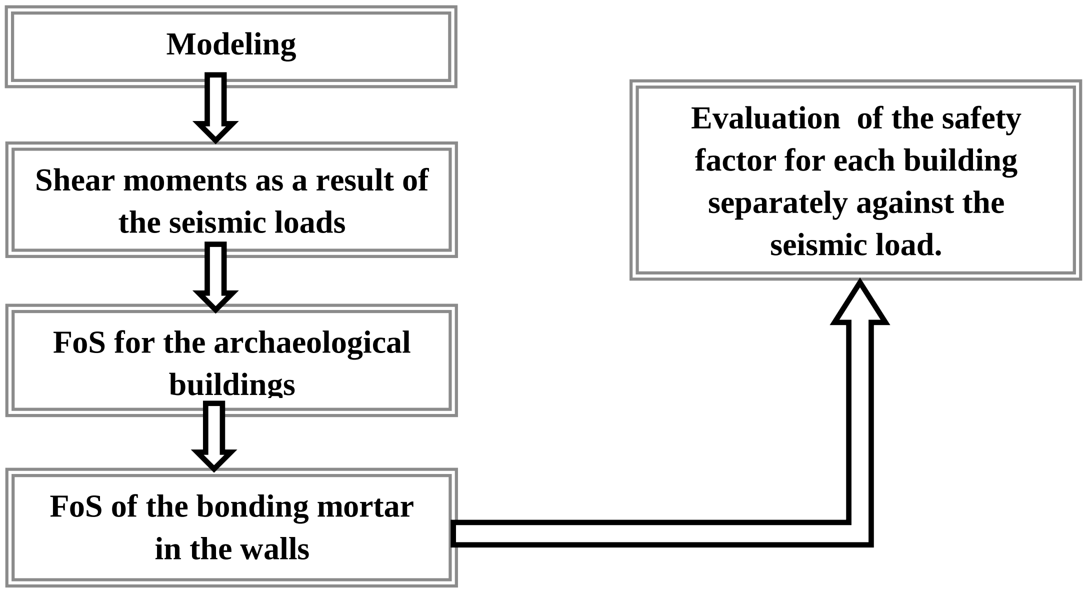


Figure 4.1 Flow chart for thesis procedure

In this chapter, we review the results obtained for the studied ancient sites within the framework of benefiting from the applications of the safety factor in the protection of ancient buildings. Engineering programs as ETABS, were used, such as in the dynamic modeling and analysis of ancient buildings. These results can be divided to two main sections:-

4.2 Modeling

It is considered one of the best means for documenting ancient buildings with mathematical and engineering standards using computer software and it aims to develop fixed or standard morphological and structural designs for ancient buildings that can be referenced in the evaluation of ancient buildings later to determine the negative changes that may occur in terms of formality.

4.3 Dynamic analysis

It specializes in evaluating and studying the stresses to which ancient buildings are exposed as a result of the dynamic loads they are exposed to it or as a result of earthquakes and ground vibrations, and exposed to more earthquakes and it is one of the most influential types of loads on archaeological buildings due to its nature, which is characterized by its great heights, as it can be exposed to severe damage as a result of the ground movement of the soil bearing the ancient buildings as a result of the earthquake movement. And the dynamic analysis processes are concerned with determining the changes that occur in buildings in terms of the soil bearing the foundations and the buildings built on them in terms of geological, physical and chemical aspects. So, the combination of modeling processes and dynamic analysis helps identify the best methods for the sustainable preservation of ancient buildings (Ebrahim et al., 2015).

4.4. Parameter define

In this chapter, discuss the modeling of archaeological buildings in Iraq using the ETABS program, and through this modeling, then begin to analysis and design the buildings against seismic loads according to the results that the program will show. Using the following equation, then should be calculate the safety factor against seismic loads;-

$$\text{FACTOR of SAFETY} = \frac{(\textbf{\textit{Resisting moment}})}{\textbf{Overturning moment}} \tag{4.1}$$

It is also necessary to calculate the weight of the walls, the width of the walls and the maximum seismic load to which the structure is exposed, which requires mentioning all the factors involved in calculating the seismic load and mentioned in the ETABS computer program.

And since all the sites are located in one city (Babylon), we must know the common factors in order to start seismic analysis. These factors are:-

1. (Ss):- Acceleration of the spectral response of the greatest earthquake in the map is taken into account at short intervals and is specified under clause.

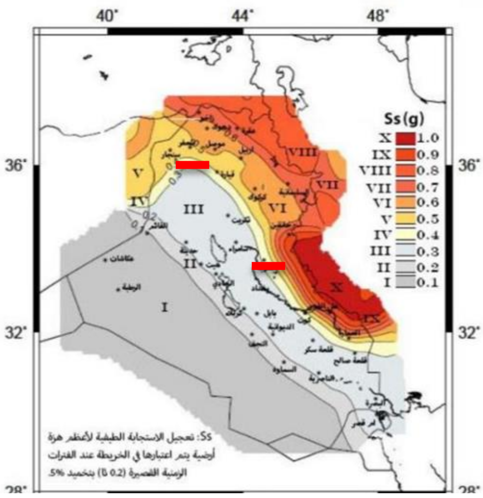


Figure 4.2 Acceleration of the spectral response at one second(Ss)

2. (S_1):- The acceleration of the spectral response of the greatest earthquake in the map is taken into account in duration of 1 second and is specified under clause.

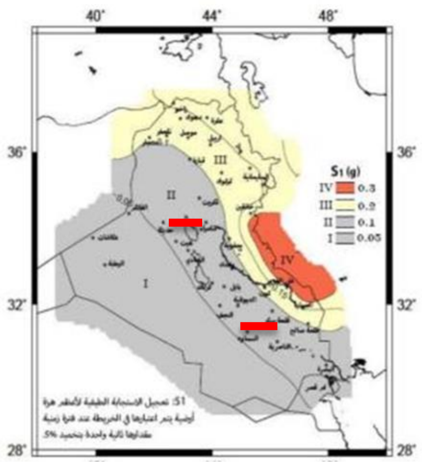


Figure 4.3 Acceleration of the spectral response at short intervals(S_1)

3.(Vs):- Shear wave Velocity, by which we can classify the soil of the site.

Table 4.1 Site classification

Site class	Greatest acceleration of the spectral earthquake response in the map for short				
	S_s<=0.25	S_s=0. 5	S_s<=0.75	S_s=1.0	S_s>=1.25
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	a	a	a	a	a

4-(Fa). Site parameter it used as a function of site class and greatest acceleration of the spectral. earthquake response in the map for short periods (0.5 sec or less).

Table 4.2 Site classification with(S_S)

Sit classification	V_S	N or N_{ch}	S_u
A hard rock	> 1500 m/s	Not	
B rock	750 to 1500 m/s	Not	
C high distance soil	370 to 760 m/s	> 50	
D hard soil	180 to 370 m/s	15 to 50	
E easy clay soil	<180 m/s	< 15	< 50 kPa
	Any soil sector thickness > 3 m have following facility - Plasticity index PI> 20 - moisture content w>=40 % - shear resistance S_u < 25kPa		
F other soil type need special test	***1-Soil prone to collapse.*** ***2-Clay soil with high organic content.*** ***3-Clay soil with very high Plasticity index.*** ***4-Thick ,loose/medium clay soil.***		

5-(F_v). Site parameter (it used as a function of site class and greatest acceleration of the spectral earthquake response in the map for short periods) (for 1 sec)

Table 4.3 Site classification with (S_1)

Sit class	Greatest acceleration of the spectral earthquake response in the map for one second				
	S_1<=0.1	S_1=0. 2	S_1=0.3	S_1=0.4	S_1>=0.5
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
E	a	a	a	a	A

6.(S_{Ds}). The design value of the spectral acceleration of earthquake motion at short periods.

7.(S_{D1}). The design value of the spectral acceleration of earthquake motion at 1 sec.

$$S_{DS}= 2/3\ S_{MS} \quad (4.2)$$

$$S_{D1}= 2/3\ S_{M1} \quad (4.3)$$

8.(S_{MS}), - (S_{M1}). The modified values for the site*(Athary et al., 2017)*

$$S_{MS}=Fa\ S_S \quad (4.4)$$

$$S_{M1}=F_vS_1 \quad (4.5)$$

And since all the selected archaeological buildings are in the same region / Iraq / and exclusively in the ancient city of Babylon, which we talked about in the previous chapters, it is necessary to refer to the basic materials that were built for these archaeological sites, and the most important of these materials is bricks, plaster and bitumen that were brought from the city of Hit in western Iraq.

The dimensions of the bricks used in the construction of most of the archaeological sites in Babylon are (23 x 10 x 8) cm, as it was built in a beautiful way and shown in the picture below, which shows the cuneiform writing used at that time

Figure 4.4 Masonry shape

We will start with the structural analysis of the brick material. Definitions of this material must be used, which include the following:-

Weight per unit volume for masonry.

$$D = M/V \tag{4.6}$$

$$= 1950\ kg/m^3$$

Table 4.4 Masonry distance

Parameter	AAC Block بلك السويريكس	Concrete Block بلك أسمنتي	Brick بلك أحمر (طوب)
Size الحجم / الأبعاد	(600x200x100-300) mm	(400x200x100-200) mm	(230x115x75) mm
Variation in dimensions التباين في الأبعاد	+/-1mm	+/-3mm	+/-5mm
Compressive strength قوة الضغط	30-50 kg/cm2	40-50 kg/cm2	25-30 kg/cm2
Dry Density الكثافة الجافة	550-700 kg/m3	1800 kg/m3	1950 Kg/m3

4.5 Masonry define

1- Modulus of elasticity of masonry.

Table 4.5 Modulus of elasticity for masonry

Material	$E_x = E_y$ (MPa)	$\nu_x = \nu_y$	$G = E/2(1+\nu)$ (MPa)
Brick	11000	0.2	4580
Mortar	2200	0.25	880

E_x, E_y = Young's modulus [MPa], G = Kirchhoff's modulus [MPa], ν_x, ν_y = Poisson's ratios.

2- Poisson's ratio of masonry.

Table 4.6 Masonry type

Brick Type	Number Tested	Young's Modulus MPa	Poisson's Ratio	Length : Width :Dep mm
Pressed Clay Red	6	14,000	0.22	226:111:75
Pressed Clay Biscuit	4	10,000	0.29	230:110:76
Pressed Clay Brown	5	7,000	0.21	227:108:74
Calcium Silicate	3	6,000	0.17	229:108:78
Concrete	4	14,000	0.33	232:109:77

Structural analysis of archaeological sites in Iraq using software

It has become known all the factors affecting the analysis and design of archaeological buildings and the relationship of these factors to seismic loads and the extent of the impact of each factor on the impact of a particular change on the archaeological building in the event of deducting the incorrect numbers. Therefore, it is necessary to obtain quick and accurate results through the use of computer programs (Etabs or SAP 2000). Therefore, the buildings must be designed first using the computer program AutoCAD and start modeling this building to show it in a three-dimensional way to facilitate viewing the building from all directions and heights, in the following explain the dimensions and shapes of archaeological sites :-

4.6 Babylonian theater

4.6.1 Site description of Babylonian theater

This site is located in the State of Iraq / Babil Province / Archaeological Babylon. The building consists of several sections, some of which have disappeared as a result of the erosion factors that went through this building, and we referred to that in the first chapter. We put under attention now the building of the Babylonian theater only, as the dimensions of the building are (25 x 5.0 x 8.7) m.

This site was built using bricks and lime plaster as a binding material, the width of the walls (850)mm, noting that there are no internal partitions connecting the walls among themselves, which makes the building more exposed to dynamic factors (earthquakes, winds, snow, etc...).

Figure 4.5 Modeling of Babylonian's Theater by 3ds MAX

4.6.2 Site design of Babylonian theater

In this field, we start designing the site as a reality after achieving an actual visit to the site and taking all dimensions to achieve the realism of the building, re-designing and drawing it inside the AutoCAD computer program, and then preparing the last output under the 3ds MAX computer program, which simulates the reality of the situation for this site.

The following figure is the final form of this archaeological site from the front and top views.

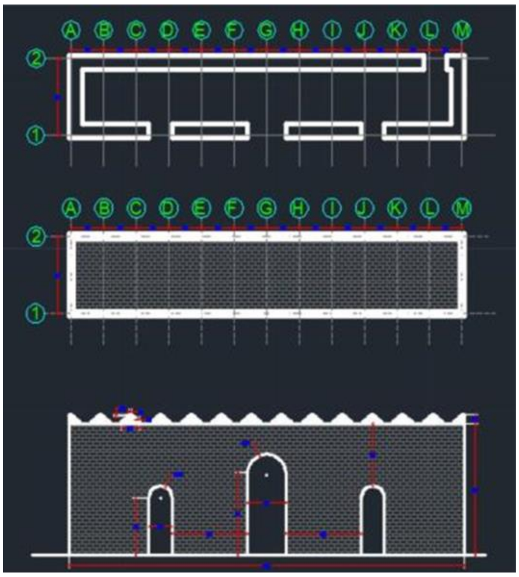


Figure 4.6 Design of Babylonian's Theater by AutoCAD

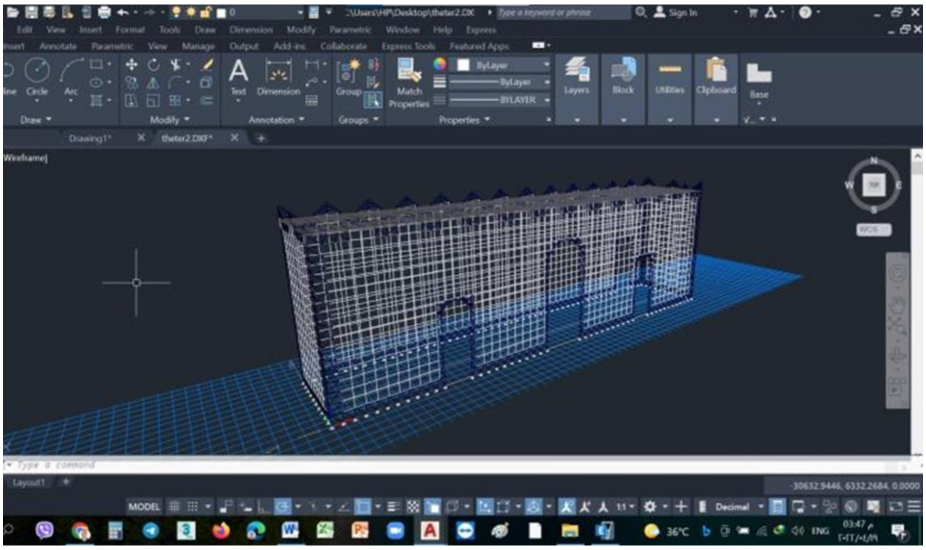


Figure 4.7 Design of Babylonian's Theater by AutoCAD

4.6.3 Site modeling of Babylonian theater

After completing the preparation of the building, it became possible to start modeling it within the analytical computer programs, and among the most important analytical programs is the Etabs program, which requires the designer to know several parameters to be inserted with high accuracy within the program, for example and then draw the building to simulate the reality of the real building. Figure 4.8 shows the simulation of the reality of the building after its modeling.

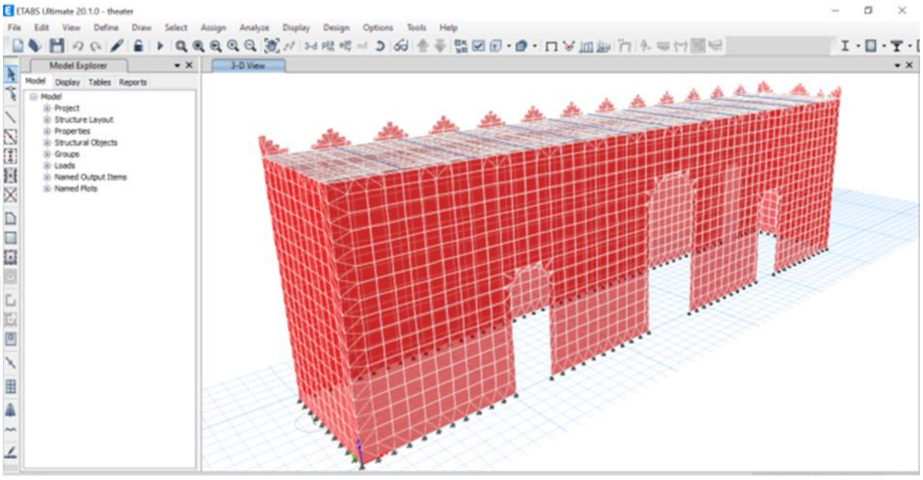


Figure 4.8 Modeling of Babylonian's Theater by CSI-Etabs

4.6.4 Dynamic analysis / Site analysis of Babylonian theater

Once all the dead loads are added to the building, should be able to evaluation the amount of precipitation in the roof and whether this precipitation is allowed or outside the limits of the code.

It is clear from the obtained results that: - U_Z = -2.860 E-08 m

The value we got (2.860 E-08 m) is within the permissible limits.

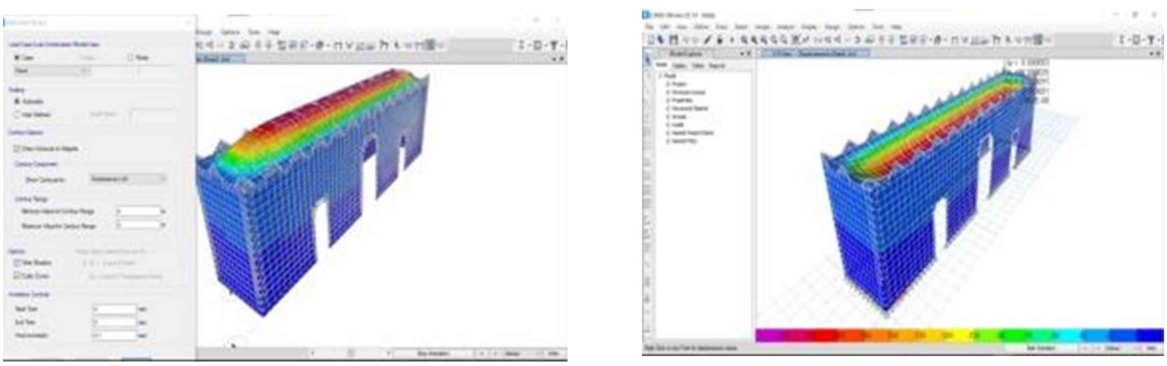


Figure 4.9 Deformed shape of Babylon theater 's roof

4.6.5 Effect of earthquake of Babylonian theater

To complete the process of analysis and structural design for this site, we must add expected loads that may negatively affect the building, causing it to be destroyed. The most important of these effects are earthquakes, winds, hurricanes and snow, and because our research is concerned only with the effect of earthquakes, the rest of the effects have been canceled.

From the above, the most important factors related to earthquakes have been clarified, which we will put in their fields in the ETABS program. It is not hidden from us that the earthquake movement will be on two axes X and Y, so it is necessary to clarify the shape of the building with these two axes.

4.6.6 The earthquake is in the X direction of Babylonian theater

The values of Ux displacement in the negative and positive directions will be noticeable, because the dimensions of the front wall of building are not small (25.6 m) in addition to the absence of internal bulkheads supporting the building and also because the roof of the building is relatively high, which makes the building sway noticeably to the right and left.

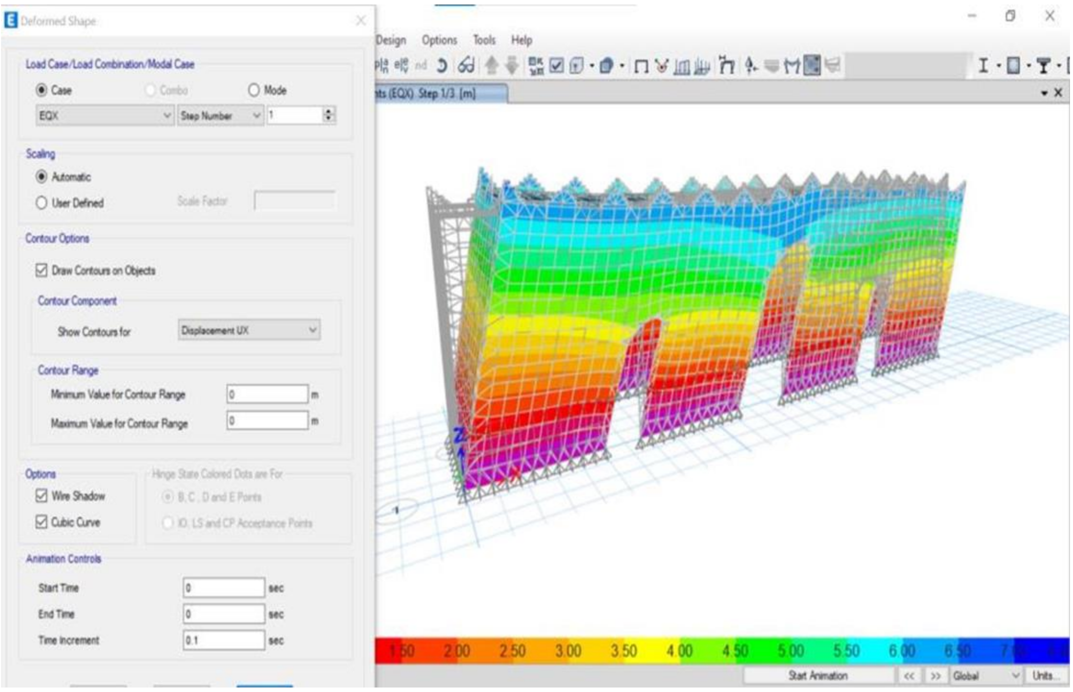


Figure 4.10 Deformed shape of Babylon theater 's walls (EQ+Ux)

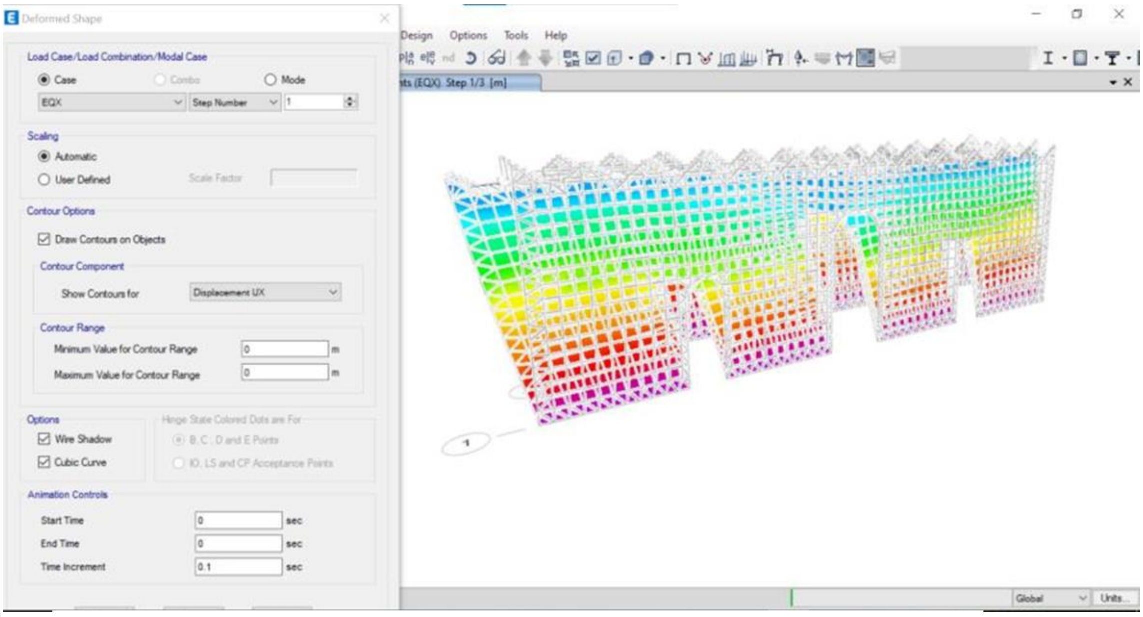


Figure 4.11 Deformed shape of Babylon theater 's walls (EQ-Ux)

4.6.7 The earthquake is in the Y direction of Babylonian theater

The values of Uy displacement in the negative and positive directions will be almost low, because the dimensions of side wall of the building are almost small (5m) in addition to the absence of internal bulkheads supporting the building and also because the roof of the building is relatively high, which makes the building swing significantly forward and backward.

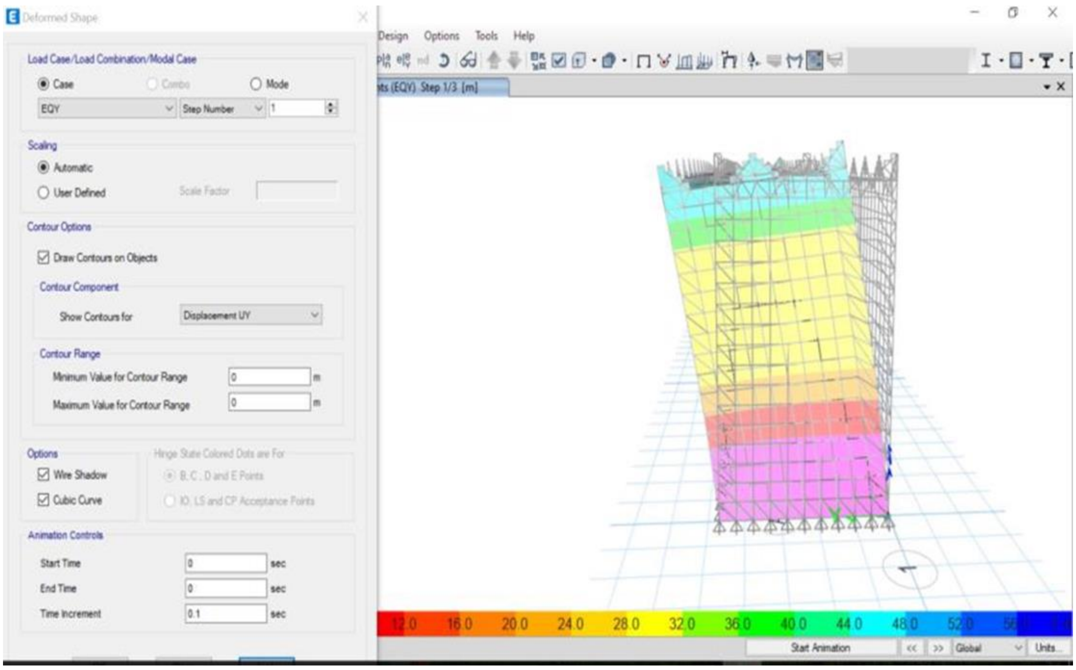


Figure 4.12 Deformed shape of Babylon theater 's walls (EQ+Uy)

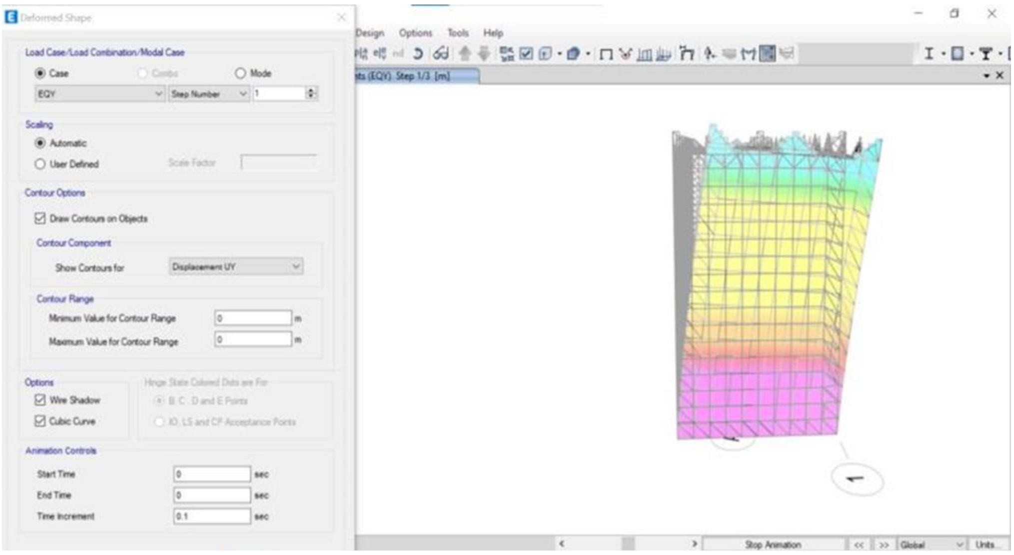


Figure 4.13 Deformed shape of Babylon theater 's walls (EQ-Uy)

4.6.8 Results of Babylonian theater

After the building was modeled using the Etabs program, and the dead loads on the roof of the building were also analyzed, the impact of earthquakes on it was also calculated. We have seen through the previous figures the extent of the impact of seismic loads on the archaeological building, which may lead to the final destruction of the building permanently. The destruction of archaeological sites in any country in the world means a high economic and cultural loss. It is necessary to find ways to ensure that these sites are preserved, and among these ways is to increase the safety factor for them.

Through the results below, t able to find the values of base share, as shown in the following tables:-

Table 4.7 Results from CSI-Etabs for Babylonian theater

Output Case	Case Type	Step Type	Step Number	FX tonf	FY tonf	FZ tonf	MX tonf-m	MY tonf-m	MZ tonf-m	X m	Y m	Z m
Dead	LinStatic			0	0	806.0927	1973.994	-10214.9989	0	0	0	0
Live	LinStatic			0	0	0	0	0	0	0	0	0
Modal	LinModEigen	Mode	1	-0.191	33.9027	0	-271.2219	-1.5279	437.6725	0	0	0
Modal	LinModEigen	Mode	2	-10.9509	1.9938	0	-15.9505	-87.6068	-951.4725	0	0	0
Modal	LinModEigen	Mode	3	250.3826	1.834	0	-14.6716	2003.0609	-786.6445	0	0	0
Modal	LinModEigen	Mode	4	1.0511	23.6708	0	-189.366	8.4092	287.2893	0	0	0
Modal	LinModEigen	Mode	5	-3.319	0.1435	0	-1.1477	-26.552	-169.8154	0	0	0
Modal	LinModEigen	Mode	6	0.3865	0.022	0	-0.1758	3.0917	-0.3423	0	0	0
Modal	LinModEigen	Mode	7	0.4483	0.0121	0	-0.097	3.5862	-1.2382	0	0	0
Modal	LinModEigen	Mode	8	0.0796	1.8537	0	-14.8294	0.6371	22.7277	0	0	0
Modal	LinModEigen	Mode	9	-2.6395	-0.1477	0	1.1818	-21.116	94.5792	0	0	0
Modal	LinModEigen	Mode	10	-0.0939	0.0075	0	-0.0596	-0.7509	0.7586	0	0	0
Modal	LinModEigen	Mode	11	-40.3005	-0.2149	0	1.7193	-322.4043	111.0677	0	0	0
Modal	LinModEigen	Mode	12	0.2394	-0.3543	0	2.8347	1.9148	-6.5075	0	0	0
EQX	LinStatic	Step By Step	1	-32.2845	0	0	0	-258.276	77.7938	0	0	0
EQX	LinStatic	Step By Step	2	-32.2845	0	0	0	-258.276	85.0491	0	0	0
EQX	LinStatic	Step By Step	3	-32.2845	0	0	0	-258.276	70.5384	0	0	0
EQY	LinStatic	Step By Step	1	0	-32.2845	0	258.276	0	-411.3344	0	0	0
EQY	LinStatic	Step By Step	2	0	-32.2845	0	258.276	0	-450.853	0	0	0
EQY	LinStatic	Step By Step	3	0	-32.2845	0	258.276	0	-371.8158	0	0	0

Table 4.8 Results from CSI-Etabs by Excel Microsoft office for Babylonian theater

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	TABLE: Base Reactions													
2	Output Case	Case Type	Step Type	Step Number	FX	FY	FZ	MX	MY	MZ	X	Y	Z	
3					tonf	tonf	tonf	tonf-m	tonf-m	tonf-m	m	m	m	
4	Dead	LinStatic			0	0	806.0927	1973.994	-10214.9989	0	0	0	0	
5	Live	LinStatic			0	0	0	0	0	0	0	0	0	
6	Modal	LinModEigen	Mode	1	-0.191	33.9027	0	-271.2219	-1.5279	437.6725	0	0	0	
7	Modal	LinModEigen	Mode	2	-10.9509	1.9938	0	-15.9505	-87.6068	-951.4725	0	0	0	
8	Modal	LinModEigen	Mode	3	250.3826	1.834	0	-14.6716	2003.0609	-786.6445	0	0	0	
9	Modal	LinModEigen	Mode	4	1.0511	23.6708	0	-189.366	8.4092	287.2893	0	0	0	
10	Modal	LinModEigen	Mode	5	-3.319	0.1435	0	-1.1477	-26.552	-169.8154	0	0	0	
11	Modal	LinModEigen	Mode	6	0.3865	0.022	0	-0.1758	3.0917	-0.3423	0	0	0	
12	Modal	LinModEigen	Mode	7	0.4483	0.0121	0	-0.097	3.5862	-1.2382	0	0	0	
13	Modal	LinModEigen	Mode	8	0.0796	1.8537	0	-14.8294	0.6371	22.7277	0	0	0	
14	Modal	LinModEigen	Mode	9	-2.6395	-0.1477	0	1.1818	-21.116	94.5792	0	0	0	
15	Modal	LinModEigen	Mode	10	-0.0939	0.0075	0	-0.0596	-0.7509	0.7586	0	0	0	
16	Modal	LinModEigen	Mode	11	-40.3005	-0.2149	0	1.7193	-322.4043	111.0677	0	0	0	
17	Modal	LinModEigen	Mode	12	0.2394	-0.3543	0	2.8347	1.9148	-6.5075	0	0	0	
18	EQX	LinStatic	Step By Step	1	-32.2845	0	0	0	-258.276	77.7938	0	0	0	
19	EQX	LinStatic	Step By Step	2	-32.2845	0	0	0	-258.276	85.0491	0	0	0	
20	EQX	LinStatic	Step By Step	3	-32.2845	0	0	0	-258.276	70.5384	0	0	0	
21	EQY	LinStatic	Step By Step	1	0	32.2845	0	258.276	0	-411.3344	0	0	0	
22	EQY	LinStatic	Step By Step	2	0	-32.2845	0	258.276	0	-450.853	0	0	0	
23	EQY	LinStatic	Step By Step	3	0	-32.2845	0	258.276	0	-371.8158	0	0	0	
24														

4.6.8.1 Calculation of safety factor against overturning moment for the walls of Babylonian theater

Results from CSI-Etabs in Table 4.8 :-

We found. EQ. X= 32.2845 Tonf EQ. Y=32.2845 Tonf

Each value means base shear of soil (foundation).

In order to calculate the safety factor for this ancient building, the following must be calculated first:

- Resisting moment from the following equation:

$$\text{Resisting moment} = \text{Wall weight} \times (\text{wall length}/2) \qquad (4.7)$$

- Calculate the share of each wall of the value of the overturning moment divided by the total overturning moment of the building, from the following equation:

$$I=b.h^3/12 \qquad I\ (\text{moment of inertia}) \qquad b(\text{wall width}) \qquad h(\text{wall height}) \qquad (4.8)$$

As for the value of the wall's overturning moment, it is an apparent result of the

4.6.8.1.1 Factor of safety for front wall at Y direction of Babylonian theater

For the front wall's share of the total seismic shear force, the moment of inertia that is perpendicular to the Y-axis must be obtained as follows:-

I_{xx} ***(for front wall)*** = $b.h^3/12$ = 25.6 × $(0.85)^3/12$ = **1.3 m^4**

I_{xx} ***(for rear wall)*** = $b.h^3/12$ = 25.6 × $(0.85)^3/12$ = **1.3 m^4**

I_{xx} ***(for left wall)*** = $b.h^3/12$ = 0.85 × $(5)^3/12$ = **8.85 m^4**

I_{xx} ***(for right wall)*** = $b.h^3/12$ = 0.85 × $(5)^3/12$ = **8.85 m^4**

$\sum I_{xx}$ = 1.3 x 2 + 8.85 x 2 = **20.3 m^4**

Shear force on (***front wall***) = shear value from Etabs results × I_{xx}(*front wall*) / $\sum I_{xx}$ (4.9)

=32.28 × 1.3 / 20.3 **= 2.06 Ton**

Overturning moment of (***front wall*****) in x direction** = 2.06 Ton × 8.7 m = **17.9 Ton.m**

Volume of (***front wall*****)** = h × w × l = 8.7 × 0.85 × 25.6 =**189.3 m^3** (4.10)

Weight of ***(front wall)*** = $d \times v$ = 1.95 Ton/ m^3 × 189.3 m^3 =**369.15 Ton** (4.11)

Resisting moment of ***(front wall)*** = Wall Weight × (wall length /2) (4.12)

= 369.15 × 0.425=**156.88 Ton.m**

Safety factor = $\frac{(\textbf{\textit{Resisting moment}})}{\textbf{Overturning moment}}$

FoS = 156.88 / (2.06 × 8.7) = 8.75 > 1 Ok .

4.6.8.1.2 Factor of safety for side wall at Y direction of Babylonian theater

Shear force on ***(side wall***) = Total shear value from Etabs results × I_{xx}(*side wall*) / $\sum I_{xx}$

=32.28 × 8.85 / 20.3 = **14 Ton**

Overturning moment of (***side wall*****) in y direction** = 14 Ton × 8.7 m = **121.8 Ton.m**

Volume of (***side wall*** **)** = h ×w × l = 8.7 × 0.85 × 5 = **36.97 m^3**

Weight of ***(side wall)*** = $d \times v$ = 1.95 Ton/ m^3 × 36.97 m^3 = **72.1 Ton**

Resisting moment of ***(side wall)*** =Wall weight × (wall length /2)

= 72.1 × 2.5 = **180.25 Ton.m**

FoS = 180.25 / (14 × 8.7) = 1.47 > 1 Ok.

4.6.8.1.3 Factor of safety for front wall at X direction of Babylonian theater

For the front wall's share of the total seismic shear force, the moment of inertia that is perpendicular to the X-axis must be obtained as follows:-

***I_{yy}* (for front wall)** = $b.h^3/12$ =25 × $(0.85)^3/12$ = **1.3 m^4**

***I_{yy}* (for rear wall)** = $b.h^3/12$ =25 × $(0.85)^3/12$ = **1.3 m^4**

***I_{yy}* (for left wall)** = $b.h^3/12$ =0.85 × $(5)^3/12$ = **8.85 m^4**

***I_{yy}* (for right wall)** = $b.h^3/12$ = 0.85 × $(5)^3/12$ = **8.85 m^4**

$\sum$ **I_{xx}** = 1.3 x 2 + 8.85 x 2 = **20.3 m^4**

Shear force *on front wall* = shear value from Etabs results × I_{yy}(*front wall*) / $\sum I_{yy}$

=32.28 × 1.3 / 20.3 = **2.06 Ton**

Overturning moment of *front wall* in x direction = 2.06Ton × 8.7 m = **140.04 Ton.m**

Volume of (*front wall*) = h ×w × l = 8.7 × 0.85 × 25.6 =**189.3 m^3**

Weight of *(front wall)* = *d* × *v* = 1.95 Ton/ m^3 × 189.3 m^3 = **369.15 Ton**

Resisting moment of *(front wall)* = wall weight × (wall length/2) = 369.15 × 12.8

= **4725.12 Ton.m**

FoS = 4725.12 / (1.3 × 8.7) = 33.74 > 1 Ok.

4.6.8.1.4 Factor of safety for side wall at X direction of Babylonian theater

Shear force on *(side wall)* = Total shear value from Etabs results × I_{yy}(*side wall*) / $\sum I_{yy}$

=32.28 × 8.85 / 20.3 = **14 Ton**

Overturning moment of(*side wall*) in x direction = 14 × 8.7 m = **121.8 Ton.m**

Volume of (*side wall*) = h ×w × l = 8.7 × 0.85 × 5 = **36.97 m^3**

Weight of (***side wall)*** = *d* × *v* = 1.95 Ton/ m^3 × 36.97 m^3 = **72.1 Ton**

Resisting moment of *(side wall)* = Wall Weight × (wall length /2)

= 72.1 × 0.425 = **30.64 Ton.m**

FoS = 30.64 / (14 × 8.7) = 0.25 < 1 not Ok.

From the results in Table 4.9, we can say that all walls for (Babylon Theater) is considered safe against overturning moment for all directions. except side wall Because it is considered a failure against the overturning moment in the X direction.

Table 4.9 Evaluation safety factor against overturning moment for the walls Babylon Theater

NO	WALL TYPE	FoS VALUE		EVALUATION
		X-DIRECTION	Y-DIRECTION	
1	FRONT WALL	**33.74**	**8.75**	Safe against Earthquakes
2	SIDE WALL	**0.25**	**1.47**	Safe against Earthquakes at y-direction only

4.6.8.2 Factor of safety (FoS) against collapse the bonding mortar of Babylonian theater

In Babylonian archaeological sites, lime powder mortar with was used as a binder at the time. In order to calculate the factor of safety against collapse the bonding mortar, we must first know the density of that material.

EQ. X= 32.2845 Tonf = 316.3 KN EQ. Y=32.2845 Tonf = 316.3 KN

Bond strength of hardened lime mortar = 0.2 MPa

$$\textbf{FoS for bond strength} = \frac{(\textit{Resisting shear bond})}{\textbf{Earthquake shear force}} \quad (4.13)$$

4.6.8.2.1. FoS for front wall at Y direction of Babylonian theater

For the front wall's share of the total seismic shear force, the moment of inertia that is perpendicular to the Y-axis must be obtained as follows:-

I_{xx} ***(for front wall)*** = $b.h^3/12$ =25.6 × $(0.85)^3/12$ = **1.3 m^4**

I_{xx} ***(for rear wall)*** = $b.h^3/12$ =25.6 × $(0.85)^3/12$ = **1.3 m^4**

I_{xx} ***(for left wall)*** = $b.h^3/12$ =0.85 × $(5)^3/12$ = **8.85 m^4**

I_{xx} ***(for right wall)*** = $b.h^3/12$ = 0.85 × $(5)^3/12$ = **8.85 m^4**

$\sum \mathbf{I_{xx}}$ = 1.3 x 2 + 8.85 x 2 = **20.3 m^4**

Earthquake shear force on (front *wall*) = Earthquake shear force (of Etabs results)

× I_{xx}(*front wall*) / ∑ I_{xx} = 316.3 × 1.3 / 20.3

= 20.25 KN

Brick dimension = (0.23 x 0.1 x 0.08) m

No. of rows (between 2 bricks) of (front *wall*) = (*h*/0.08)= 8.7 /0.08 = **108.75 rows**

No. of columns (between 2 bricks) of (front *wall*) = (*l*/0.23) = 25.6 / 0.23 = **111.3 columns**

Lime mortar area for *front wall* (horizontally) = *b* × *l* × No. of row of (front wall)

= 0.85 ×25.6 × 108.75 = **2366 m^2**

Lime mortar area for *front wall* (vertically) = *h* × *b* × No. of columns of (front wall)

= 8.7 × 0.85 x 111.3 = **823 m^2**

4.6.8.2.2 FoS for side wall at Y direction of Babylonian theater

Earthquake shear force on(*side wall*) = Earthquake shear force (of Etabs results) ×

I_{xx}(*side wall*) / ∑ I_{xx} = 316.3 × 8.85 / 20.3

= 137.9 KN

Brick dimension = (0.23 x 0.1 x 0.08) m

No. of row of (side *wall*) = (*h*/0.08) = 8.7 /0.08 =**108.75 row**

No. of columns of (side *wall*) = (*l*/0.23) = 5 / 0.23 = **21.7 col.**

Lime area for *side wall* (horizontally) = *w* × *l* × No. of row of (side wall)

= 0.85 × 5 × 108.75 = **462.2 m^2**

Lime Volume for *side wall* (vertically) = *h* × *w* × No. of columns of (side wall)

= 8.7 × 0.85 × 21.7 = **160.5 m^2**

Total area for *side wall* = 462.2 + 160.5 = **622.7 m^2**

Bond strength = 200 KN/m^2

Resisting shear bond of *(side wall)* = Total Area × bond strength

= 622.7 × 200 = **124540 KN**

FoS = 124540 / 137.9 = 903 > 1 Ok

4.6.8.2.3 FoS for front wall at X direction of Babylonian theater

For the front wall's share of the total seismic shear force, the moment of inertia that is perpendicular to the X-axis must be obtained as follows:-

I_{yy} ***(for front wall)*** = $b.h^3/12 = 0.85 \times (25.6)^3/12 =$ **1188.3 m^4**

I_{yy} ***(for rear wall)*** = $b.h^3/12 = 0.85 \times (25.6)^3/12 =$ **1188.3 m^4**

I_{yy} ***(for left wall)*** = $b.h^3/12 = 5 \times (0.85)^3/12 =$ **0.255 m^4**

I_{yy} ***(for right wall)*** = $b.h^3/12 = 5 \times (0.85)^3/12 =$ **0.255 m^4**

$\sum I_{yy} = 1188.3 \times 2 + 0.25 \text{ x } 2 =$ **2377.1 m^4**

Earthquake shear force on(*front wall*) = Earthquake shear force (of Etabs results)

$\times I_{yy}(\textit{front wall})/\sum I_{yy}$

= 316.3 × 1.3 / 20.3 **= 20.25 KN**

No. of row of (*front wall*) = (*h*/0.08)= 8.7 /0.08 =**108.75 row**

No. of columns of (*front wall*) = (*l*/0.23) = 25.6 / 0.23 = **111.3 col.**

Lime mortar area for *front wall*(horizontally) = *b* × *l* × No. of row of (front wall)

= 0.85 ×25.6 × 108.75 = **2366 m^2**

Lime mortar area for *front wall* (vertically) = *h* × *b* × No. of columns of (front wall)

= 8.7 × 0.85 x 111.3 = **823 m^2**

Total Area for front wall = 2366 + 823 = **3189 m^2**

Bond strength of hardened lime mortar = 0.2 MPa = 200 KN/m^2

Resisting shear bond of *(front wall)* = Total Area × bond strength

= 3189 m^2 × 200 KN/m^2

= **637812.7 KN**

FoS = 637812.7 / 20.25 = 31497 > 1 Ok

4.6.8.2.4 FoS for side wall at X- direction of Babylonian theater

Earthquake shear force on(*side wall*) = Earthquake shear force (of Etabs results) ×

I_{xx}(*side wall*)/∑ I_{xx}

= 316.3 × 8.85 / 20.3 **= 137.9 KN**

Brick dimension = (0.23 x 0.1 x 0.08) m

No. of row of (*side wall*) = (*h*/0.08)= 8.7 /0.08 =**108.75 row**

No. of columns of (*side wall*) = (*l*/0.23) = 5 / 0.23 = **21.7 col.**

Lime area for *side wall*(horizontally) = *w* × *l* × No. of row of (side wall)

= 0.85 ×5 × 108.75 = **462.2 m^2**

Lime Volume for *side wall* (vertically) = *h* × *w* × No. of columns of (side wall)

= 8.7 × 0.85 × 21.7 = **160.5 m^2**

Total Area for *side wall* = 462.2 + 160.5 = **622.7 m^2**

Bond strength = **200 KN/m^2**

Resisting shear bond of *(side wall)* = Total Area × bond strength

= 622.7 × 200 = **124540 KN**

FoS = 124540 / 137.9 = 903 > 1 Ok

Table 4.10 Evaluation safety factor against collapse the bonding mortar of Babylonian theater

NO	WALL TYPE	FoS VALUE		EVALUATION
		X- DIRECTION	Y- DIRECTION	
1	FRONT WALL	**31497**	**31497**	Safe against Earthquakes
2	SIDE WALL	**903**	**903**	Safe against Earthquakes

From the results in Table 4.10 we can say that the side wall of (Babylon Theater) is considered very safe against collapse the bonding mortar of Babylonian theater.

Finally , we can say that the Babylonian theater is considered to be safe against collapse the bonding mortar

4.7 Ishtar gate

4.7.1 Site description of Ishtar Gate

This site is located in the State of Iraq / Babil Province / Archaeological Babylon. The building consists of several sections, some of which have disappeared as a result of the erosion factors that went through this building, and we referred to that in the first chapter. We put under attention now the building of the Ishtar Gate only, as the dimensions of the building are (16 x 11.4 x 13.9) m.

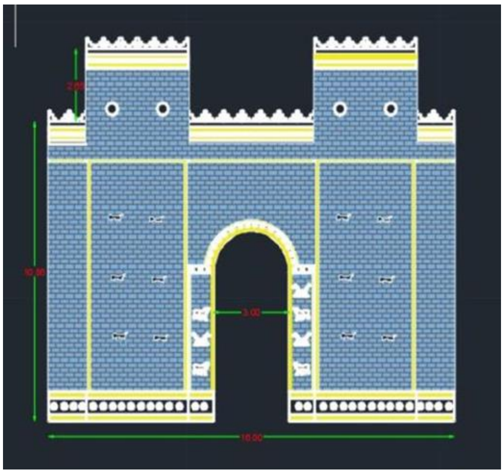
This site was built using bricks and lime plaster as a binding material, the width of the walls (850)mm, noting that there are no internal partitions connecting the walls among themselves, which makes the building more exposed to dynamic factors (earthquakes, winds, snow, etc...).

Figure 4.14 Modeling Ishtar Gate by 3ds MAX

4.7.2 Site design of Ishtar Gate

Now, Start designing the site as a reality after achieving an actual visit to the site and taking all dimensions to achieve the realism of the building, re-designing and drawing it inside the AutoCAD computer program, and then preparing the last output under the 3ds Max computer program, which simulates the reality of the situation for this site.

The following figure is the final form of this archaeological site from the front and top views.



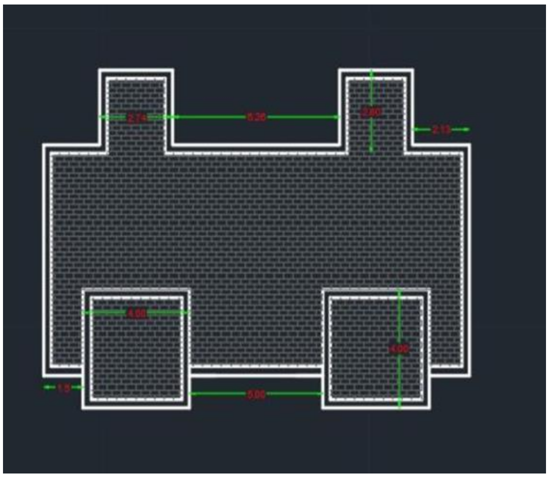


Figure 4.15 Design of Ishtar Gate by AutoCAD program

4.7.3 Site modeling of Ishtar Gate

After completing the preparation of the building, it became possible to start modeling it within the analytical computer programs, and among the most important analytical programs is the Etabs program, which requires the designer to know several parameters to be inserted with high accuracy within the program, then draw the building to simulate the reality of the real building. Figure 4.16 shows the simulation of the reality of the building after its modeling.

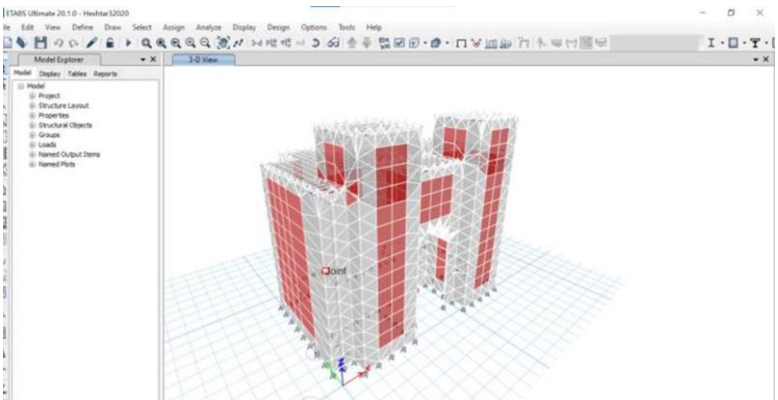


Figure 4.16 Modeling of Ishtar Gate by CSI-Etabs

4.7.4 Dynamic analysis / Site analysis of Ishtar Gate

Once all the dead loads are added to the building, we will be able to evaluation the amount of precipitation in the roof and whether this precipitation is allowed or outside the limits of the code.

It is clear from t The value we got (-7.255 E-07 m) is within the permissible limits. he obtained results that: - U_Z = -7.255 E-07 m.

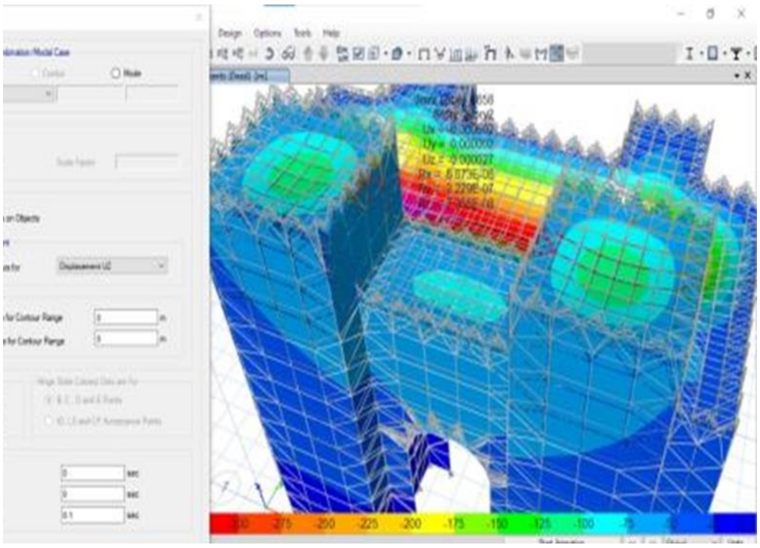


Figure 4.17 Deformed shape of Ishtar Gate's

4.7.5 Effect of earthquake of Ishtar Gate

To complete the process of analysis and structural design for this site, we must add expected loads that may negatively affect the building, causing it to be destroyed. The most important of these effects are earthquakes, winds, hurricanes and snow, and because our research is concerned only with the effect of earthquakes, the rest of the effects have been canceled.

From the above, the most important factors related to earthquakes have been clarified, which put in their fields in the ETABS program. It is not hidden from us that the earthquake movement will be on two axes X and Y, so it is necessary to clarify the shape of the building with these two axes.

4.7.6. The earthquake is in the X direction of Ishtar Gate

The values of Ux displacement in the negative and positive directions will be noticeable, because the dimensions of the building are not small (16 m) in addition to the absence of internal bulkheads supporting the building and also because the roof height of the building is relatively high, which makes the building sway noticeably to the right and left.

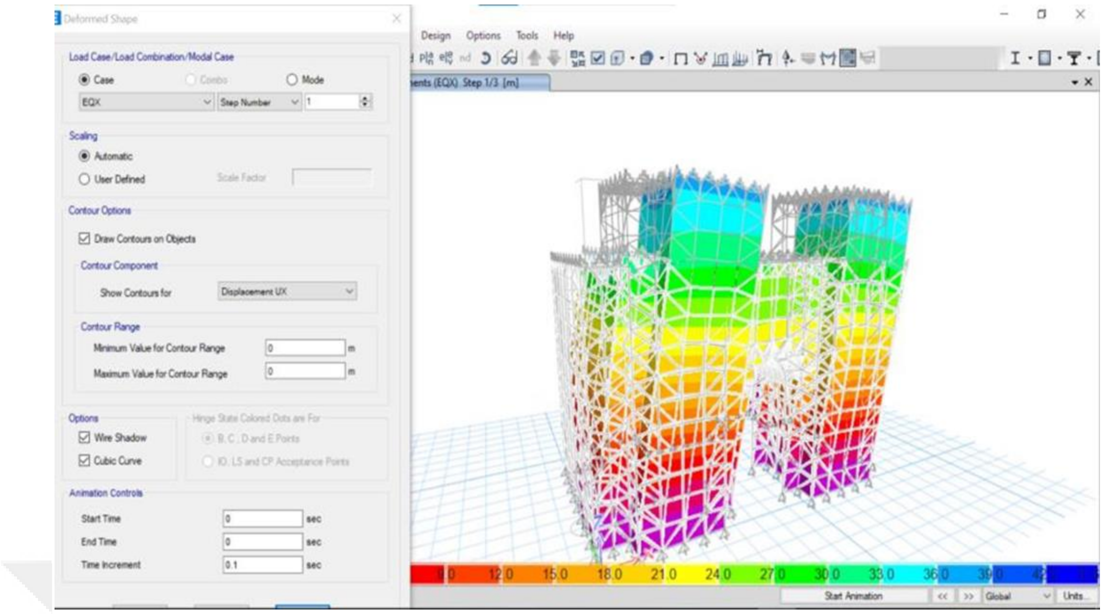


Figure 4.18 Deformed shape of Ishtar Gate's walls (EQ+Ux)

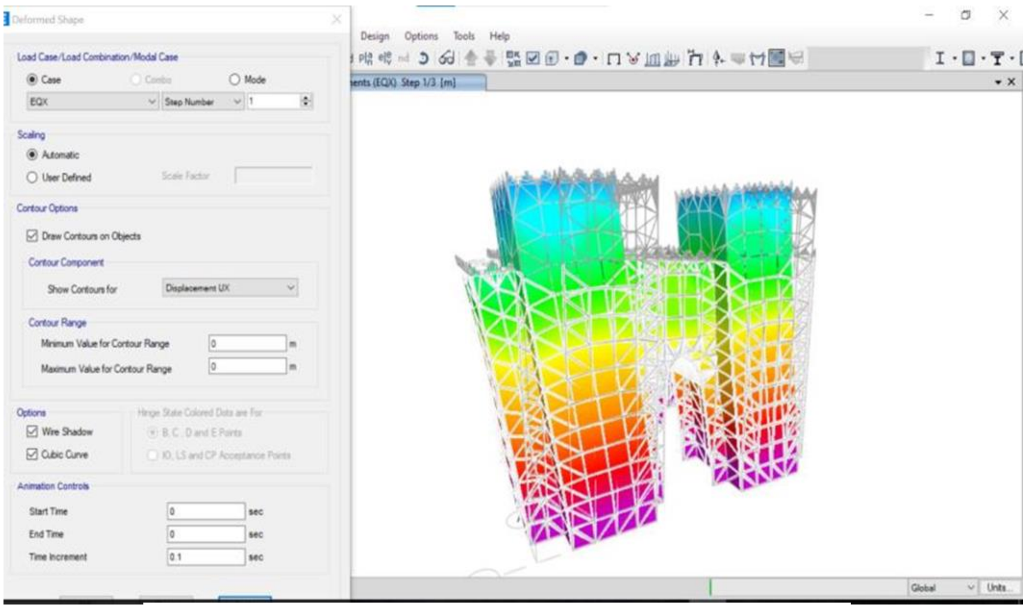


Figure 4.19 Deformed shape of Ishtar Gate's walls

4.7.7 The earthquake is in the Y direction of Ishtar Gate

The values of Uy displacement in the negative and positive directions will be almost low, because the dimensions of the building are almost small (11.4 m) in addition to the absence of internal bulkheads supporting the building and also because the height of the roof of the building is relatively high, which makes the building swing significantly forward and backward.

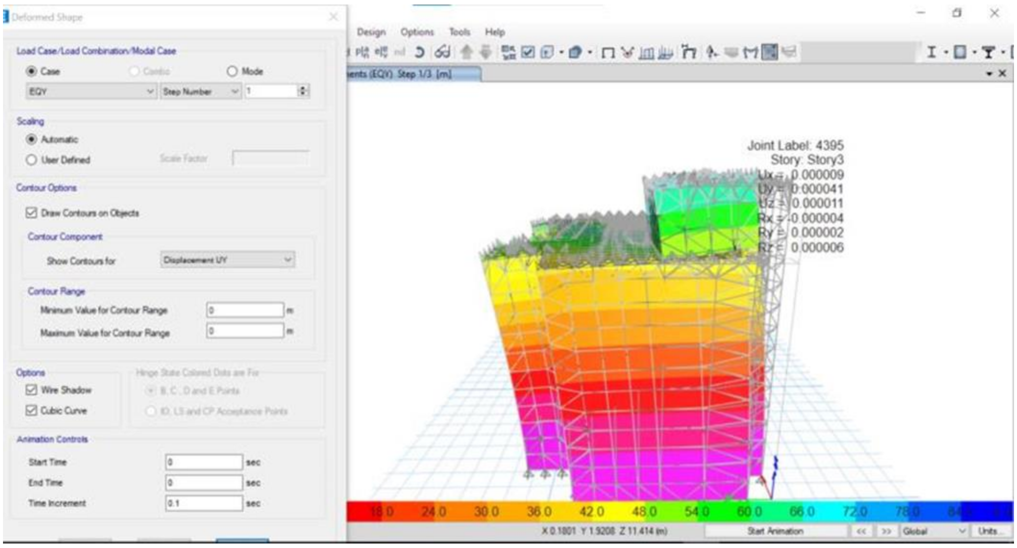


Figure 4.20 Deformed shape of Ishtar Gate's walls (EQ+Uy)

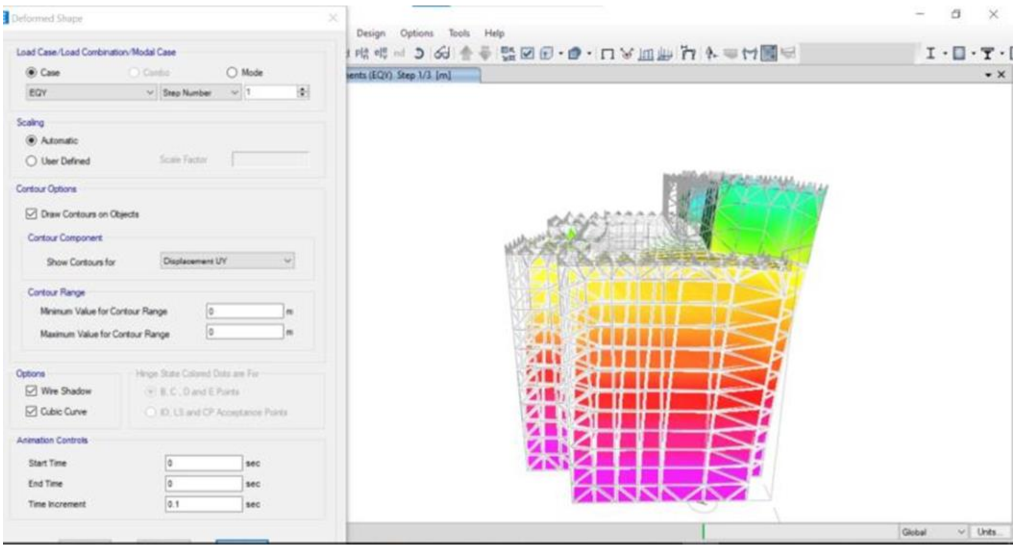


Figure 4.21 Deformed shape of Ishtar Gate's walls (EQ-Uy)

4.7.8 Results of Ishtar Gate

After the building was modeled using the Etabs program, and the dead loads on the roof of the building were also analyzed, the impact of earthquakes on it was also calculated. We have seen through the previous figures the extent of the impact of seismic loads on the archaeological building, which may lead to the final destruction of the building permanently. The destruction of archaeological sites in any country in the world means a high economic and cultural loss. It is necessary to find ways to ensure that these sites are preserved, and among these ways is to increase the safety factor for them.

Through the results below, we will be able to find the values of base share, as shown in the following tables:-

Table 4.11 Results from CSI-Etabs for Ishtar Gate

Base Reactions

Units: As Noted Hidden Columns: No Sort: None Filter: None Base Reactions

Output Case	Case Type	Step Type	Step Number	FX tonf	FY tonf	FZ tonf	MX tonf-m	MY tonf-m	MZ tonf-m	X m	Y m	Z m
Dead	LinStatic			0	0	1696.5856	8114.4514	-13579.2331	0	0	0	0
Live	LinStatic			0	0	0	0	0	0	0	0	0
Modal	LinModEigen	Mode	1	-0.0103	38.7153	0	-431.7295	-0.1145	309.856	0	0	0
Modal	LinModEigen	Mode	2	-70.7765	-0.0319	0	0.3514	-787.211	258.556	0	0	0
Modal	LinModEigen	Mode	3	-12.1825	-0.0284	0	0.3083	-130.965	636.1251	0	0	0
Modal	LinModEigen	Mode	4	14.453	-0.0979	0	1.0024	115.1919	-594.9195	0	0	0
Modal	LinModEigen	Mode	5	-0.211	46.0797	0	-519.4025	-2.4839	369.6904	0	0	0
Modal	LinModEigen	Mode	6	-0.0177	-6.1076	0	82.7314	0.0652	-46.4293	0	0	0
Modal	LinModEigen	Mode	7	0.511	28.8424	0	-236.1306	5.7683	226.8644	0	0	0
Modal	LinModEigen	Mode	8	-22.5653	0.1948	0	-0.7821	-258.6563	104.2436	0	0	0
Modal	LinModEigen	Mode	9	-0.0947	4.6315	0	-63.3037	-1.1452	35.7508	0	0	0
Modal	LinModEigen	Mode	10	16.5269	-0.2602	0	2.4187	202.5669	-489.6166	0	0	0
Modal	LinModEigen	Mode	11	17.9008	-0.3704	0	4.6833	200.4949	249.5108	0	0	0
Modal	LinModEigen	Mode	12	-0.5081	0.2153	0	65.4659	-6.1023	-1.6296	0	0	0
EQX	LinStatic	Step By Step	1	-70.363	0	0	0	-782.3768	316.111	0	0	0
EQX	LinStatic	Step By Step	2	-70.363	0	0	0	-782.3768	316.111	0	0	0
EQX	LinStatic	Step By Step	3	-70.363	0	0	0	-782.3768	316.111	0	0	0
EQY	LinStatic	Step By Step	1	0	-70.363	0	782.3768	0	-562.9297	0	0	0
EQY	LinStatic	Step By Step	2	0	-70.363	0	782.3768	0	-562.9297	0	0	0
EQY	LinStatic	Step By Step	3	0	-70.363	0	782.3768	0	-562.9297	0	0	0

Record: 1 of 20 Add Tables... Done

Table 4.12 Results from CSI-Etabs by Excel Microsoft office for Ishtar Gate

TABLE: Base Reactions

Output Case	Case Type	Step Type	Step Number	FX	FY	FZ	MX	MY	MZ	X	Y	Z
				tonf	tonf	tonf	tonf-m	tonf-m	tonf-m	m	m	m
Dead	LinStatic			0	0	1696.5856	8114.4514	-13579.2331	0	0	0	0
Live	LinStatic			0	0	0	0	0	0	0	0	0
Modal	LinModEigen	Mode	1	-0.0103	38.7153	0	-431.7295	-0.1145	309.856	0	0	0
Modal	LinModEigen	Mode	2	-70.7765	-0.0319	0	0.3514	-787.211	258.556	0	0	0
Modal	LinModEigen	Mode	3	-12.1825	-0.0284	0	0.3083	-130.965	636.1251	0	0	0
Modal	LinModEigen	Mode	4	14.453	-0.0979	0	1.0024	115.1919	-594.9195	0	0	0
Modal	LinModEigen	Mode	5	-0.211	46.0797	0	-519.4025	-2.4839	369.6904	0	0	0
Modal	LinModEigen	Mode	6	-0.0177	-6.1076	0	82.7314	0.0652	-46.4293	0	0	0
Modal	LinModEigen	Mode	7	0.511	28.8424	0	-236.1306	5.7683	226.8644	0	0	0
Modal	LinModEigen	Mode	8	-22.5653	0.1948	0	-0.7821	-258.6563	104.2436	0	0	0
Modal	LinModEigen	Mode	9	-0.0947	4.6315	0	-63.3037	-1.1452	35.7508	0	0	0
Modal	LinModEigen	Mode	10	16.5269	-0.2602	0	2.4187	202.5669	-489.6166	0	0	0
Modal	LinModEigen	Mode	11	17.9008	-0.3704	0	4.6833	200.4949	249.5108	0	0	0
Modal	LinModEigen	Mode	12	-0.5081	0.2153	0	65.4659	-6.1023	-1.6296	0	0	0
EQX	LinStatic	Step By Step	1	-70.363	0	0	0	-782.3768	316.111	0	0	0
EQX	LinStatic	Step By Step	2	-70.363	0	0	0	-782.3768	316.111	0	0	0
EQX	LinStatic	Step By Step	3	-70.363	0	0	0	-782.3768	316.111	0	0	0
EQY	LinStatic	Step By Step	1	0	-70.363	0	782.3768	0	-562.9297	0	0	0
EQY	LinStatic	Step By Step	2	0	-70.363	0	782.3768	0	-562.9297	0	0	0
EQY	LinStatic	Step By Step	3	0	-70.363	0	782.3768	0	-562.9297	0	0	0

Base Reactions / Program Control

4.7.8.1 Calculation of safety factor against overturning moment for the walls of Ishtar Gate

Results from CSI-Etabs in Table 4.12 :-

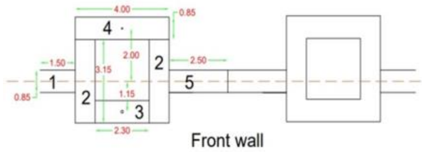
We found**:-** EQ. X= 70.363 Tonf EQ. Y=70.363 Tonf

Each value means base shear of soil (foundation) .

4.7.8.1.1 Factor of safety for front wall at Y direction of Ishtar Gate

For the front wall's share of the total seismic shear force, the moment of inertia that is perpendicular to the Y-axis must

be obtained as follows:-



I_{xx} ***(for front wall)*** = (I_{xx1} + $(I_{xx2}).2$ + I'_{xx3} + I'_{xx4} + I_{xx5})

$I_{xx1}= b.h^3/ 12 = 1.5 \times (0.85)^3/12 =$ **0.07 m⁴**

$I_{xx2}=(b.h^3/ 12).2 = (0.85 \times (3.15)^3/12) \times 2 =$ $\mathbf{4.4\ m^4}$

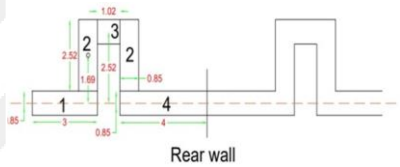
$I_{xx5} = b.h^3/ 12 = 2.5 \times (0.85)^3 / 12 =$ $\mathbf{0.12\ m^4}$

$I'_{xx3}= b.h^3/ 12 + A_3.(d_3)^2 = 2.3 \times (0.85)^3/12 + (0.85 \times 2.3) \times (1.15)^2 =$ $\mathbf{2.7\ m^4}$

$I'_{xx4}= b.h^3/ 12 + A_4.(d_4)^2 = 4 \times (0.85)^3/12 + (0.85 \times 4) \times (2)^2 =$ $\mathbf{13.8\ m^4}$

I_{xx} ***(for front wall)*** = (0.07 + 4.4 + 0.12 + 2.7+ 13.8) × 2 = $\mathbf{21.1\ m^4}$

$I_{xx1}= b.h^3/ 12$



I_{xx} ***(for rear wall)*** = (I_{xx1} + $(I_{xx2}).2$ + I'_{xx3} + I_{xx4}) × 2

$I_{xx1}= b.h^3/ 12 = 3 \times (0.85)^3/12 =$ $\mathbf{0.15\ m^4}$

$I_{xx2}=(b.h^3/ 12 + A_2.(d_2)^2) . 2= ((0.85 \times (2.52)^3 /12 + (2.52 \times 0.85) \times (1.69)^2)).2$

$= \mathbf{14.5\ m^4}$

$I'_{xx3}= b.h^3/ 12 + A_3.(d_3)^2= 1.02 \times (0.85)^3/12 + 1.02 \times 0.85 \times (2.52)^2 =$ $\mathbf{5.55\ m^4}$

$I_{xx4} = b.h^3/ 12 = 4 \times (0.85)^3 / 12 =$ $\mathbf{0.2\ m^4}$

I_{xx} ***(for rear wall)*** = (0.15 + 14.5 + 5.55 + 0.2) = $\mathbf{20.4\ m^4}$

I_{xx} ***(for left wall)*** = $b.h^3/12 = 0.85 \times (7.78)^3/12 =$ $\mathbf{33.35\ m^4}$

I_{xx} ***(for right wall)*** = $b.h^3/12 = 0.85 \times (7.78)^3/12 =$ $\mathbf{33.35\ m^4}$

$\sum \mathbf{I_{xx}} = 21.1 + 20.4 + 2\ (33.35) = \mathbf{108.2\ m^4}$

Shear force on(***front wall***) = shear value from Etabs results × I_{xx}(*front wall*) / $\sum I_{xx}$

=70.363 × 21.1 / 108.2 **= 13.72 Ton**

Overturning moment of(***front wall*****) in x direction** = 13.72 Ton × 12.5 m = **171.5 Ton.m**

Volume of (***front wall*****)** = h × w × l = 12.5 × 0.85 × 38.4 **= ~ 408 m³**

Weight of ***(front wall)*** = *d* × *v* = 1.95 Ton/ m³ × 408 m³ =**795.6 Ton**

Resisting moment of ***(front wall)*** = Wall Weight × (wall length /2)

= 795.6 × 0.425=**338.13 Ton.m**

FoS = 338.13 / 171.5 = 1.97 > 1 Ok .

4.7.8.1.2 Factor of safety for side wall at Y direction of Ishtar Gate

Shear force on *(side wall*) = Total shear value from Etabs results × I_{xx}(*side wall*) / $\sum I_{xx}$

=70.363 × 33.35 / 108.2 = **21.7 Ton**

Overturning moment of side wall in y direction = 21.7 Ton × 11.25 m = **244.1 Ton.m**

Volume of (*side wall*) = h ×w × l = 11.25 × 0.85 × 7.78 = **74.4 m^3**

Weight of *(side wall)* = *d* × *v* = 1.95 Ton/ m^3 × 74.4 m^3 = **145 Ton**

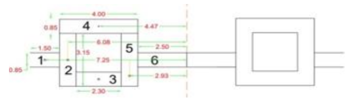
Resisting moment of *(side wall)* =Wall weight × (wall length /2) = 145 × 3.89

= **564 Ton.m**

FoS = **564 / 244.1 = 2.3 > 1 Ok.**

4.7.8.1.3 Factor of safety for front wall at X direction of Ishtar Gate

For the front wall's share of the total seismic shear force, the moment of inertia that is perpendicular to the Y-axis must be obtained as follows:-



***I_{yy}* (for front wall)** = (I'_{yy1} + I'_{yy2}+ I'_{yy3}+ I'_{yy4}+ I'_{yy5}).2 + I_{yy6}

I'_{yy1}= 1.5 x $(0.85)^3$/12 + A_1 x $(d_1)^2$= 0.07 + (1.5 x 0.85) x $(7.25)^2$ = **67.07 m^4**

I'_{yy2}= 0.85 x $(3.15)^3$/12 + A_2 x $(d_2)^2$= 2.21 + (3.15 x 0.85) x $(6.08)^2$ = **101 m^4**

I'_{yy3}= 2.3 x $(0.85)^3$/12 + A_3 x $(d_3)^2$= 0.1 + (2.3 x 0.85) x $(4.47)^2$ = **39.16 m^4**

I'_{yy4}= 4 x $(0.85)^3$/12 + A_4 x $(d_4)^2$= 0.2 + (4 x 0.85) x $(4.47)^2$ = **68.13 m^4**

I'_{yy5}= 0.85 x $(3.15)^3$/12 + A_5 x $(d_5)^2$= 26.56 + (3.15 x 0.85) x $(2.93)^2$ =**49.56 m^4**

I'_{yy6}= 5 x $(0.85)^3$/12 = **0.25 m^4**

***I_{yy}* (for front wall)** = (**67.07+101+39.16+68.13+49.56**) x **2** + **0.25** =**650 m^4**

***I_{yy}* (for rear wall)** = (I'_{yy1} + I'_{yy2}+ I'_{yy3}+ I'_{yy4}).2 + I_{yy5}

I'_{yy1}= 3 x $(0.85)^3$/12 + A_1 x $(d_1)^2$= 0.15 + (3 x 0.85) x $(6.51)^2$ = **96.5 m^4**

I'_{yy2}= 0.85 x $(2.52)^3$/12 + A_2 x $(d_2)^2$=13 + (2.52 x 0.85) x $(5.44)^2$ = **76.4 m^4**

I'_{yy3}= 1.02 x $(0.85)^3$/12 + A_3 x $(d_3)^2$= 0.05 + (1.02 x 0.85) x $(4.5)^2$ = **17.6 m^4**

I'_{yy4}= 2.52 x $(0.85)^3$/12 + A_4 x $(d_4)^2$= 0.13 + (2.52 x 0.85) x $(3.56)^2$ = **27.27 m^4**

I'_{yy6}= 8 x $(0.85)^3/12$ = **4.9 m^4**

I_{yy} (for rear wall) = (**96.5** + **76.4** + **17.6** + **27.27**).**2** + **4.9** = **440.4 m^4**

I_{yy} (for left wall) = $b.h^3/12$ =0.85 × $(7.78)^3/12$ = **33.35 m^4**

I_{yy} (for right wall) = $b.h^3/12$ =0.85 × $(7.78)^3/12$ = **33.35 m^4**

$\sum$ **I_{yy}** = 650 + 440.4 + 33.35 x 2 = 1157.1 **m^4**

Shear force *on front wall* = shear value from Etabs results × I_{yy}(*front wall*) / $\sum I_{yy}$

=70.363 × 650 / 1157.1 = **39.5 Ton**

Overturning moment of *front wall* in x direction = 39.5 Ton × 0.425 = **16.78 Ton .m**

Volume of (*front wall*) = h ×w × l = 12.5 × 0.85 × 38.4 = **408 m^3**

Weight of *(front wall)* = *d* × *v* = 1.95Ton/ m^3 × 408 m^3 = **795.6 Ton**

Resisting moment 0f *(front wall))* = wall weight × (wall length/2) = 795.6 × 0.425

= **338.13 Ton.m**

FoS = 338.13 / 16.78 = 20 > 1 Ok.

4.7.8.1.4 Factor of safety for side wall at X direction of Ishtar Gate

Shear force on *(side wall)* = Total shear value from Etabs results × I_{yy}(*side wall*) / $\sum I_{yy}$

=32.28 × 8.85 / 20.3 = **14 Ton**

Overturning moment of(*side wall*) in x direction = 14 × 11.25 m = **157.5 Ton.m**

Volume of (*side wall*) = h ×w × l = 8.7 × 0.85 × 5 = **36.97 m^3**

Weight of *(side wall)* = *d* × *v* = 1.95Ton/ m^3 × 36.97 m^3 = **72.1 Ton**

Resisting moment of *(side wall)* = Wall Weight × (wall length /2) = 72.1 × 0.425 = **30.64 Ton.m**

FoS = 30.64 / 157.5) = 0.2 < 1 not Ok.

Table 4.13 Evaluation safety factor against overturning moment for the walls Ishtar gate

NO	WALL TYPE	FoS VALUE		EVALUATION
		X- DIRECTION	Y- DIRECTION	
1	FRONT WALL	**20**	**1.97**	Safe against Earthquakes
2	SIDE WALL	**0.2**	**2.3**	Safe against Earthquakes at y-direction only

From the results in Table 4.13, we can say that all walls for (Ishtar Gate) is considered safe against overturning moment for all directions. Except side wall because it is considered a failure against the overturning moment in the X direction.

4.7.8.2 (FoS) for against collapse the bonding mortar of Ishtar Gate

In Babylonian archaeological sites, limestone powder mortar with was used as a binder at the time. In order to calculate the factor of safety against collapse the bonding mortar, we must first know the density of that material.

EQ. X= 70.363 Tonf EQ. Y=70.363 Tonf

Bond strength of hardened lime mortar = 0.2 MPa

4.7.8.2.1 FoS for front wall at Y direction of Ishtar Gate

Using the same methods for finding the moment of inertia in the previous steps, we find that the total sum of the moment of inertia I_{xx} :-

$$\sum \mathbf{I_{xx}} = 21.1 + 20.4 + 2\,(33.35) = \mathbf{108.2\ m^4}$$

Earthquake shear force on(*front wall*) = Earthquake shear force (of Etabs results)

$\times\ I_{xx}(\textit{front wall}) / \sum I_{xx}$

$= 689.5 \times 21.1 / 108.2 = \mathbf{134.5\ KN}$

Brick dimension = (0.23 x 0.1 x 0.08) m

No. of rows (between 2 bricks) of (*front wall*) = (h/0.08)= 11.25 /0.08 = **140.6 rows**

No. of columns (between 2 bricks) of (*front wall*) = (l/0.23) = 20.4 / 0.23 = **88.7 columns**

Lime mortar area for *front wall*(horizontally) = $b \times l \times$ No. of row of (front wall)

$= 0.85 \times 20.4 \times 140.6 = \mathbf{2438\ m^2}$

Lime mortar area for *front wall*(vertically) = $h \times b \times$ No. of columns of (front wall)

= 11.25 × 0.85 x 88.7 = **848 m^2**

Total Area for front wall = 2438 + 848 = **3286 m^2**

Bond strength of hardened lime mortar = 0.2 MPa = 200 KN/m^2

Resisting shear bond of *(front wall)* = Total Area ×bond strength=3286 m^2 × 200 KN/m^2 = **657200 KN**

FoS = **657200 / 134.5 = 4886 > 1 Ok**

4.7.8.2.2 FoS for side wall at Y direction of Ishtar Gate

Earthquake shear force on(*side wall*) = Earthquake shear force (of Etabs results) ×

I_{xx}(*side wall*) / $\sum I_{xx}$

= 689.5 × 33.35 / 108.2 **= 212.5 KN**

Brick dimension = (0.23 x 0.1 x 0.08) m

No. of row of (*side wall*) = (h/0.08)= 11.25 /0.08 =**140.6 row**

No. of columns of (*side wall*) = (l/0.23) = 7.78 / 0.23 = **33.8 col.**

Lime area for *side wall*(horizontally) = $w \times l \times$ No. of row of (side wall)

= 0.85 ×7.78 × 140.6 = **929.7 m^2**

Lime Volume for *side wall*(vertically) = $h \times w \times$ No. of columns of (side wall)

= 11.25 × 0.85 × 33.8 = **323.2 m^2**

Total Area for *side wall* = 929.7 + 323.2 = **1253 m^2**

Bond strength = **200 KN/m^2**

Resisting shear bond of *(side wall)* = Total Area × bond strength

= 1253 × 200 = **250582 KN**

FoS = 250582 **/ 212.5 = 1179 > 1 Ok**

4.7.8.2.3. FoS for front wall at x direction of Ishtar Gate

EQ. X= 70.363 Tonf = **689.5 KN** EQ. Y=70.363 Tonf = **689.5 KN**

$\sum \mathbf{I_{yy}}$ = 650 + 440.4 + 33.35 x 2 = 1157.1

Earthquake shear force on(*front wall*) = Earthquake shear force (of Etabs results)×

I_{yy}(*front wall*)/∑I_{yy}

= 689.5 × 650 / 1157.1 **= 387.3 KN**

No. of row of (*front wall*) = (*h*/0.08)= 11.25 /0.08 =**140 row**

No. of columns of (*front wall*) = (*l*/0.23) = 20.4 / 0.23 = **88.7 col.**

Lime mortar area for *front wall*(horizontally) = *b* × *l* × No. of row of (front wall)

= 0.85 ×20.4 × 140 = **2427.6 m^2**

Lime mortar area for *front wall*(vertically) = *h* × *b* × No. of columns of (front wall)

= 11.25 × 0.85 x 88.7 = **848 m^2**

Total Area for front wall = 2427.6 + 848 = **3275.8 m^2**

Bond strength of hardened lime mortar = **0.2 MPa** = **200 KN/m^2**

Resisting shear bond of *(front wall)* = Total Area × bond strength

= 3275.8 m^2 × 200 KN/m^2

= **655158.7 KN**

FoS = 655158.7 / 387.3 = 1692 > 1 Ok

4.7.8.2.4 FoS for side wall at X direction of Ishtar Gate

Earthquake shear force on(*side wall*) = Earthquake shear force (of Etabs results)

× I_{xx}(*side wall*)/∑ I_{xx}

= 689.5 × 33.35 / 1157.1 **= 19.87 KN**

Brick dimension = (0.23 x 0.1 x 0.08) m

No. of row of (*side wall*) = (*h*/0.08)= 11.25 /0.08 =**140 row**

No. of columns of (*side wall*) = (*l*/0.23) = 7.78 / 0.23 = **33.8 col.**

Lime area for *side wall*(horizontally) = *w* × *l* × No. of row of (side wall)

= 0.85 ×7.78 × 140 = **925.8 m^2**

Lime Volume for *side wall*(vertically) = *h* × *w* × No. of columns of (side wall)

= 11.25 × 0.85 × 33.8 = **323 m^2**

Total Area for *side wall* = 925.8 + 323 = **1249 m^2**

Bond strength = 200 KN/m^2

Resisting shear bond of *(side wall)* = Total Area × bond strength

= 1249 × 200 = **249802 KN**

FoS = 249802 **/ 19.87 = 12572 > 1 Ok**

Table 4.14 Evaluation safety factor against collapse the bonding mortar Ishtar gate

NO	WALL TYPE	FoS VALUE		EVALUATION
		X- DIRECTION	Y- DIRECTION	
1	FRONT WALL	**1692**	**4886**	Safe against Earthquakes
2	SIDE WALL	**12572**	**1179**	Safe against Earthquakes

From the results in Table 4.14 we can say that the side wall of Ishtar Gate is considered very safe against collapse the bonding mortar of Ishtar Gate.

Finally , we can say that the Ishtar Gate is considered to be safe against collapse the bonding mortar.

4.8 NATMAKH TEMPLE

4.8.1 Site Description of Natmakh temple

This site is located in the State of Iraq / Babil Province / Archaeological Babylon. The building consists of several sections, some of which have disappeared as a result of the erosion factors that went through this building, and we referred to that in the first chapter. We put under attention now the building of the Ishtar Gate only, as the dimensions of the building are (35.95 x 53.22 x 12.05) m.

This site was built using bricks and lime plaster as a binding material, the width of the walls (850)mm, noting that there are no internal partitions connecting the walls among themselves, which makes the building more exposed to dynamic factors (earthquakes, winds, snow, etc...).

Figure 4.22 Natmakh Temple

4.8.2 Site design of Natmakh temple

In this field, we will start designing the site as a reality after achieving an actual visit to the site and taking all dimensions to achieve the realism of the building, re-designing and drawing it inside the AutoCAD computer program, and then preparing the last output under the 3ds Max computer program, which simulates the reality of the situation for this site.

The following figure is the final form of this archaeological site from the front and top views.

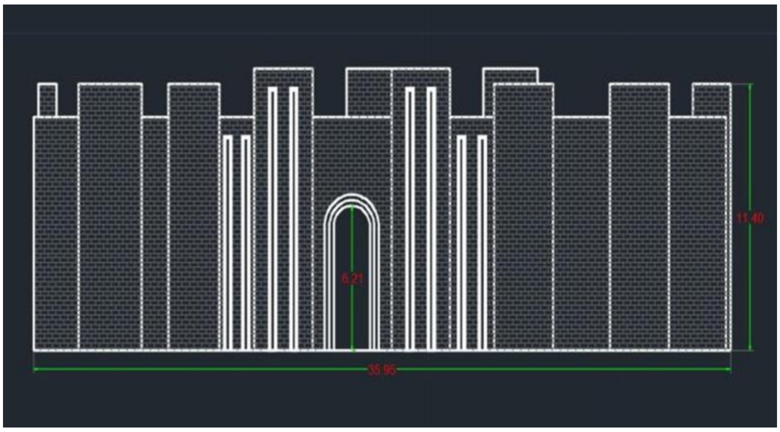


Figure 4.23 Design of Natmakh Temple by AutoCAD program

4.8.3 Site Modeling of Natmakh temple

After completing the preparation of the building, it became possible to start modeling the building within the analytical computer programs, and among the most important analytical programs is the Etabs program, which requires the designer to know many parameters to be inserted with high accuracy within the program, in order to draw the building to simulate the reality of the real building. Figure 4.24 shows the simulation of the reality of the building after its model.

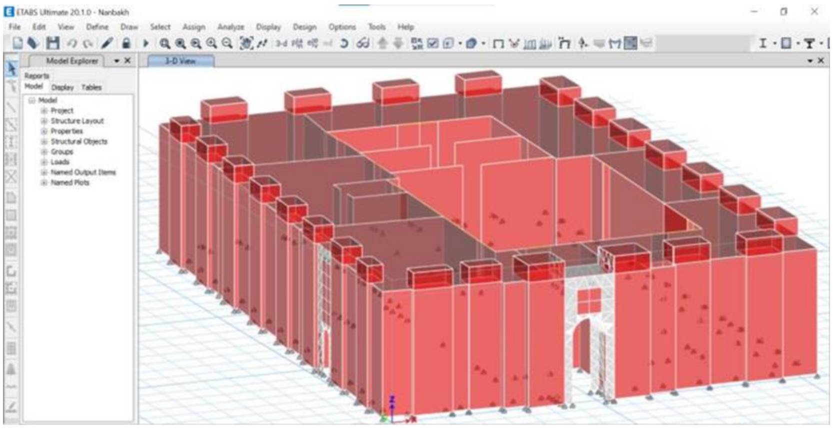


Figure 4.24 Modeling of Natmakh Temple by CSI-Etabs

4.8.4 Dynamic Analysis / Site Analysis of Natmakh temple

Once all the dead loads are added to the building, we will be able to evaluation the amount of precipitation in the roof and whether this precipitation is allowed or outside the limits of the code.

It is clear from the obtained results that: - U_Z = -4.973 E-07 m.

The value we got (-4.973 E-07 m) is within the permissible limits.

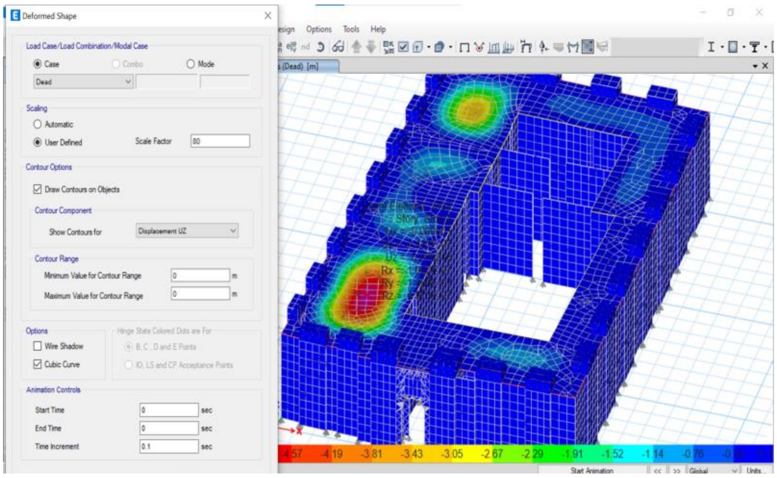


Figure 4.25 Deformed shape of Natmakh Temple's roof

4.8.5 Effect of Earthquake of Natmakh temple

To complete the process of analysis and structural design for this site, we must add expected loads that may negatively affect the building, causing it to be destroyed. The most important of these effects are earthquakes, winds, hurricanes and snow, and because our research is concerned only with the effect of earthquakes, the rest of the effects have been canceled.

From the above, the most important factors related to earthquakes have been clarified, which we will put in their fields in the ETABS program. It is not hidden from us that the earthquake movement will be on two axes X and Y, so it is necessary to clarify the shape of the building with these two axes.

4.8.6 The Earthquake is in the X direction of Natmakh temple

The values of Ux displacement in the negative and positive directions will be noticeable, because the dimensions of the building are not small (53.22 m) in addition to the absence of internal bulkheads supporting the building and also because the roof height of the building is relatively high, which makes the building sway noticeably to the right and left.

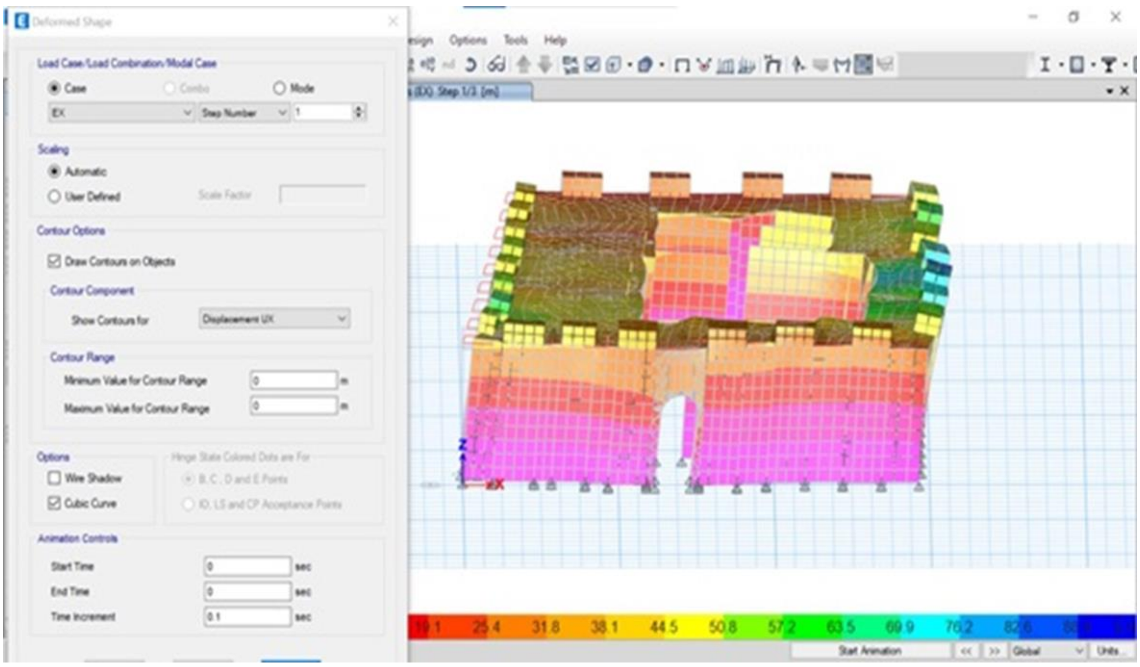


Figure 4.26 Deformed shape of Natmakh Temple's walls (EQ+Ux)

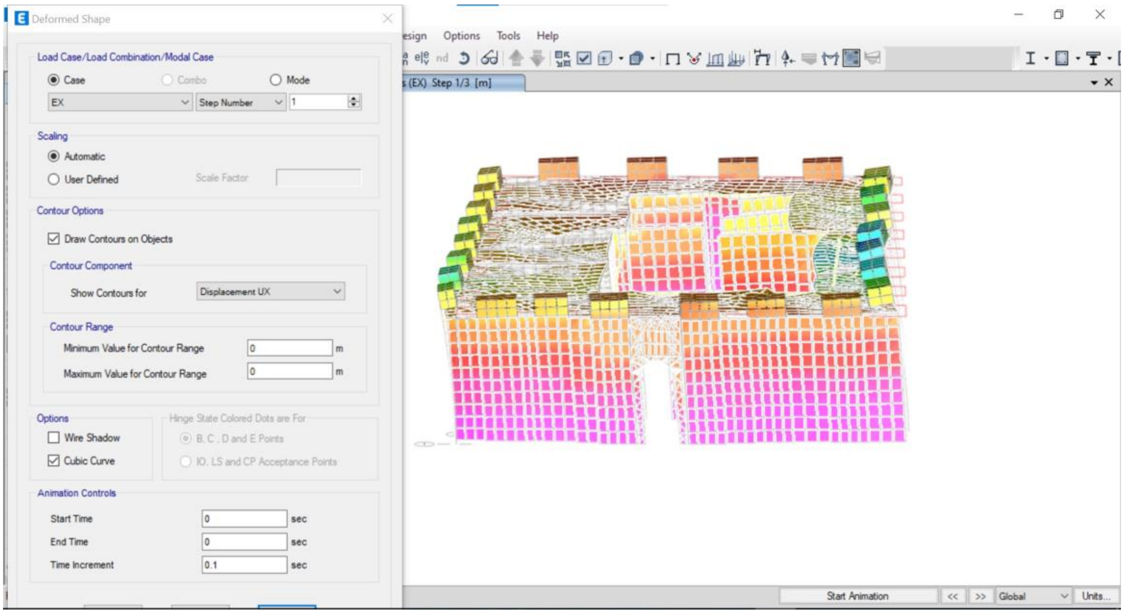


Figure 4.27 Deformed shape of Natmakh Temple's walls (EQ-Ux)

4.8.7 The Earthquake is in the Y direction of Natmakh temple

The values of Uy displacement in the negative and positive directions will be almost low, because the dimensions of the building are almost small (11.4 m) in addition to the absence of internal bulkheads supporting the building and also because the height of the roof of the building is relatively high, which makes the building swing significantly forward and backward.

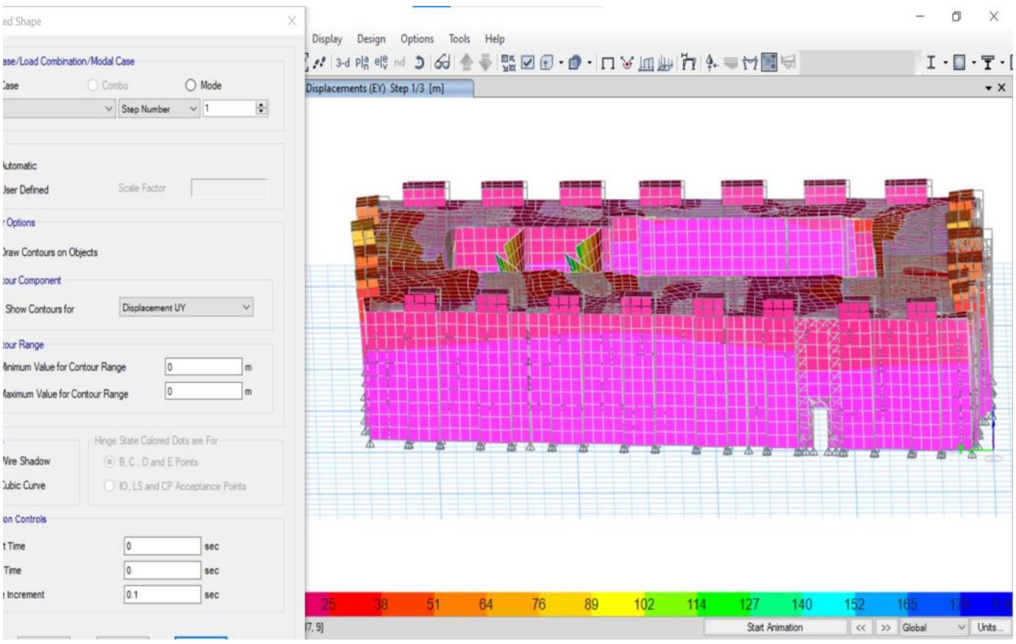


Figure 4.28 Deformed shape of Natmakh Temple's walls (EQ+Uy)

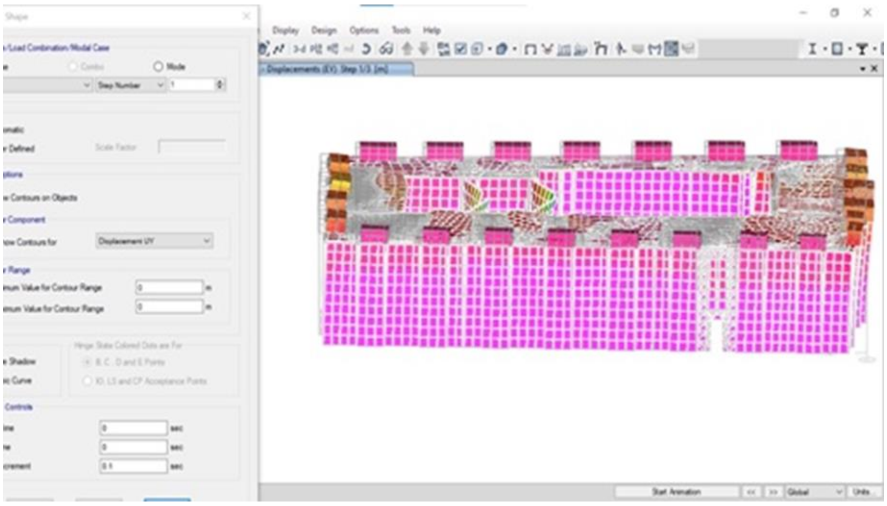


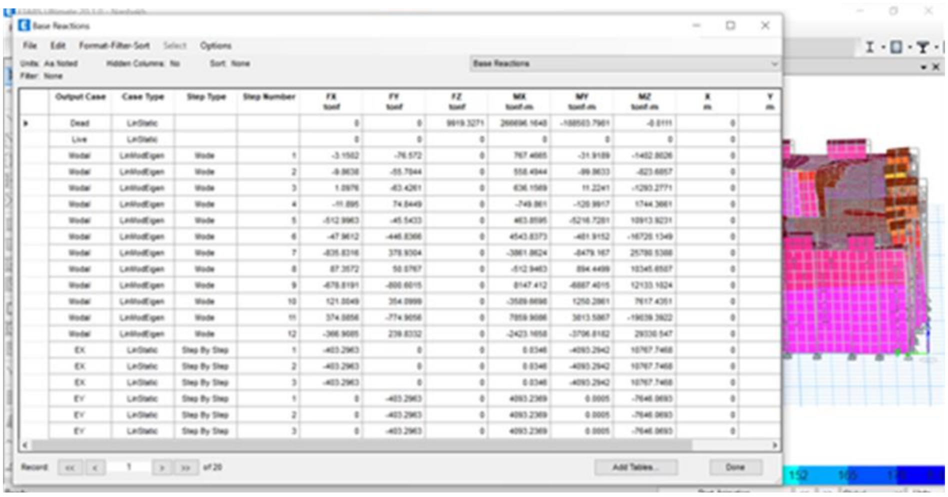
Figure 4.29 Deformed shape of Natmakh Temple's walls (EQ-Uy)

4.8.8 Results of Natmakh temple

After the building was modeled using the Etabs program, and the dead loads on the roof of the building were also analyzed, the impact of earthquakes on it was also calculated. We have seen through the previous figures the extent of the impact of seismic loads on the archaeological building, which may lead to the final destruction of the building permanently. The destruction of archaeological sites in any country in the world means a high economic and cultural loss. It is necessary to find ways to ensure that these sites are preserved, and among these ways is to increase the safety factor for them.

Through the results below, we will be able to find the values of base share, as shown in the following tables:-

Table 4.15 Results from CSI-Etabs for Natmakh temple



Output Case	Case Type	Step Type	Step Number	FX tonf	FY tonf	FZ tonf	MX tonf-m	MY tonf-m	MZ tonf-m	X m	Y m
Dead	LinStatic			0	0	9919.3271	266696.1648	-188503.7981	-0.0111	0	
Live	LinStatic			0	0	0	0	0	0	0	
Modal	LinModEigen	Mode	1	-3.1502	-76.572	0	767.4665	-31.9189	-1402.8026	0	
Modal	LinModEigen	Mode	2	-9.8638	-55.7844	0	558.4944	-99.8633	-823.6857	0	
Modal	LinModEigen	Mode	3	1.0976	-63.4261	0	636.1569	11.2241	-1293.2771	0	
Modal	LinModEigen	Mode	4	-11.895	74.8449	0	-749.861	-126.9917	1744.3661	0	
Modal	LinModEigen	Mode	5	-512.9963	-45.5433	0	463.8595	-5216.7281	10913.9231	0	
Modal	LinModEigen	Mode	6	-47.9612	-446.8366	0	4543.8373	-481.9152	-16726.1349	0	
Modal	LinModEigen	Mode	7	-835.8316	378.9304	0	-3861.8624	-8479.167	25790.5388	0	
Modal	LinModEigen	Mode	8	87.3572	50.8767	0	-512.9463	894.4499	10345.6587	0	
Modal	LinModEigen	Mode	9	-678.8191	-800.6015	0	8147.412	-6887.4015	12133.1024	0	
Modal	LinModEigen	Mode	10	121.8049	354.0999	0	-3589.8698	1250.2861	7617.4351	0	
Modal	LinModEigen	Mode	11	374.8856	-774.9056	0	7859.9086	3813.5867	-19839.3922	0	
Modal	LinModEigen	Mode	12	-366.9085	239.8332	0	-2423.1658	-3706.8182	29330.547	0	
EX	LinStatic	Step By Step	1	-403.2963	0	0	0.0346	-4093.2942	10767.7468	0	
EX	LinStatic	Step By Step	2	-403.2963	0	0	0.0346	-4093.2942	10767.7468	0	
EX	LinStatic	Step By Step	3	-403.2963	0	0	0.0346	-4093.2942	10767.7468	0	
EY	LinStatic	Step By Step	1	0	-403.2963	0	4093.2369	0.0005	-7646.0693	0	
EY	LinStatic	Step By Step	2	0	-403.2963	0	4093.2369	0.0005	-7646.0693	0	
EY	LinStatic	Step By Step	3	0	-403.2963	0	4093.2369	0.0005	-7646.0693	0	

Table 4.16 Results from CSI-Etabs by Excel Microsoft office for Natmakh

TABLE: Base Reactions												
Output Case	Case Type	Step Type	Step Number	FX	FY	FZ	MX	MY	MZ	X	Y	Z
				tonf	tonf	tonf	tonf-m	tonf-m	tonf-m	m	m	m
Dead	LinStatic			0	0	9919.3271	266696.1648	-188503.7981	-0.0111	0	0	0
Live	LinStatic			0	0	0	0	0	0	0	0	0
Modal	LinModEigen	Mode	1	-3.1502	-76.572	0	767.4665	-31.9189	-1402.8026	0	0	0
Modal	LinModEigen	Mode	2	-9.8638	-55.7844	0	558.4944	-99.8633	-823.6857	0	0	0
Modal	LinModEigen	Mode	3	1.0976	-63.4261	0	636.1569	11.2241	-1293.2771	0	0	0
Modal	LinModEigen	Mode	4	-11.895	74.8449	0	-749.861	-120.9917	1744.3661	0	0	0
Modal	LinModEigen	Mode	5	-512.9963	-45.5433	0	463.8595	-5216.7281	10913.9231	0	0	0
Modal	LinModEigen	Mode	6	-47.9612	-446.8366	0	4543.8373	-481.9152	-16720.1349	0	0	0
Modal	LinModEigen	Mode	7	-835.8316	378.9304	0	-3861.8624	-8479.167	25780.5388	0	0	0
Modal	LinModEigen	Mode	8	87.3572	50.0767	0	-512.9463	894.4499	10345.6507	0	0	0
Modal	LinModEigen	Mode	9	-678.8191	-800.6015	0	8147.412	-6887.4015	12133.1024	0	0	0
Modal	LinModEigen	Mode	10	121.0049	354.0999	0	-3589.6698	1250.2861	7617.4351	0	0	0
Modal	LinModEigen	Mode	11	374.0856	-774.9056	0	7859.9086	3813.5867	-19039.3922	0	0	0
Modal	LinModEigen	Mode	12	-366.9085	239.8332	0	-2423.1658	-3706.8182	29330.547	0	0	0
EX	LinStatic	Step By Step	1	-403.2963	0	0	0.0346	-4093.2942	10767.7468	0	0	0
EX	LinStatic	Step By Step	2	-403.2963	0	0	0.0346	-4093.2942	10767.7468	0	0	0
EX	LinStatic	Step By Step	3	-403.2963	0	0	0.0346	-4093.2942	10767.7468	0	0	0
EY	LinStatic	Step By Step	1	0	-403.2963	0	4093.2369	0.0005	-7646.0693	0	0	0
EY	LinStatic	Step By Step	2	0	-403.2963	0	4093.2369	0.0005	-7646.0693	0	0	0
EY	LinStatic	Step By Step	3	0	-403.2963	0	4093.2369	0.0005	-7646.0693	0	0	0

Base Reactions / Program Control

4.8.8.1 Calculation of safety factor against overturning moment for the walls of Natmakh temple

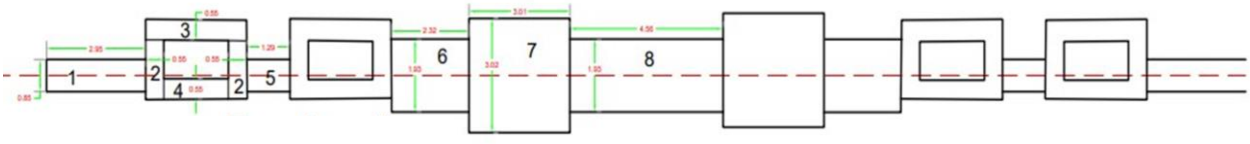
Results from CSI-Etabs in Table (4.16) :-

We found:- EQ. X= 403.29 Tonf EQ. Y=403.29 Tonf

Each value means base shear of soil (foundation).

To get the factor of safety, the following values must be obtained from distributed the weights according to moment of inertia.

4.8.8.1.1 Factor of safety for front wall at Y direction of Natmakh temple



For the front wall's share of the total seismic shear force, the moment of inertia that is perpendicular to the Y-axis must be obtained as follows:-

$\boldsymbol{I_{xx}}$ ***(for front wall)*** $= ((I_{xx1} + ((I'_{xx2}).2 + I'_{xx3} + I'_{xx4}) \times 2 + I_{xx5} + I_{xx6} + I_{xx7}).2 + I_{xx8})$

$I_{xx1} = b.h^3/12 = 2.95 \times (0.85)^3/12 = \mathbf{0.15\ m^4}$

$I'_{xx2} = (b.h^3/12 + A \times d^2).2 = (0.55 \times (1.58)^3/12) + 1.58 \times 0.55 \times (0.43)^2) \times 2 = \mathbf{0.68\ m^4}$

$I_{xx5} = b.h^3/12 = 1.29 \times (0.85)^3/12 = \mathbf{0.06\ m^4}$

$I'_{xx3} = b.h^3/\ 12 + A_3.(d_3)^2 = 3 \times (0.54)^3/12 \ + (\ 3 \times 0.54\ ) \times (1.21)^2 = \mathbf{2.31\ m^4}$

$I'_{xx4} = b.h^3/\ 12 + A_4.(d_4)^2 = 1.92 \times (0.55)^3/12 \ + (\ 1.92 \times 0.55\ ) \times (0.36)^2 \ = \mathbf{0.16\ m^4}$

$I_{xx6} = b.h^3/\ 12 = 2.32 \times (1.93)^3 / 12 = \mathbf{1.4\ \ m^4}$

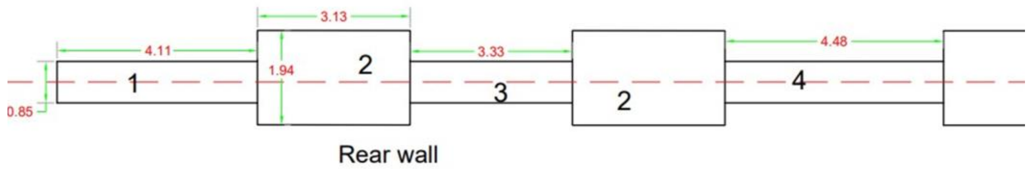
$I_{xx7} = b.h^3/\ 12 = 3.01 \times (3.02)^3 / 12 = \mathbf{6.9\ \ m^4}$

$I_{xx8} = b.h^3/\ 12 = 4.56 \times (1.93)^3 / 12 = 2.7\ \ \mathbf{m^4}$

$\boldsymbol{I_{xx}}$ ***(for front wall)*** = ((0.15 + (0.68+2.31+0.16) x 2 +0.06+1.4+6.9)2 +2.7

= **32.32 $\mathbf{m^4}$**

$\boldsymbol{I_{xx}}$ ***(for rear wall)*** $= (\ I_{xx1} + (I_{xx2}).2 + I_{xx3}) \times 2\ + I_{xx4}$



$I_{xx1} = b.h^3/\ 12\ = 4.11 \times (0.85)^3/12\ = \mathbf{0.2\ \ m^4}$

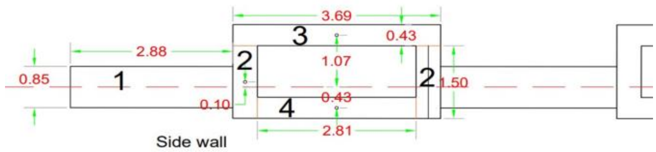
$I_{xx2} = b.h^3/\ 12 = (3.13 \text{ x } (1.94)^3 /12) \text{ x } 2 = \mathbf{3.8\ m^4}$

$I_{xx3} = b.h^3/\ 12 = 3.33 \times (0.85)^3/12 = \mathbf{0.17\ m^4}$

$I_{xx4} = b.h^3/\ 12 = 4 \times (0.85)^3 / 12 = \mathbf{0.2\ m^4}$

$\boldsymbol{I_{xx}}$ ***(for rear wall)*** =(0.2 + 3.8 + 0.17) x 2 + 0.2) = **8.54 $\mathbf{m^4}$**

$\boldsymbol{I_{xx}}$ ***(for left wall)*** $= (\ I_{xx1} + (\ I'_{xx2})\ .2 + I'_{xx3} + I'_{xx4}\ ).7 +\ I_{xx1}$



$I_{xx1} = b.h^3/\ 12\ = 2.88 \times (0.85)^3/12 = \mathbf{0.15\ m^4}$

$I'_{xx2} = (\ b.h^3/\ 12 + A \text{ x } d^2\ ).2 = (0.43 \times (1.5)^3/12) + 1.5 \text{ x } 0.43 \text{ x } (0.1)^2) \text{ x } 2 = \ \mathbf{0.25\ m^4}$

$I'_{xx3} = b.h^3/\ 12 + A_3.(d_3)^2 = 3.69 \times (0.43)^3/12 \ + (\ 3.69 \times 0.43\ ) \times (1.07)^2 = \mathbf{1.83\ m^4}$

$I'_{xx4} = b.h^3/\ 12 + A_4.(d_4)^2 = 2.81 \times (0.43)^3/12 \ + (\ 2.81 \times 0.43\ ) \times (0.43)^2 \ = \mathbf{0.3\ m^4}$

$\boldsymbol{I_{xx}}$ ***(for left wall)*** =(**0.15** + **0.25** + **1.83** + **0.3**) × **7** + **0.15** = **17.86 $\mathbf{m^4}$**

$\boldsymbol{I_{xx}}$ ***(for right wall)*** $= b.h^3/12 = 0.85 \times (7.78)^3/12 = \mathbf{17.86\ m^4}$

$\sum \mathbf{I_{xx}} = 32.32 + 8.54 + 2 \times (17.86) = \mathbf{76.58\ m^4}$

Shear force on(***front wall***) = shear value from Etabs results × I_{xx}(*front wall*) / $\sum I_{xx}$

=403.29 × 32.32 / 76.58 = **170 Ton**

Overturning moment of(*front wall*) in x direction = 170 Ton × 17.87 m =3041.5 **Ton.m**

Volume of (*front wall*) = h × w × l = 10.8 × 1.4 × 35.74 **= ~ 540.5 m^3**

Weight of (*front wall*) = *d* × *v* = 1.95Ton/ m^3 × 540.5 m^3 = **1054 Ton**

Resisting moment of *(front wall)* = Wall Weight × (wall length /2)

= 1054 × 0. 7 =**737.8 Ton.m**

FoS = 737.8 / 3041.5 = 0.24 < 1 not Ok .

4.8.8.1.2 Factor of safety for side wall at Y direction of Natmakh temple

Shear force on *(side wall*) = Total shear value from Etabs results × I_{xx}(*side wall*) / $\sum I_{xx}$

=403.29 × 17.86 / 76.58 = **94 Ton**

Overturning moment of side wall in y direction = 94Ton × 0.425 m = **40 Ton.m**

Volume of (*side wall*) = h ×w × l = 53 × 0.85 × 10.78 = **485.6 m^3**

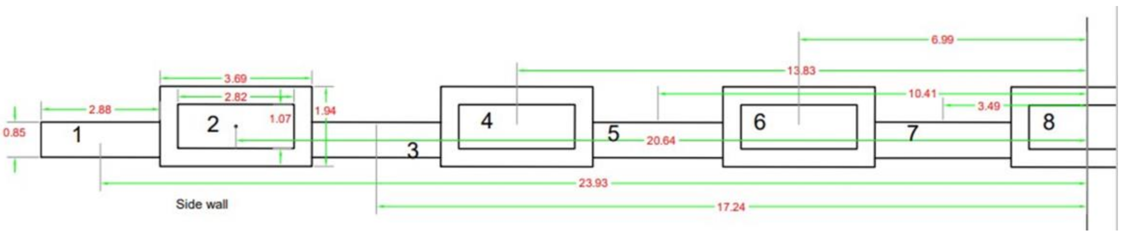
Weight of *(side wall)* = *d* × *v* = 1.95Ton/ m^3 × 485.6 m^3 = **947 Ton**

Resisting moment of *(side wall)* =Wall weight × (wall length /2) = 947 × 0.425 = **402.5 Ton.m**

FoS = **402.5 / 40 = 10 > 1 Ok.**

4.8.8.1.3 Factor of safety for front wall at X direction of Natmakh temple

I_{yy} (for left wall) $=(I'_{yy1}+ I'_{yy2}+ I'_{yy3}+ I'_{yy4}+ I'_{yy5}+ I'_{yy6}+ I'_{yy7})2+ I_{yy8}$



$I'_{yy1} =(b.h^3/ 12 + A \times d^2)=2.88 \times (0.85)^3/12 + 2.88 \times 0.85 \times (23.93)^2 = 1400$

$I'_{yy2} =(b.h^3/ 12 + A \times d^2)_1 - (b.h^3/ 12 + A \times d^2)_2 =3.69 \times (1.94)^3/12 + 3.69 \times 1.94 \times (20.64)^2- (2.82 \times (1.07)^3/12 +2.82 \times 1.07 \times(20.64)^2)=2.24 +3049 – (0.28+1285$

= 3050 m^4

$I'_{yy3} =(b.h^3/ 12 + A \times d^2)=2.88 \times (0.85)^3/12 + 2.88 \times 0.85 \times (17.24)^2 =$ **727.7 m^4**

$I'_{yy4} =(b.h^3/ 12 + A \times d^2)_1 - (b.h^3/ 12 + A \times d^2)_2 =3.69 \times (1.94)^3/12 + 3.69 \times 1.94 \times$

$(13.83)^2$- (2.82 x $(1.07)^3/12$ +2.82 x 1.07 x $(13.83)^2$)=2.24 +18936 – (0.28+ 7981)

= **10956 m^4**

I'_{yy5} =($b.h^3/12$ + A x d^2) = 2.88 x $(0.85)^3/12$ + 2.88 x 0.85 x $(10.41)^2$ = 0.14 + 265

=**265.14 m^4**

I'_{yy6} =($b.h^3/12$ + A x d^2 $)_1$ - ($b.h^3/12$ + A x d^2 $)_2$=3.69 x $(1.94)^3/12$ + 3.69 x 1.94 x $(7)^2$- (2.82 x$(1.07)^3/12$ +2.82 x 1.07 x $(7)^2$)=2.24 +350 – (0.28+ 147.85)= **204 m^4**

I'_{yy7}=($b.h^3/12$ + A x d^2)=2.88 x $(0.85)^3/12$ + 2.88 x 0.85 x $(3.5)^2$ =0.147 + 30 = **30.15 m^4**

I'_{yy4} =($b.h^3/12)_1$ - ($b.h^3/12)_2$ =3.69 x $(1.94)^3/12$ -(2.82 x $(1.07)^3/12$) =2.24 -0.247= **1.99 m^4**

I_{yy} (for left wall) =(**1400 +3050 + 727.7** + **10956** +**265.14** +**204**+ **30.15**)2+ **1.99**

=**33268 m^4**

I_{yy} (for right wall) = $b.h^3/12$ =0.85 × $(7.78)^3/12$ = **33268 m^4**

∑ **I_{yy}** = 650 + 440.4 + 66536 = **67626 m^4**

Shear force *on front wall* = shear value from Etabs results × I_{yy}(*front wall*) / ∑ I_{yy}

=403.29 × 650 / 67626 = **3.9 Ton**

Overturning moment of *front wall* in x direction = 3.9 Ton × 11.5 = **44.85 Ton .m**

Volume of (*front wall*) = h ×w × l = 11.5 × 0.85 × 35.75 = **349.45 m^3**

Weight of *(front wall)* = *d* × *v* = 1.95Ton/ m^3 × 349.45 m^3 = **628 Ton**

Resisting moment 0f *(front wall))* = wall weight × (wall length/2)

= 628 × 0.425= **267 Ton.m**

FoS = 267 / 44.85 = 6 > 1 Ok.

4.8.8.1.4 Factor of safety for side wall at X direction of Natmakh temple

Shear force on *(side wall)* = Total shear value from Etabs results × I_{yy}(*side wall*) / ∑ I_{yy}

=403.29 × 33268 / 67626 = **198.4 Ton**

Overturning moment of(*side wall*) in x direction = 198.4 × 11.5 m = **55 Ton.m**

Volume of (*side wall*) = h ×w × l = 11.5 × 0.85 × 53.22 = **520.22 m^3**

Weight of *(side wall)* = *d* × *v* = 1.95 Ton/ m^3 × 520.22 m^3 = **1014.4 Ton**

Resisting moment of *(side wall)* = Wall Weight × (wall length /2) = 1014.4 × 0.425

= **431.13 Ton.m**

FoS = 431.13 / 55) = 7.8 > 1 Ok

Table 4.17 Evaluation safety factor against overturning moment for the walls Natmakh temple walls

NO	WALL TYPE	FoS VALUE		EVALUATION
		X- DIRECTION	Y- DIRECTION	
1	FRONT WALL	**6**	**0.24**	Safe against Earthquakes at x-direction only
2	SIDE WALL	7.8	**10**	Safe against Earthquakes

From the results in Table 4.17, we can say that all walls for (Natmakh temple) is considered safe against overturning moment for all directions. Except front wall because it is considered a failure against the overturning moment in the Y direction.

4.8.8.2 Factor of safety against collapse the bonding mortar of Natmakh temple

In Babylonian archaeological sites, lime powder mortar with was used as a binder at the time. In order to calculate the factor of safety against collapse the bonding mortar, we must first know the density of that material.

EQ. X= 403.29 Tonf = 3952 KN EQ. Y=403.29 Tonf = 3952 KN

Bond strength of hardened lime mortar = 0.2 MPa

S.F. for bond strength = $\frac{(\textit{Resisting shear bond})}{\textbf{Earthquake shear force}}$

4.8.8.2.1 FoS for front wall at Y direction of Natmakh temple

Using the same methods for finding the moment of inertia in the previous steps, we find that the total sum of the moment of inertia I_{xx}.

$$\sum \mathbf{I_{xx}} = 32.32 + 8.54 + 2 \times (17.86) = \mathbf{76.58\ m^4}$$

Earthquake shear force on(*front wall*) = Earthquake shear force (of Etabs results) × I_{xx}(*front wall*) / $\sum I_{xx}$

= 3952× 32.32 / 76.58 **= 1668 KN**

Brick dimension = (0.23 x 0.1 x 0.08) m

No. of rows (between 2 bricks) of (*front wall*) = (*h*/0.08)= 11. 5 /0.08 = **143.75 rows**

No. of columns (between 2 bricks) of (*front wall*) = (*l*/0.23) = 35.75 / 0.23 = **155 columns**

Lime mortar area for *front wall*(horizontally) = *b* × *l* × No. of row of (front wall)

= 0.85 ×35.75 × 143.75 = **4368 m^2**

Lime mortar area for *front wall*(vertically) = *h* × *b* × No. of columns of (front wall)

= 11. 5 × 0.85 x 155 = **1515 m^2**

Total Area for front wall = 4368 + 1515 = **5883 m^2**

Bond strength of hardened lime mortar = 0.2 MPa = 200 KN/m^2

Resisting shear bond of *(front wall)* = Total Area × bond strength

= 5883 m^2 × 200 KN/m^2 = **1176600 KN**

FoS = 1176600 / 1668 = 705 > 1 Ok

4.8.8.2.2 FoS for side wall at Y direction of Natmakh temple

Earthquake shear force on(*side wall*) = Earthquake shear force (of Etabs results)

× I_{xx}(*side wall*) / ∑ I_{xx}

= 3952× 17.86 / 76.58 **= 921.6 KN**

Brick dimension = (0.23 x 0.1 x 0.08) m

No. of row of (*side wall*) = (*h*/0.08)= 11. 5 /0.08 =**143.75 row**

No. of columns of (*side wall*) = (*l*/0.23) = 53.22/ 0.23 = **231.4 col.**

Lime area for side wall(horizontally) = *w* × *l* × No. of row of (side wall)

= 0.85 ×53.22 × 143.75 = **6502 m^2**

Lime Volume for *side wall*(vertically) = *h* × *w* × No. of columns of (side wall)

= 11. 5 × 0.85 × 231.4 = **2262 m^2**

Total Area for *side wall* = 6502 + 2262 = **8764 m^2**

Bond strength = 200 KN/m^2

Resisting shear bond of *(side wall)* = Total Area × bond strength

= 8764 × 200 = **1752800 KN**

FoS = 1752800 / 921.6 = 1902 > 1 Ok.

4.8.8.2.3 FoS for front wall at x direction of Natmakh temple

EQ. X= 403.29 Tonf = 3952 KN EQ. Y=403.29 Tonf = 3952 KN

$\sum$ **I_{yy}** = 650 + 440.4 + 66536 = **67626 m^4**

Earthquake shear force on(*front wall*) = Earthquake shear force (of Etabs results)

$\times I_{yy}$(*front wall*)/$\sum I_{yy}$

= 3952 × 650 / 67626 **= 38 KN**

No. of row of (*front wall*) = (h/0.08)= 11. 5 /0.08 =**143.75 row**

No. of columns of (*front wall*) = (l/0.23) = 35.75 / 0.23 = **155.4 col.**

Lime mortar area for *front wall*(horizontally) = $b \times l$ × No. of row of (front wall)

= 0.85 ×35.75 × 143.75 = **4368 m^2**

Lime mortar area for *front wall*(vertically) = $h \times b$ × No. of columns of (front wall)

= 11. 5 × 0.85 x 155.4 = **1519 m^2**

Total Area for front wall = 4368 + 1519 = **5887 m^2**

Bond strength of hardened lime mortar = **0.2 MPa** = **200 KN/m^2**

Resisting shear bond of *(front wall)* =Total Area ×bond strength

= 5887 m^2 ×200 KN/m^2 =**1177400 KN**

FoS = **1177400 / 38 = 31000 > 1 Ok.**

4.8.8.2.4 FoS for side wall at X direction of Natmakh temple

Earthquake shear force on(*side wall*) = Earthquake shear force (of Etabs results)

× I_{xx}(*side wall*)/$\sum I_{xx}$

= 3952 × 33268 / 67626 **= 1944 KN**

Brick dimension = (0.23 x 0.1 x 0.08) m

No. of row of (*side wall*) = (h/0.08)= 11. 5 /0.08 =**143.75 row**

No. of columns of (*side wall*) = (l/0.23) = 53.22 / 0.23 = **231.4 col.**

Lime area for *side wall*(horizontally) = $w \times l \times$ No. of row of (side wall)

= 0.85 ×53.22 × 143.75 = **6503 m^2**

Lime Volume for *side wall*(vertically) = $h \times w \times$ No. of columns of (side wall)

= 11. 5 × 0.85 × 231.4 = **2262 m^2**

Total Area for *side wall* = 6503 + 2262 = **8765 m^2**

Bond strength = 200 KN/m^2

Resisting shear bond of *(side wall)* = Total Area × bond strength

= 8765 × 200 = **1753000 KN**

FoS = 1753000 / 1944 = 901 > 1 Ok

Table 4.18 Evaluation safety factor against collapse the bonding mortar Natmakh temple

NO	WALL TYPE	FoS VALUE		EVALUATION
		X- DIRECTION	Y- DIRECTION	
1	FRONT WALL	**31000**	**705**	Safe against Earthquakes
2	SIDE WALL	**901**	**1902**	Safe against Earthquakes

From the results in Table 4.18 we can say that the side wall of Natmakh temple is considered very safe against collapse the bonding mortar of Natmakh temple.

Finally , we can say that the Natmakh temple is considered to be safe against collapse the bonding mortar.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5 .1 Conclusions

In this chapter, we shed light on the most important results that could be obtained from the present study; those results were concentrated in two main directions:

5.1.1 The importance of modeling of ancient buildings

In the context of architectural documentation, emphasizes the importance of the modeling process for ancient buildings in order to preserve ancient . Documenting and rooting the architectural and geographical values of ancient buildings and the surrounding area in order to benefit in preserving the spatial memory of the site and to facilitate the process of rehabilitation, development, and future restoration of the site is defined as architectural documentation of ancient buildings. It also aspires to create a database that will assist researchers, planners, and policymakers in making informed decisions. Ancient building documentation is also regarded as a form of preventive maintenance for these structures, as it anticipates the risks that they may face in the future as a result of natural and human factors. The technical document must have a specific goal, such as delivering concise information in a short amount of time. This data should be organized in a logical and easy-to-follow manner. Documentation is a method of scientific research in which facts and information are recorded by describing each of the building's components.

The new version of the ETABS program incorporates significant advancements in the field of seismic design, and it performs dynamic analysis of the error by determining the actual behavior of the facility by calculating and evaluating the dissipated energy within the structure during its exposure to the earthquake. One of the most significant benefits that could be gained from using the program in studying the protection of ancient facilities from earthquake risks includes:-

1. By linking the earthquake's time history with the response spectrum, it is possible to create a man-made earthquake on the origin: (Response Spectrum and Time History)

2. To judge the structural integrity of the element more quickly; create Demand/Capacity Diagrams (D/C) with their tables.

3. Techniques such as (Construction Sequencing) and the effects of time on the studied element are examples of nonlinear modeling techniques (shrinkage and creep).

4. Degradation of Stiffness.

5. The ability to model the shear wall joints.

6. Steel connections and Base Plate connections were designed and verified.

We conclude from the results that we obtained from the modeling of the three buildings, as follows:-

5.1.1.1 Conclusions for Babylonian theater

1. we find that all the walls have overcome earthquakes in all directions except for the side walls that may collapse as a result of the earthquake in the X direction unless these walls are treated by the necessary methods that comply with the rules of the World Organization of UNESCO.

2. while we find that the bonding mortar between the bricks has The shear resistance is greatly overcome, by the safety factor results against shear strength and this is the reason why the building has survived to this day.

5.1.1.2 Conclusions for Ishtar gate

1. we find that all the walls have overcome earthquakes in all directions except for the side walls that may collapse as a result of the earthquake in the X direction unless these walls are treated by the necessary methods that comply with the rules of the World Organization of UNESCO.

2. while we find that the bonding mortar between the bricks has The shear resistance is greatly overcome, by the safety factor results against shear strength and this is the reason why the building has survived to this day.

5.1.1.3 Conclusions for Natmakh Temple

1-we find that all the walls have overcome earthquakes in all directions except for the front wall that may collapse as a result of the earthquake in the y direction unless these walls are treated by the necessary methods that comply with the rules of the World Organization of UNESCO.

2- while we find that the bonding mortar between the bricks has The shear resistance is greatly overcome, by the safety factor results against shear strength and this is the reason why the building has survived to this day.

5.1.2 The importance of the safety factor in the sustainability of preserving ancient buildings

The importance of the safety factor in evaluating ancient building protection is highlighted by the fact that ancient sites are constantly exposed to threats and undesirable factors, whether natural or human-made, and their exposure to risks as a result of human activity may be a direct cause of weakening their stability in the face of natural hazards, the nature of which varies. Some of the elements affecting the building are ubiquitous and intangible (such as heat and noise), while others may not be exposed to the building throughout its lifetime (such as fire, destructive winds, and earthquakes), and others are always present (such as fire, destructive winds, and earthquakes) (such as water, heat and cold), These factors are determined by their type and quantity, as well as the degree of danger and impact of each of them, through the specifications and conditions of construction in each country, and the method of treating the external surface is determined to provide the necessary protection. The building's structural structure is covered to deal with the factors and risks that are expected to affect it. The emphasis on safety and protection confirms the foundation of the building layers' superficial integrity. Although construction may begin with small building units such as bricks, prefabricated building units, or prefabricated elements, complete coverage of all the spaces within the building provides the best protection. As a result, it is critical to comprehend the significance of each of the multiple layers of building protection because it is the foundation for achieving a good building design through building specifications and conditions. The effect can be determined using the techniques provided by the building's conditions and specifications, and then the appropriate cover surface for dealing with it can be selected.

5.2 Recommendations

In response to the conclusions that were mentioned based on the results obtained during this thesis, the most prominent of which was the appearance of a low value of the safety factor in some walls against seismic loads, so we recommend that some measures should be taken in this regard. In order to increase the safety factor by decreasing the value of the overturning moment. These measures include:-

1. Injecting worn-out walls with a concrete mixture mixed with mineral fibers.
2. Periodically treat the walls with termite repellents.
3. The necessity of paving the roads with rubber materials to absorb the vibrations caused by the walking of the tourists.
4. We recommend that researchers take the foundations into consideration and find a safety factor for them as well.

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