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The Idea of ‘Loosening the Bond Between Ground and Structure’ in Antiquity and Archaeological Evidence on Antiseismic Foundations

Antik Çağda ‘Yapı ile Zemin Arasındaki Bağı Gevşetme’ Düşüncesi ve Antisismik Temellere Arkeolojik Kanıtlar

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THE IDEA OF 'LOOSENING THE BOND BETWEEN GROUND AND STRUCTURE' IN ANTIQUITY AND ARCHAEOLOGICAL EVIDENCE ON ANTISEISMIC FOUNDATIONS

ABSTRACT

Antiseismic structures in antiquity are often overlooked or disputed by those working in the field, even though they are not mentioned in written sources. At the very least, it should be recognized that some of the traditional structures and building techniques of ancient cultures in Anatolia and surrounding regions were antiseismic before today's concrete structures. In fact, these techniques were sometimes applied over a wide geographical area and sometimes in a narrower region, as if under the control of a central government, administration or idea, and continue to be used for a long time. Archaeological studies reveal that some construction methods were widely used to support structures affected by dynamic loads. Such methods were applied and developed by engineers, architects and artisans who were fully aware of the effects of earthquakes on structures. Therefore, antiseismic structures must have emerged due to awareness of earthquake hazards. Wood in foundations and walls in Anatolia in the Bronze Ages, sand in Mesopotamia and Egypt, sand, ash, coal and lime in Greek architecture, and opus caementicum in Rome were applied in and under the foundation in more durable or long-lasting building construction techniques. Undoubtedly, wood and wood foundations have been known and used since the Bronze Age. Unfortunately, with the emergence of new materials and technologies, the traditional architectural understanding of Anatolia was almost wholly removed from construction practice. As in modern constructions, in archaeological studies, attention is paid to the structures' above-ground units, while the underground foundation sections are overlooked. Data about the use of wood in the groundwork is sometimes discovered by chance. This article demonstrates that the idea of loosening the bond between structure and ground was known in ancient times. Although the technical solutions used in the past match the principles of base insulation, it is arguable whether they are genuinely antiseismic as they are today.

Keywords: Antiquity, Building Foundations, Antiseismic Foundations, Structure and Ground, Earthquake.

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ANTİK ÇAĞDA 'YAPI İLE ZEMİN ARASINDAKİ BAĞI GEVŞETME' DÜŞÜNCESİ VE ANTİSİSMİK TEMELLERE ARKEOLOJİK KANITLAR

ÖZ

Antik çağda antisismik yapıların varlığı, yazılı kaynaklarda ifade edilmese de, arazide çalışanlar tarafından çoğu kez gözden kaçırılmakta veya tartışma konusu yapılmaktadır. En azından günümüz beton yapıları öncesi Anadolu'da ve çevre bölgelerde sürgün vermiş kadim kültürlerdeki bazı geleneksel yapıların ve yapı tekniklerinin antisismik olduğu kabul edilmelidir. Hatta bu teknikler, bazen geniş bir coğrafyada bazen de daha dar bir bölgede, sanki bir merkezi yönetim, idare veya düşüncenin kontrolü altında uygulanmış gibidir ve uzun süre kullanılmaya devam eder. Arkeolojik çalışmalar, dinamik yüklerden etkilenen yapıların desteklenmesi amacıyla bazı inşa tekniklerinin yaygın olarak kullanıldığını ortaya koymaktadır. Bu tür teknikler, depremlerin yapılar üzerindeki etkilerini kesinlikle farkında olan ve bilen mühendis, mimar ve ustalar tarafından uygulanmış ve geliştirilmiştir. Dolayısıyla antisismik yapılar, deprem tehlikesinin bilincinde olan bir düşüncenin sonucu ortaya çıkmış olmalıdır. Bronz Çağlar'ında Anadolu'da temeller ve duvarlarda ahşap, Mezopotamya ve Mısır'da kum, Yunan mimarisinde kum, kül, kömür ve kireç, Roma'da opus caementicum, daha dayanıklı veya uzun ömürlü yapı inşaat tekniklerinin temel ve temel altındaki uygulamalarıdır. Elbette ki ahşap ve ahşabın yer verildiği temeller Bronz Çağı'ndan beri bilinmekte ve kullanılmaktadır. Ne yazık ki yeni malzemelerin ve teknolojilerin ortaya çıkmasıyla Anadolu'nun geleneksel mimari anlayışı neredeyse tamamen inşaat pratiğinden çıkarılmıştır. Modern inşaatlarda olduğu gibi arkeolojik çalışmalarda da yapıların, göze gelen temel üstü birimlerine dikkat edilirken, toprak altında kalan temel bölümlerine dikkat edilmemektedir. Alt yapıda ahşap kullanıldığına dair bilgiler ise bazen rastlantı sonucu keşfedilmiştir. Bu makale antik çağda yapı ile zemin arasındaki bağı gevşetme düşüncesinin bilindiğini göstermektedir. Geçmişte kullanılan teknik çözümler, taban yalıtımı ilkelerine uysa da, bugünkü gibi gerçek anlamda antisismik düşünceye sahip oldukları ise tartışılabilir.

Anahtar Kelimeler: Antik Çağ, Bina Temelleri, Sismik Temeller, Yapı ve Zemin, Deprem.

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INTRODUCTION

Two significant earthquakes centred in Kahramanmaraş (06.02.2023) brought the consideration of building materials and construction techniques back to the agenda. In developing better designs to protect buildings from earthquake damage, site selection, materials and especially foundation isolation have emerged as solutions. At the same time, in recent years, there has been a great deal of interest in the seismic history of ancient monuments, especially the remains uncovered by archaeological studies. The reason for this interest in past structures and the secret of their survival is how to build durable structures that will protect against future earthquakes. For this purpose, the need to be careful from land selection to load-bearing elements and to live a happy life with solid and reinforced structures comes to the fore. This need brings migration to rural areas and horizontal architecture to the fore.

Wood, the oldest building material, is also the primary material of buildings that offer a healthy and happy living space. Although it has not survived to the present day, wood was the primary material for buildings with deep foundations, as seen in early examples from the Bronze Age. In time, stone, then concrete and steel came to the fore. Nevertheless, wood continues to be widely used as a building material. Numerous architectural examples show that, excluding fires, wooden structures are generally more durable, more natural, and the most renewable and cheapest building material.

Although earthquakes are simply remembered for their destructive characteristics, they actually bring about change. This change, in turn, differentiates cities into rural and central areas and buildings according to their materials and techniques since earthquakes often allowed the building of new houses, palaces or religious structures in a newer or more fashionable style in antiquity. However, this depended on political, social and financial stability. The evidence suggests that ancient architects and builders, at least in some periods and regions, were aware of the effects of earthquakes on buildings, their weaknesses and the precautions that should be taken to prevent earthquake damage. Even today, the first reaction after an earthquake is to build buildings with fewer storeys, that is, low-rise buildings where wood is used frequently to resist earthquakes. Accordingly, buildings with wooden beams and girders were common in Anatolia until the advent of reinforced concrete buildings[1].

[1] The types of masonry structures that survive and continue to be used in Anatolia today are made with logs or large-sawn timber. These timbers and logs were fastened using a method called "çantı", and sometimes wooden nails were used only at the joints. There are two types of wooden structures: log and hewn-sawn timber. The bark was peeled or roughly hewn into four or six faces in log structures and used in its natural state. Timber frame buildings are seen in two common types, filled or unfilled, depending on the seismicity of their geographical location and the abundance of building materials. Masonry buildings made only of wood may show architectural and structural differences according to climatic and economic conditions. The load-bearing systems of wooden buildings, which are generally located in earthquake zones, are of two types:

Since the beginning of human history, first natural shelters were preferred to protect human life, and then artificial shelters were built. These artificial shelters have been constructed using natural materials for thousands of years. Diverse in their methods and materials, such structures have been constantly tested by destruction through human hands or natural disasters. Only the best examples of buildings have survived earthquakes and the test of time. From the past to the present, Anatolia has been applying old methods to build traditional structures with the same natural and artificial materials, which are very simple and convenient to produce. The ancient architecture of this geography is, in fact, a living tradition, and it is with this intention that construction activities are carried out.

The necessity of resisting seismic effects in Anatolia and its environs had existed in the building construction tradition long before the scientific approach to the problem began, and earthquake engineering methods were introduced. From the beginning, earthquake-resistant solutions were developed empirically by learning from the behaviour of buildings, as emphasized in post-earthquake damage studies. The need to develop strategies to resist earthquakes is a constant challenge, and from early times, learning from the past has been an excellent way to improve the quality of buildings. Anatolia, Mesopotamia, Iran, Egypt, and the Aegean cultures and the systems used in their various structures offer remarkably nuanced solutions[2].

These examples refer to construction techniques and systems that have been continuously improved after each earthquake and are still effective while offering interesting suggestions for new designs. Examples are the interlocking of stones and walls, regularity in plan and height, and reduction of dead loads. This study presents early examples of earthquake-resistant systems, highlighting the most meaningful aspects of the basic techniques of ancient buildings compatible with modern seismic design concepts. These examples deserve special attention as they can inspire new constructive strategies to deliver effective and environmentally compatible results with existing sustainability principles. This fact is fundamental as cultures adjacent to the Mediterranean are in earthquake zones.

Anatolia has faced many severe and destructive earthquakes for thousands of years due to its location in the Mediterranean earthquake zone. Wooden structures, which are light in structure and have been proven safe against earthquakes with their flexibility, have always been preferred in this geography, aware of their importance[3]. The nature of the Mediterranean appeals to the human eye and adds

filled (hımış) and unfilled (bağdadi). Today, the buildings and parts of the buildings in Anatolia where wood or timber is used are human living spaces, while the stone-bearing lower floor or masonry stone foundation on which these buildings sit serves as stables or for other needs of the family.

2 Kirikov 1992.

3 The rate of use of timber in buildings is directly proportional to earthquake zones and forested areas. Therefore, this traditional material of Anatolia is generally subject to two different systems such as all-timber or timber-masonry. In these types of systems, the building material is natural materials such as wood, stone

to this taste the aesthetic beauty of the buildings it builds. Therefore, this situation has made us forget the dangers arising from the Mediterranean geology and climate from time to time. Perhaps the earthquakes show that the Mediterranean, particularly Anatolia, is not a paradise freely available for human enjoyment. For this reason, it has paved the way for living and building here, despite its difficulties-rather than other geographies. Of course, building types in Anatolia and the surrounding geographies depend on the geographical characteristics of the region (forested, rainy, dry, etc.), the culture of life, and the economic conditions mentioned. Archaeological excavations and artistic and philological documents provide essential clues about the use of wood in buildings and river stones in foundations from the Neolithic[4] to the Classical Period[5].

Layered river stones were used in Anatolian Bronze Age building foundations to prevent moisture from reaching the building or to absorb earthquake forces before they reached the building. Although it is challenging to find concrete traces of the use of wood, which is weak against climatic conditions and fire, in foundations in archaeological sites, traces of burnt wood have been found in the gaps and holes of beams and uprights in foundations and walls. This is because engineers, architects, and professional workers in the field of construction can understand the causes and effects of earthquakes by observing the damage to structures. Those lacking this observation, as the visible parts of the structures attract more attention, are still victims of earthquakes.

In general, a building has two parts. The visible part, the part above ground, is the superstructure. The other, often overlooked, is the foundation, which can take several forms (foundations, walls, slabs, piles, caissons, etc.) and be as costly as the superstructure. To properly design a foundation, the engineer in charge must have a detailed knowledge of the soil and geological conditions at the site; this is today realized by taking samples of the elements in the ground. This is because the soil properties greatly influence the earthquake characteristics and behaviour of the structure itself since, during an earthquake, a so-called compression process occurs between the soil and the structure, which can aggravate or mitigate the earthquake effect. This fascinating, unpredictable and ever-changing movement was probably recognized by the ancient builders, who paid much attention to the preparation of the ground of a structure. However, a building should have structural principles such as weight and distribution according to the centre of gravity, proportionality, lightness and low centre of gravity, flexibility (especially in materials) and closedness (horizontally and vertically). In line with these principles, devices that reduce the intensity of the oscillation reaching the structure from the ground (seismic shock isolation) and earthquake-resistant foundations with sufficiently

and mud ("mudbrick" etc.).

4 Vann 1976, 107-108.

5 Ulrich 2007, 61, 72-89.

deep, flexible (ductile) bearings, abiding by the principle of robustness, are essential. Were these principles necessary for earthquake-resistant structures applied in ancient buildings? Of course, except for rare examples, there are no preserved drawings or models of ancient buildings. Such structures, dismantled down to their foundations, as seen at archaeological sites, have often been turned into ready-made quarries to reuse the material; many yielded only scant information or remains. However, some have survived to the present day and demonstrate the excellence of their construction. Therefore, it is often impossible to know the thoughts of the ancient architects who created excellent buildings, what design decisions they made to protect them against earthquakes, and how they put into practice the experience of their predecessors. Nevertheless, it is clear that the instructors of the builders were natural phenomena, especially earthquakes and earthquake experiences.

The experience of earthquakes implies an awareness of a natural phenomenon that is constantly active. The origins of human sensitivity to this problem are, therefore, as old as the art of building. The Mediterranean region, where the ancient building tradition is often associated with seismic activity, is an effective observation point in this regard. From the beginning, builders and the local population were directed to carefully analyze the earthquake phenomenon using the essential tools available: observation and experience. This is why, over time, local communities, faced with frequent and destructive earthquakes, have adopted specific construction methods and preferred to stay in the same place rather than change or abandon their habitat[6].

Mediterranean peoples, especially Anatolian settlers, accepted the possibility of a major earthquake at any time and chose their construction techniques accordingly since they were the builders themselves. So, what are the ideas and principles underlying this absorber foundation design? The principles of earthquake-resistant construction are not very diverse[7]. In fact, they have been known in the past and are still practised. The solution is generally seen as a 'change in the type of structure and construction materials' because you can change both the structure and the techniques, just as a change in people and their thinking. However, because the laws of nature remain unchanged, like solid foundations, the principles of designing earthquake-resistant structures never change.

6 Seneca, Natural Questions, VI.

7 An earthquake-resistant building is one that ensures life safety and prevents material damage during an earthquake. Unfortunately, this requirement is often far from reality. In antiquity, despite some design deficiencies, poor workmanship or lack of knowledge, this expectation was almost fully met. It is necessary not only to protect oneself from a collapsing building or a falling building element or object, but also to think that it is better to stay in the building than to leave it, and to work until it is put into practice. This will lead to buildings with excellent construction quality, excellent design, durable, lightweight and flexible materials, and real resistance to earthquake loads and shocks.

Laying solid foundations, even without the correct ground, was one of the most severe problems of antique construction as it is today. From the Neolithic Period, builders did not stop developing building technologies to add strength, durability and longevity to their works. While they initially lived in simple dwellings, public buildings such as palaces and monumental buildings serving religious purposes, as is the case today, began to apply these monumental architecture and technologies with growing cities. Most of these ancient structures are located in active regions of Anatolia and on terrain with poor bearing capacity. Despite this, archaeological evidence shows that people did not abandon their living spaces, and the destruction of these spaces by natural disasters such as earthquakes did not lead them to abandon their cities. On the contrary, they lived in the same place, sometimes attaching symbolic or religious values to their hometowns[8]. Instead of abandoning the destroyed site, they strived to solve the problems. For this purpose, they tried to understand the problem, find methods to deal with it, raise awareness about more accurate ground conditions and problems, and continue to come up with solutions.

In the first stage, they checked whether the soil structure of the area where the building will be built, such as hardness-softness and moist-dry, was suitable to carry the load distribution; not every structure rising from the ground may have the appropriate technique and material for the ground structure. Therefore, they also focused on the level between the ground and the structure. In this level, often referred to as the sub-foundation, applications related to the interaction between the ground and the foundation were prioritized. Many of the basic features of ancient infrastructure systems are also the source of modern antiseismic technologies. Foundation isolation, considered a saviour, especially today, is often mentioned as a new idea to prevent damage caused by movements in earthquake zones and is frequently tried to be made use of[9].

Before discussing the use of wood in foundations, it may be understandable to look at how the antecedents of this logic called ‘foundation isolation’ emerged. The antecedents or prototypes of foundations built according to geotectonic movements are more evident from the methods of transportation of construction materials than from the constructions themselves. These prototypes are pillow foun-

8 Mounds are the best examples of rebuilding a living space on top of a destroyed or damaged occupation layers. The reason behind why cities are not abandoned as a result of natural or man-made destruction, especially earthquakes, is not always symbolic in meaning or religious. Geography and location have always been taken into account. There are various reasons such as dominance over agricultural lands, water resources and river transportation, being located on trade routes or at intersections, security, etc.

9 Tsuneo Okada of the University of Tokyo stated after the Kobe earthquake that there are two basic approaches to avoid earthquake damage. One method is to build as many strong structures as possible. He states that “This gives you more lateral strength; it prevents a building from collapsing on people on the first floor.”. The other approach is to “make a building somehow flexible. Then, when the earthquake hits, part of it will sway, like a tree bending with the wind. They are made sort of like a pendulum”. One way to achieve this, according to some experts, is to isolate the foundation from the surrounding soil by placing it on rubber, steel, etc. plains that dampen ground movement. Reid 1995.

dations consisting of timbers embedded between stone blocks or bricks. In this system, the walls are isolated from the ground. Another type of foundation is the trench foundation dug under the wall. They, therefore, knew how to move a stone block or tree trunk on the ground or drag it to the cart, as seen in the depictions of art from Egypt, Mesopotamia, and Anatolia (Fig. 1). However, this knowledge does not explain how to bury a large mass of several stones or a large block of stone. This is why the first monuments consisted of permanently erected stones. It was understood that the reason why a planted stone remained standing for a long time was the change in depth. But the prototypes of wooden foundations, which appeared in the form of a grid, may possibly have been bases made of primitive logs. These early types must have been used on grounds such as damps, wet and lakeside areas. The use of such early types improved the quality of life and made it possible to stay in the same place for a longer period. In general, where wood was readily available, the ground was very soft and wet. The wooden base or floor provided a certain degree of insulation and also helped to strengthen the dwelling.

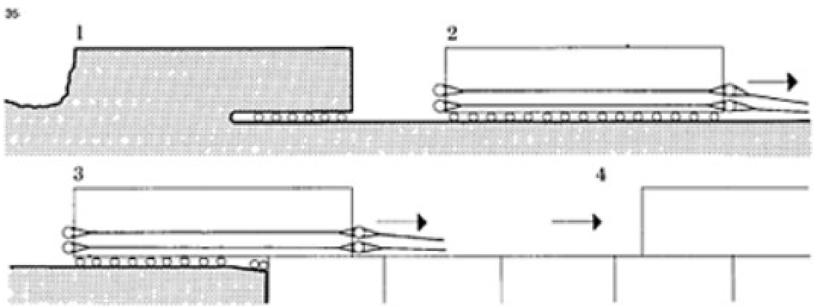

Fig. 1. Reconstruction showing megaliths from Baalbek being transported on round logs (Adam 1994, Fig. 35).

Although "seismic isolation" is presented as a recently emerging term in scientific circles and communication (press and media) tools and accepted as a new "concept", it should be remembered that the idea is not new in human history[10]. When archaeological documents and evidence are examined, it will be seen that

[10] Today, modern research continues on the development of architectural and technical designs to protect buildings from earthquake damage, and on foundation isolation to reduce seismic energy. There are also preliminary studies on the origins of such developments and the approaches and developments in ancient civilizations. The work of B. Carpani is the first collective evidence that the basic idea behind foundation isolation is far from being a modern development: Carpani 2014; Carpani 2017. With more careful and purposeful excavation and research studies, as the number of examples increases, the pioneers of foundation isolation will be given their due, and the idea of loosening the bond between the ground and the structure, such as placing layers of sand or clay under the foundations, will contribute to today's anti-seismic practices by making the old common again.

base isolation is not a new and modern system[11]. Nevertheless, people have abandoned the technical developments they have tried and advanced for the abovementioned reasons. Therefore, works that require keeping the connection between the ground and the structure flexible, such as placing sand and clay layers and timber under the foundation, date back to the Bronze Age[12].

The most common earthquake protection system was to place a thin layer of sand under foundations to achieve a "slip isolation" system. "Foundation isolation" represents a new approach to developing better design methods and protection technologies to reduce earthquake effects, especially in the field of seismic engineering, including the last quarter of the last century. Although "seismic isolator", or "seismic isolation"[13] as it is referred to, is described as a modern or innovative technology, the basic concept behind foundation isolation and its application is far from being a new development. In fact, the idea of "decoupling the movement between the structure and the ground or loosening the bond between the two", in the modern sense, began in the 19th century or so. Yet its antecedents go back as far as the Bronze Age. In ancient times, the central concept of earthquake protection was to stop or prevent seismic waves from damaging structures. However, while these ancient practices of foundation isolation are technical solutions, they do not necessarily indicate a perfect understanding of everything. Various human endeavours have searched for different techniques to construct more durable buildings. After all, one might imply that the words and material-related technical thinking about 'decoupling the movement between the superstructure and the ground' in general terms are also new. However, careful research reveals that while the state of the art may be new, the application of the idea may be much older[14]. It is, therefore, worth noting that the concept of isolation was adapted and used in ancient times. Because without a solid foundation system, these structures would not have survived for centuries.

Several types of foundations built to withstand seismic movements include large cut stones, beds of small stones, direct placement on bedrock and large 'orthostats', especially connected stone blocks. Especially under the columns or walls, or even on the rocks, some flat small stones were laid as a cushion to absorb the first shock of the earthquake forces on the soil prepared in advance in the foundation pits; this system continues uninterruptedly from the Bronze Age to ancient Rome and is even used in rural Anatolia today. Some large foundation stones (orthostats) were placed on these small stones, usually without mortar, where the walls

11 For the history of seismology, see Ben-Menahem 1995.

12 Carpani 2017, 9.

13 Stevenson 1868, 557-566; Barbat – Bozzo 1997, 154-155.

14 F. Milizia, when describing earthquake-resistant houses, recommends building a wooden structure, not exceeding in height its width, not anchored to the ground, but free-standing on a stone platform, strongly connected to each other. In an earthquake, he concludes, a house designed in this way can only tremble but never collapse, because "this house is a chest": Milizia 1781, Chapter 10; Stevenson 1868, 557-566.

were built (Fig. 20). During earthquakes, a slight shift or movement occurs as these small stones move. The orthostat stones are left empty around the perimeter to ensure the better functioning of this foundation. The orthostat stones also prevent moisture from penetrating into the structure. In Anatolia today, placing small flat stones under pillars, columns, and walls is a tradition that serves the same purpose. Since the technique was introduced early on, it was adapted to other areas. As in the method of moving blocks on wooden logs[15] (Fig. 1), using small round stones placed underneath to move or turn large blocks of stone on a flat surface is still the most common method used by stonemasons today. However, it must be recognized that the movement of the ground beneath a building during an earthquake is the most critical issue and that this movement is very complex. In the modern era, this is explained by mathematics and functions. Still, in reality, during an earthquake, the ground motion beneath the building is caused by several types of waves, which have their own lengths, oscillation periods, amplitudes and speeds of motion simultaneously. As a result, all points of the ground and the foundation of the building move differently, although sometimes in slightly different ways. Therefore, each earthquake or ground motion is different and is not repeated in the case of the next earthquake. In this sense, what are the fundamental and innovative applications that are very important for a structure?

Besides the building foundations in Anatolia and Syria, innovative practices are also known from the Aegean[16]. The palaces of Crete[17], most notably Knossos and Malia[18], and the houses in the Akrotiri settlement supply good examples of wood use. In the buildings of this period, mudbrick, stone and wood were used together[19]. In the following periods in Greek architecture[20], apart from wooden beams and crepidoma, the connection of stones with dowels and clamps[21]and support with wood or metal[22] emerged with the same logic. The Greeks used the ordinary construction method of joining blocks together without mortar. Egypt first used this technique, and the Romans borrowed it from the Greeks[23]. This method was designed to withstand possible movements and seismic shocks. However, in these examples, it is seen that the walls were reinforced rather than the foundations[24]. This was because the most damage occurred in the load-bearing elements, while problems caused by the ground required the reconstruction of the building. If the building had proper foundations, such systems and measures were unnecessary.

15 Adam 1977, 31-63, Fig. 14; Adam 1994, Fig.35.
16 Lloyd – Mellaart 1956, 122.
17 Thompson 1960, 59; Marthari 1990.
18 Evans 1928; Palyvou 1988; Palyvou 1990.
19 Mainstone 1975, 167.
20 Livadefs 1956; Martin 1965.
21 Martin 1965, 22-9.
22 Dinsmoor 1922; Martin 1965, 240.
23 Adam 1994, 96.
24 Dinsmoor 1922; Martin 1965.

The reason is that the pressure is transmitted vertically only through the columns and walls. Therefore, the effect of clamping can be mentioned against the slips caused by trussless roof systems. As a result, earthquakes' destructive effects have led to the prevalence of these reinforced structures. It was also common knowledge that earthquakes around the Mediterranean created such effects. Because as will be mentioned, Greek engineers and architects knew the techniques and antiseismic functions they inherited from the East and Egypt, such as metal reinforcement[25], and used them consciously. The only thing that is unknown is the lack of clear written documentation explaining why architects and builders chose certain types of structural designs to prevent collapse due to seismic shocks.

The prevalence of various construction materials in a region enables the emergence of building characters and types[26]. When the time interval between significant earthquakes is long, people seem to forget about earthquakes and their destructive effects and no precautions are taken. However, constantly recurring earthquakes keep human memory alive and strong, ensuring that antiseismic constructions are not forgotten, and they also lead to the emergence of new techniques. It is possible to see these changes in archaeological documents. Therefore, seismicity can be a factor that strongly affects building style and history in certain areas, the best example of which is the Mediterranean Seismic Zone Cultures. However, because the threat of earthquakes is not constant, expensive and architecturally annoying structural restraints are sometimes ignored or relegated to oblivion.

In this case, what needs to be done is to put soil, sand, ash, etc., between the ground and the structure[27], as is the case today. The aim is to consider the elements that make ancient structures earthquake-resistant, such as layer placement, from today's perspective and to analyze them according to today's attitude. Although some structural tips used by ancient builders to increase the earthquake resistance of their structures are overlooked, overall earthquake-resistant construction experiences can be evaluated for today's buildings. Questions such as How many people died due to faulty structures? How much material-economic loss was experienced? Rather than numerical results such as, what are the ancient anti-earthquake techniques and practices that reduce the destructive effects of earthquakes, and what are the symptoms of these practices? should be taken into consideration. Therefore, the impact of the earthquake on structures and the precautions taken should be known.

25 Martin 1965, 238.

26 Roman mortar, for example, originated in Italy with volcanic material that could be found in the east. In the Cyclades, preservation of wood was at the forefront of stone architecture. There are adobe bricks in the inner regions of Anatolia. In Samos, many things remain the same for a long time, especially due to the continuity of earthquakes, in the architectural area with its convenient location, economic and political shelter.

27 Doudoumis et al. 2002; Xiao et al. 2004, 3-4.

In short, many essential elements of construction technology that can provide seismic resistance can be seen in buildings from the Bronze Age to the Roman period. However, it is vital to appreciate that the seismic-resistant design elements inherent in classical Roman structures are little more than a coincidence. For this purpose, the article discusses 'foundation isolation'; that is to say, it focuses on the gap between the foundation and the ground, and antiseismic designs are mentioned.

It is worth emphasizing this point first on the Bronze Age building foundations. The types and development of buildings in Anatolia, according to region, generally depend on the construction material. Security, economy, political and ideological reasons, the complex structure of society, religious tendencies, traditions, etc., can also be added to the reasons for this diversity. In other words, the structure was produced by utilizing the available materials. However, even this material shows that the Anatolian engineers, architects and artisans who continued to settle in the same area did not forget one thing: They experienced significant earthquakes, and the recurrence intervals between these disasters were very short. If the time interval between earthquakes exceeds a human life, earthquake-related problems are generally forgotten quickly, indicating no precautions are taken. However, if people constantly face repeated earthquakes, like the people of Anatolia, this creates a strong earthquake memory in the community and, more importantly, on the minds of the persons involved in construction activities. As a result, it is seen that earthquake-resistant, that is, antiseismic construction techniques are not forgotten or ignored. Therefore, seismicity is a factor that controls the building style, technique and historical development of construction in certain areas. However, it should also be noted that sometimes, since the threat of devastating earthquakes is not constant as it is today, it is economically expensive. That is, in terms of construction cost, architectural and structural limitations and suggestions could sometimes be ignored and forgotten. The predecessor peoples of Mesopotamia, Egypt, Anatolia and the Aegean were able to determine which structures were earthquake-resistant and left behind both archaeological and historical evidence that shows us that they were able to build such structures.

In this study, it is primarily emphasized that earthquakes were a determining factor in the prevalence of antiseismic structures and techniques in the early period, namely the Anatolian Bronze Age and Aegean cultures, and even in determining the building style and examples from neighbouring cultures, such as Mesopotamia and Egypt, and in the Classical period, Greek and Persian, were presented.

BUILDING FOUNDATIONS IN BRONZE AGE ANATOLIA

During this period, masters and builders raised the foundations of the buildings on pillow stones dug into the bedrock to prevent the houses from sinking into the ground. In fact, loading the weight directly on the stones rather than the soil was the first step towards creating modern foundations. Wood-log-based structures and the origin of this technique go back approximately three thousand years. It should not be surprising that these ancient examples are found in the Middle East. This geography not only houses the oldest traces of humanity's past but also regularly experiences the most shocking earthquakes. Similar earthquakes continue to occur in the same geography. Therefore, searching for new systems today is necessary, just like the ancient people, engineers, architects and artisans.

R. Naumann, in his work "Old Anatolian Architecture", draws attention to the presence of dense wood content in the structures of the Bronze Age settlements in Anatolia. Of course, there are other materials, such as stone and mudbrick. The exception is the structure built entirely of stone[28]. However, wood is frequently used for reporting purposes and on walls[29]. The use of wood on the roof is in the form of a triangular box that extends from bottom to top and is also flexible. Using these wooden beams or logs in the foundations and superstructure until they were bent had only one purpose: to increase the resistance against comprehensive earthquakes and to provide durability to the structure.

In this early period, foundations continue to be excavated until a solid ground is found in architecture. Their foundation structures vary depending on the soil characteristics they sit on. If the bedrock is close to the surface, the foundation sits directly on this rock without levelling the stone ground or after levelling the bedrock separately for each stone foundation. If the mudbrick wall rests on the rock, as in Boğazköy, a bed made of wooden beams is placed between the bedrock and the mudbrick wall[30]. Wood was used in stone foundations even in very early periods. Even today, it can be understood from the fact that wood is frequently preferred in buildings, how flexible it is in earthquakes as a building material and that it is a safe building material against earthquakes.

[28] Naumann 1998, 58.

[29] The construction technique in which timbers are used in walls is achieved through a three-dimensional wooden frame embedded in the stone wall to connect the various structural parts and contribute to the overall seismic resistance. In general, such an application protects the entire building by absorbing the effects of seismic ground movements. This technique, called *opus craticium*, spread throughout the Mediterranean during the Roman period. This system was developed in the 18th century under the name *la casa baraccata* in Italy, *pombaline gaiola* in Portugal, *hımış* in Turkiye. Many different names given to same method can be found almost all over the world. This system, which has even spread to geographies without earthquakes, has often been used in northern Europe, Central Asia or Japan, America and North Africa, including countries in earthquake zones. They are examples of how a solid structure is built, not only from an artistic perspective: Özgüç 1966, 29-52; Langenbach 1989, 30-43; Abdessamed-Foufa – Benouar 2010, 270-293.

[30] Naumann 1998, 58-59; Mielke 2009, 81-106.

One of the earliest examples of using wood in foundations is Beycesultan, and the other is Acemhöyük Palace[31]. In Acemhöyük, this Bronze Age settlement of Anatolia, wooden logs were used on stone slabs to strengthen the structure and provide seismic insulation (5^{th}-4^{th} millennium BC)[32]. This tradition continues to be used in rural areas in Anatolia for a long time. In both settlements, monumental buildings such as palaces rose in parallel with the level of prosperity. The extensive use of wood in these settlements and the foundation system indicate that it had a particular application for strengthening foundations.

The basic structures of Beycesultan Palace provide remarkable information (Figs. 2-4). Wooden logs were placed transversely after laying the stone rows in the foundation pits. In the Early Bronze Age, transverse wooden beams were also used between the stone walls in Beycesultan (Layer IV). In this settlement, a different foundation was unearthed in one of the rooms of the palace in the 5th layer (beginning of the 2^{nd} millennium BC). Deep holes were dug and round wooden logs were placed side by side at intervals at the bottom, and some of the timbers were filled with broken stones and nailed to the ground[33]. This foundation grid was reinforced first by placing transverse logs on top, then another course of longitudinal logs on top of them, and again boards on top of all. This grid, with a thickness of 80 cm., is completed with a stone floor.

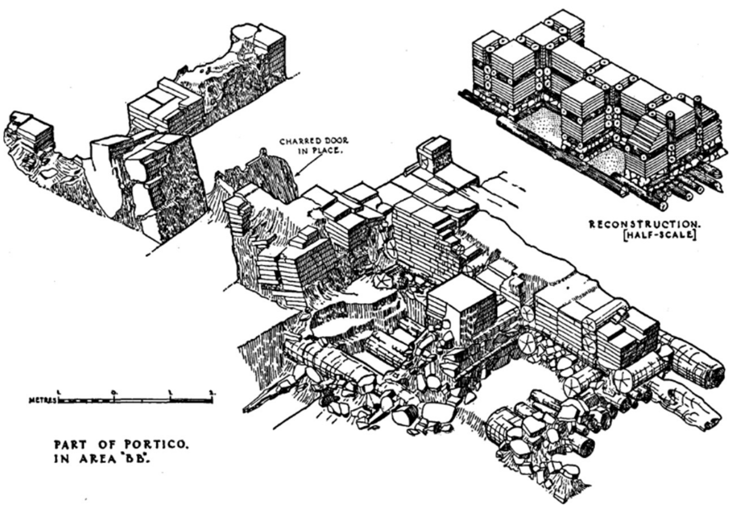

Fig. 2. Beycesultan. Architectural remains of room 32. (Lloyd 1960, Fig.3).

[31] Carpani 2014, 1-14.
[32] Carpani 2014, 2-3.
[33] Lloyd 1960, 31-41; Naumann 1998, 61, Fig. 35a-b; Newton-Kuniholm 2004.

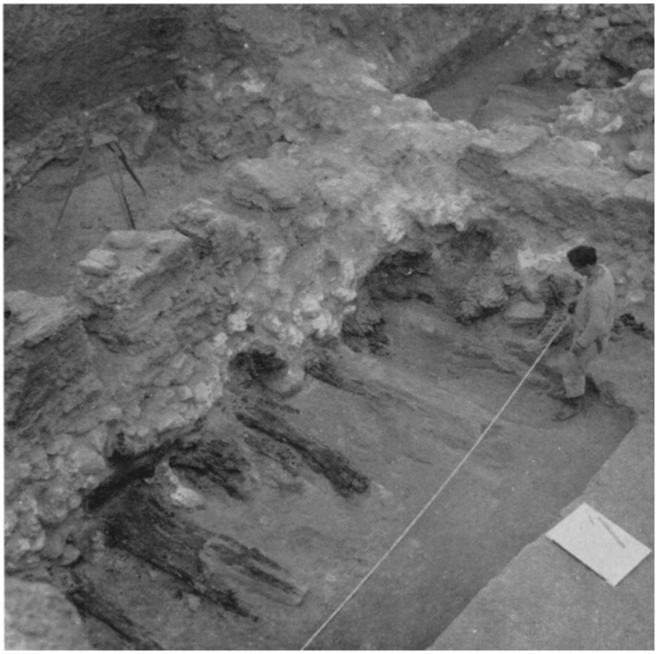

Fig. 3. Wooden foundations on the south wall of room 28 in Beycesultan. (Lloyd 1960, Fig.3).

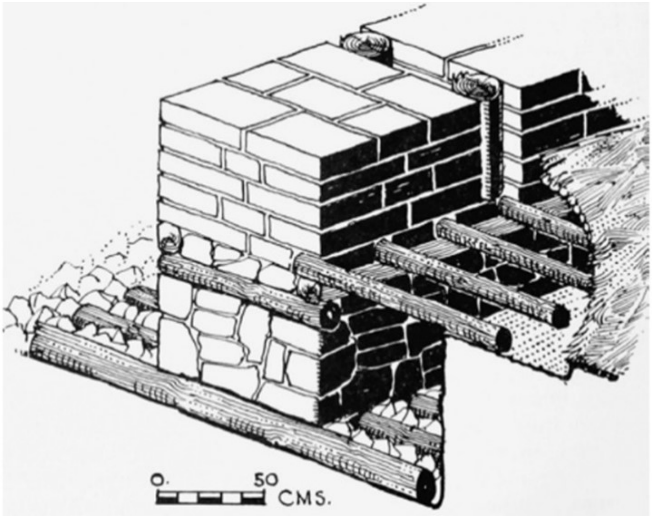

Fig. 4. Beycesultan. Plate V. Palace wall. (Naumann 1998, Fig. 35b).

Another example of a building with similar infrastructure to Beycesultan is the Acemhöyük palace. A similar foundation system is seen here (Fig. 5). However, compared to Beycesultan, the foundations of Acemhöyük (1774 BC) have a slightly different and interesting structure. Here, the wooden logs are on a layer of protruding limestone base slabs set directly into the ground[34]. Wall thicknesses are generally four meters wide. The primary purpose of this regulation is to prevent concussions.

Apart from these two examples, another example showing that Anatolian builders successfully passed the tests with the ground is Troy (Fig. 6). An unnoticeable antiseismic system was placed under the walls that visitors admire with admiration as they pass by today. These walls, built of large square-shaped stones, belong to the 1st layer of the settlement VI (1700-1300 BC) and are without towers. However, they attract attention with their small saw-shaped protrusions on the exterior. Additionally, the slight inclination of the stones and walls increases their durability. An interesting feature of this structure is that its foundations do not reach the bedrock. According to the excavation report, ancient builders deliberately left a layer of hard soil ranging from 20 to 120 cm between the bedrock and the wall. Experts have interpreted this sub-base preparation as "an earth cushion" that acts as an antiseismic device, a simple "shock absorber"[35].

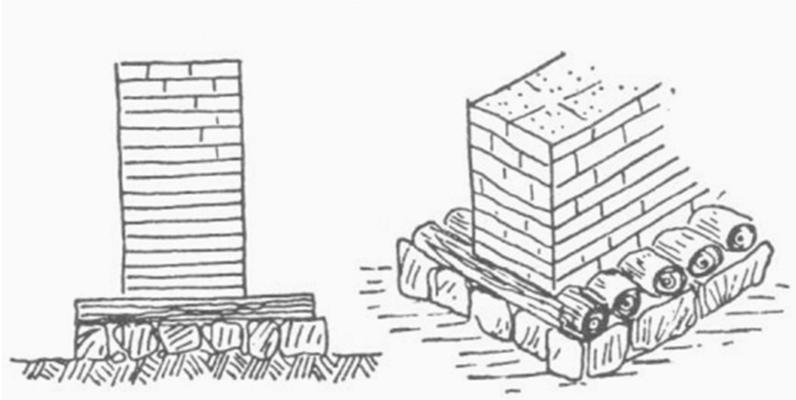

Fig. 5. Acemhöyük. Wooden grill under adobe walls (2000-1900 BC) (Naumann 1998, Fig.36).

[34] Özgüç 1966, 36; Naumann 1998, 61, Fig. 36; Carpani 2014, 3.
[35] Blegen et al. 1953; Rapp 1982, 43-58; Carpani 2014, 4.

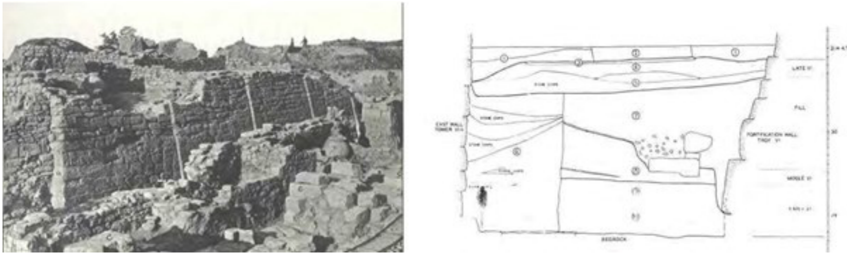

Fig. 6. Troy city walls. View (Dörpfeld 1902) and Section (Blegen 1953).

The origins of these foundation systems discussed are unknown. However, it can be said that such practices originate from traditional knowledge regarding the use of wood. The use of timber survived for a long time, from the Bronze Age to the Roman period and today's countryside. Therefore, the long experience using wood and wood-component structures may represent a system created and developed as a solution by an administration or traditional construction thought. Because, as will be stated, a similar background can be expressed in the architecture of the islands and the Minoan culture. In addition, this construction culture wants the memory of seismic events and awareness of damage not to be lost, which means that the turnaround time of events in terms of work experience is close to a generation time. Such awareness encourages local communities not to forget and abandon construction criteria but to analyze, maintain and improve them. Differently, in cases where earthquakes are rare, people and artisans will lose consciousness and forget seismic solutions over time or even prefer misleading interpretations (as is the case today).

TEMPLE FOUNDATIONS IN MESOPOTAMIA AND EGYPT

A method similar to the one used on the city walls of Troy is also evident in the foundations of the Oval Temple (3rd millennium BC) located in Tutub (Khafajah) east of Baghdad in Mesopotamia (Figs. 7-8)[36]. It is seen that the foundations of this large ellipse-shaped religious structure (Oval Temple, Early Dynastic II: 2750-2600 BC) rest on a huge sub-base. After the foundations were excavated, a sand bed (64,000 m2) with a thickness of approximately 8 m was created. Because it has been determined that there is no sand at any point other than the temple foundations, the sand is relatively pure, there is no trace of organic matter, and therefore it was most likely brought from outside the settlement. Before the construction of the temple, the entire area was excavated and filled with sand. After the filling was completed, the surface was carefully levelled, and on sand, the wall foundations were made of sun-dried bricks to a height of 1.20-1.40 m. Above the sands, the

[36] Delougaz 1940, 11; Schaudig 2010, 144-147; Carpani 2014, 4-5.

space between the foundations was filled with compacted clay, forming a thick and hard mass in which the foundations were embedded. A brick wall was built on top of the clay layer. Different suggestions have been put forward and debated on the purpose of such a tremendous amount of labour. However, it is understood that the purification of the temples started with the materials.

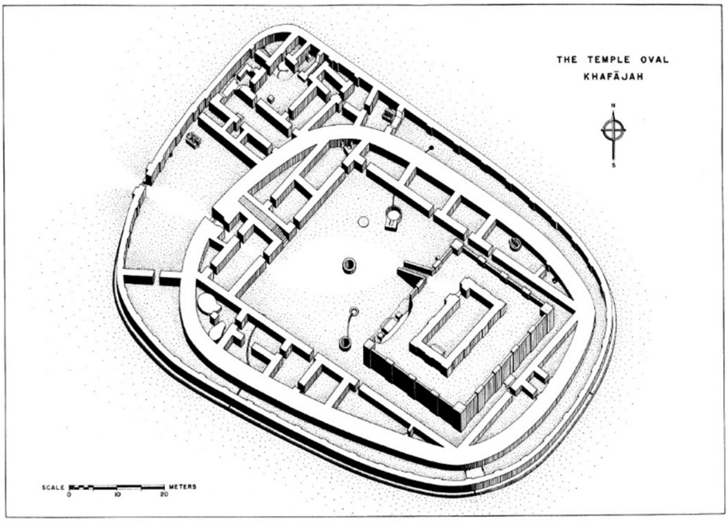

Fig. 7. Oval Temple (Delougaz 1940, Pl.V).

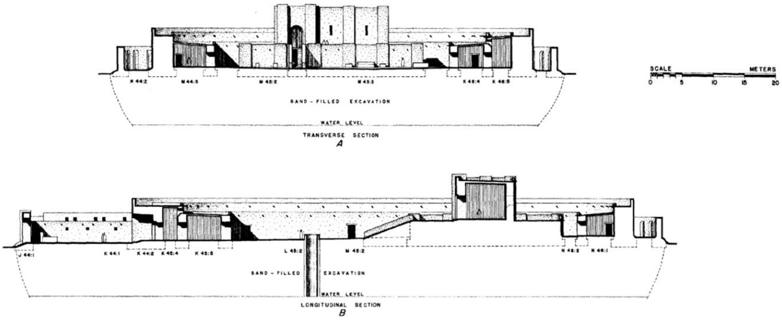

Fig. 8. Oval Temple. Sections ((Delougaz 1940, Pl.VI).

Written documents regarding Mesopotamian temple construction and restoration also clarify the subject. According to these documents, using pure and clean sand (soil)[37] in the foundations of buildings, especially temples, is linked to belief. Since temples were man-made sacred places, they had to be purified. In this context, they had to be constantly protected against human pollution and disrespect since the moment of construction. For this reason, votive inscriptions were placed on the foundations of the buildings, and care was taken when selecting materials to construct the foundations of the buildings. Therefore, a temple is not just a stone, sun-dried brick or brick.

A similar practice can be observed in the Oval Temple in Lagash[38], built in the same period as the Khafajah Oval Temple, with the same method and logic. In addition, the same practice was repeated in the Harbor temple built by Nabonidus in Ur[39]. In fact, King Nabonidus, one of the first archaeologists, mentions that, apart from this temple, he had the foundations of the temple in Sippar-Anunitu filled with clean soil from outside the city[40]. In Mesopotamia, a layer of sand under the floor of the Temple of Ninurta in Babylon and cylinder seals belonging to Nabopolassar were unearthed inside[41]. The other temple with a sand layer is the Ishtar Temple in Agade[42]. Additionally, as can be seen from the Troy example, sand under the foundation provides adequate protection and is one of the most accurate methods for equal load distribution (since there is no volumetric change). Also, under certain conditions, a sand layer can reduce the impact of seismic shocks. But whatever the reason, archaeological evidence shows that the construction process of the Khafajah Oval Temple complex was carried out according to a detailed plan and well-developed technical knowledge. Although the presence of a sand layer is a practical construction technique, it is more of a ritual practice.

Unlike ritualic Mesopotamia, the building foundations at Tell Jemmeh in Israel[43] (Fig. 12) also have antiseismic insulation. Possibly, the use or application of this clean sand dates back to 10 BC. It is a common feature of 19th-century foundation pits. Before the first row of bricks, a 3-5 cm thick layer of sand was laid, and the foundations were placed on this layer. Once the masonry foundation reached ground level, the foundation trench was further backfilled with clean sand.

Laying sand beds under foundation walls was a common construction method in ancient times. This system was used in Ancient Egypt in buildings located on

[37] Ellis 1968, 10, 15.
[38] Hansen 1980-1983, 424.
[39] Heinrich – Seidl 1982, 324-325.
[40] Schaudig 2001, 44-63.
[41] Ellis 1968, 104, 108-124.
[42] Ellis 1968, 15.
[43] Beek 1996, 1-8.

the alluvial Nile floodplain[44]. Much more important are the foundations, or rather the ground preparation under a foundation, which the Egyptians attached great importance to. Even in the modern age, it can be seen that in many places, the intricacies of soil mechanics, which were not yet understood, were also used by the Egyptians, and their functions were not well understood. In Egypt, the ground bed was prepared in accordance with the nature of the place where the temple would be built. If a building was to be built on flat land with soft soil, then traditional foundations would be changed. Later generations widely used the method of amending soft soils, but its first practitioners can be said to be Egyptians.

Once a foundation pit, or a trench, was dug, the Egyptians took the soft soil and filled the pit with sand to create a necessary layer, as at Medinet Habu (Fig. 9) and Tell Belim (Figs. 10-11)[45]. In fact, compacted sand is part of the foundation because it resists compression so well. If a building was to be built on a rock, the area required for the building to be built was levelled. For this purpose, unnecessary rocks were cut and shaved, and cavities or depressions were filled with gravel and sand[46]. The temple of Ramses IV at Der el-Bahri was erected on a rock protruding into the surface in the form of a hillside. The rock was levelled to obtain a horizontal surface to prevent the foundation from slipping during an earthquake. First, a pit was dug, and then this stepped base was filled with dry sand. After this arrangement, the foundation blocks were placed on the sand filling. In other words, sand filling has always been between the foundation and the bedrock. This system is not widely practised today, but it was the sub-foundation practice of the Egyptians and all subsequent ancient builders.

Fig. 9. View from the Medinet Habu-Royal Palace Excavations. The sand layer used under the columns (Hölscher 1941, Pl. 29).

[44] Carpani 2014, 6.

[45] Josephson 2005, 403-406.

[46] Hölscher 1941, 11-12, 38, 51, 53-55; Spencer 2011, 31-49; Spencer 2017, 37-52.

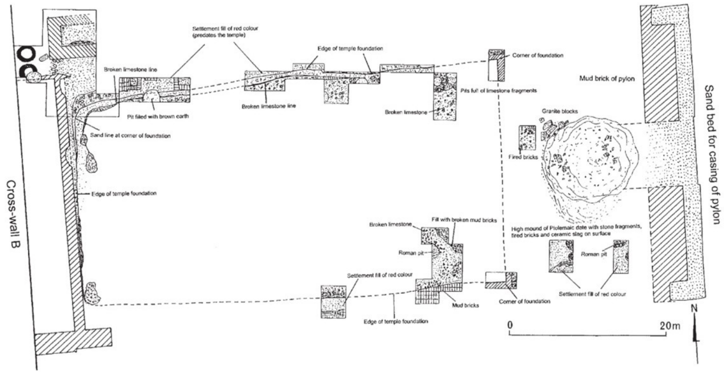

Fig. 10. Temple plan and sand beds at Tell Belim. (Spencer 2017, Fig.4).

Fig. 11. Sand bed foundations of the temple at Tell Belim (Spencer 2017, Pl. X.2).

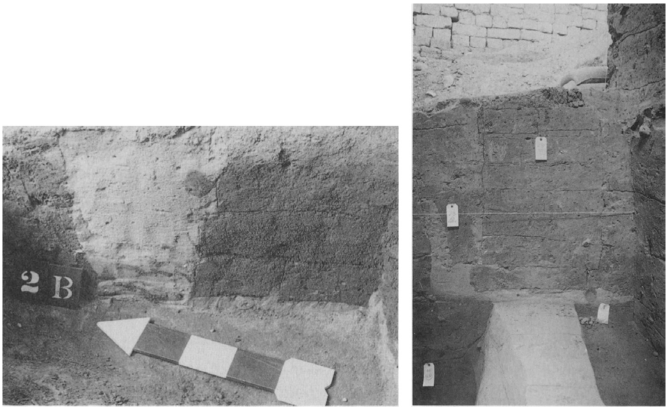

Fig. 12. Sand base layer and sand-filled foundations at Tell Jemmeh (Beek 1996, Figs. 6-7).

Preparing the foundation bed with sand has two purposes. On the one hand, the load is transmitted to the ground in one piece, so there is evenly distributed settling of the building weight and no stress concentration in the foundation. On the other hand, it functions as a seismic insulation system that absorbs earthquake shocks and allows the structure to slide on the sand relative to the moving ground during the earthquake. Almost beyond any doubt, the Egyptians knew very well the importance of preparing the ground foundation for a building. In any case, during the Middle Kingdom (late 3rd millennium BC to 17th century BC), sand barriers up to 80 cm thick were placed under the columns[47]. The thickness of the sand fill depended on the weight of the structure standing on it. In the city of Ramesseum in Upper Egypt, the thickness of the bedding under a heavy column was twice that under a traditional wall. The foundations under the massive columns named after the pharaoh Takhark in the courtyard of the Great Temple of Amon have an interesting design. The foundation pit for the column foundations was dug, and the foundation was filled with 10-20 cm thick sand beds. In general, the New Kingdom Age saw significant progress in establishing solid foundations. The foundations were deepened to 5-6 meters, and the traditional limestone was replaced with sandstone. Thus, the foundations were tried to be made more monolithic and were formed by assembling tightly placed large blocks

Placing sand under foundations was also used, especially in temples of the Ptolemaic period[48]. The black sand layer under the temple foundations of the Ptolemaic-Roman Period in Tell Timai (Fig. 15) is another example of the sub-foundation applications of this period[49]. Here, the depth of the stone foundations reflects the builders' and architects' ability to find a suitable ground surface on which to lay the foundations, as well as the ancient builders' awareness of ecological conditions. As mentioned above, reaching the base for foundations, blocks based on a commonly placed sand bed, is a feature of temples in the Late Period and Ptolemaic-Roman construction. During the excavations that were carried out next to the stone foundations, the last row of stones resting on a very thin sterile ground and a layer of black sand were identified. This fine sand layer was used both to level the ground horizontally and to strengthen the foundations.

An interesting example of this type of sub-foundation technique in its well-developed form is in Mendes[50], within a substantial sacred building dating to the mid-6th century BC. Here, in the absence of bedrock, this method ensures that

47 Petrie 1897, 11; Karakhanyan et al. 2010.

48 For the mythological and cultic meaning of the use of clay in Egyptian architecture, see Spencer 1979; Ritner 1993. In Egypt, the use of sand was associated with the primitive mound on which the first temple was built and was thought to have purifying qualities. Additionally, the role of sand in Egyptian and Mesopotamian founding rituals was important. See Weinstein 1973, 420-3, 434; Spencer 1979; Ritner 1993, 155; For Mesopotamian rituals, see. Ellis 1968, 10, 13-16; Ambos 2004, 78-79; Ambos 2013.

49 Bennett 2019, 220, Fig. 4.

50 Carpani 2014, 6.

the bearing pressure of the construction is evenly distributed over the alluvial soil. Since sand is a good drainage material, it prevents the settling of the building and significantly protects it from the destabilizing effect of annual floods. A similar practice exists in Tanis and Karnak[51]. Since the foundations on which the column base of the Great Hypostyle Hall in Karnak rested were seated on a sand bed, one of the columns fell sideways[52]. A similar situation also took place at the temple of Amenhotep in Luxor[53].

In short, it is understood that including sand layers in the foundations of buildings, especially temples, in Mesopotamia, Egypt, and even the Levant is ritualistic (to place votive materials) but, at the same time, an engineering project and preparation for the foundations of the building.

In addition, the geographical context in which these architectural traditions emerged and took root and the economy on which their societies were founded profoundly influenced building design. Economic activities based on maritime trade moved to other regions by constantly travelling throughout the Mediterranean basin, which was affected by a homogeneous and strong seismic hazard. This movement necessitated the development of the carpentry industry while allowing us to learn what solutions were used by other cultures. The solution to foundation problems against earthquakes has also been developed experimentally. This experimental approach, based on careful examination of building behaviour and material damage, constitutes the primary source for developing and identifying earthquake resistance solutions used by the Bronze Age cultures.

In Aegean Bronze Age architecture, it is seen that several antiseismic practices developed early, in recognition of the fact that earthquakes destroyed settlements[54]. Especially in Minoan palaces and villas and in the settlement of Thera-Akrotiri, lighter walls were superimposed on the stone walls built in the basement or ground floors. They built wooden frames in which stone and brick elements were integrated, using vertical, horizontal and transverse beams, and clay and plaster were later applied to them[55]. Particularly in Crete, great importance was given to preparing floor coverings for buildings. Even the most minor irregularities in the ground layer are completely smoothed or cut out. Depressions and crevices were filled with construction materials. Flat surfaces in the form of steps were created on the slopes where the buildings were built. A sand-gravel layer is placed between the ground layer and the building foundation. One of its functions was to distribute the foundation load evenly and absorb earthquake shocks. The most interesting

51 Legrain 1900, 121-140; Clarke – Engelbach 1990, 72.
52 Carpani 2014, 6, Fig. 8.
53 Carpani 2014, 6.
54 Tsakanika 2006.
55 Shaw 2009, 101, especially 170; Hnila 2021.

aspect of the Knossos palace is that the masonry is thoroughly reinforced with wooden beams in vertical and horizontal directions. This system made the wall monolithic and elastic so that it worked as a unified whole. Likewise, stone blocks and wooden beams were used to connect the walls, creating a unified closed system that made the building earthquake-proof. Another interesting aspect of this palace is its columns. They were wider at the top, narrower at the bottom, and looked unusually shaped. However, when thought carefully, it shows that this is a correct application. The beams are supported by the upper end of the column, and its end forms the column capital, corresponding to the load-bearing parts of the beams. A hinge is already formed at the column's base, allowing the column to operate so that it can be compressed rather than bent. The buildings of Knossos were at least three stories high. As a rule, the ground floor is built deeper into the ground and has a more significant number of longitudinal and transverse interconnected walls than the upper floors. All this provided a strong and reliable foundation for the upper floors.

Evaluation of all that evidence shows how widely these techniques have spread, not only on walls in Greece but also on infrastructures and foundations in Anatolia. The frequent occurrence of earthquakes in Mesopotamia, Anatolia or the Aegean region and especially the fact that Crete is located in the most active seismic region also prove that there are efforts in this direction. Accordingly, these regions have been devastated by frequent earthquakes. Even the Palace of Knossos shows that despite all the precautions and the earthquake prevention improvements used here, it was not enough to save the palace.

As can be seen, the construction techniques of the Bronze Age civilizations, especially the foundation and sub-foundation works, show that people actively struggled against the effects of earthquakes. Still, from then until our day, there has always been a problem with earthquake-resistant construction. This gap in knowledge and application continues. Nevertheless, the foundations of such a study were laid at that time. Studying and understanding these systems is both crucial and urgent, not only to advocate or preserve ancient traditions but also to learn from them. All these techniques create an environmentally compatible tangible heritage and are promising options for sustainability in the context of adaptation to earthquake geography. The aim is to produce earthquake-resistant construction through the use of local materials with little energy. This type of architecture can be a starting point for sustainable revitalization projects of extraordinary examples at risk of being lost, with the participation of local workers and artisans. Examining such real and accurate examples is essential, as they are much more transparent and more understandable in today's building construction. Such local cultural heritage elements represent the concrete expression of a tradition that has been refined over time in parallel with the disasters affecting our geography and region. As a result, it shows that the builders in the Bronze Age and later in the Mediterranean basin, mainly in Anatolia and Greece, where earthquakes were frequent, were aware of seismic behaviour and frequently encountered it.

FOUNDATIONS IN ANCIENT GREEK TEMPLES AND DIFFERENT BUILDINGS WITH CERTAIN INTERESTING DESIGNS

The influence of Greek thought and practice spread throughout Greece (the south of the Balkan Peninsula), as well as Hellenic cities and colonies along the Mediterranean coast, the Black Sea coastal region and Asia Minor. In the 4th century BC, the troops of Alexander the Great, king of Macedon, defeated the Persians in Egypt and Syria and established a series of Greek-eastern monarchies, extending the conquests eastward to India. With their influence spreading over such a wide area, it is clear that the Greeks not only introduced their culture and construction skills to other peoples but also absorbed all the helpful knowledge they learned in the conquered countries. What they didn't integrate was the dependence on mortar to connect the dome, vault, and walls. As will be stated, the newest and most costly technical applications were applied in the temples of the gods whose powers they feared. Despite these extensive sources of information in early civilizations, which frequently referred to natural disasters in texts from classical genres such as poetry and history, ancient societies appear to have lacked knowledge about the nature of catastrophic events. They often associate these natural disasters with gods or superstitions. For example, in Greek mythology, Zeus was responsible for droughts, and Poseidon, the god of the sea, was the creator of earthquakes[56]. Despite these false assumptions, ancient civilizations gradually developed solutions to reduce the destructive effects of the environment and end crises in their lives. Walls from structures that varied from defensive structures to bridges and temples are various examples of these efforts. With these structures that have been examined, adopted and developed, we have learned the seismic construction techniques of the Ancient Age[57].

Ancient Greek builders had their own theories of construction, including those of earthquake-resistant construction, which they followed by using or rejecting specific construction techniques that existed at the time. The best examples of this are seen in temples. The most striking element in Greek temples is the beam-column system, which is ductile and dominant in the Archaic and Classical periods. The load-bearing elements, namely the walls and columns, were provided by iron dowels and clamps closed with lead, as similarly attested in Egypt.

The fact that the ancient Greek builders tried to give enough flexibility to the structure of their unique temples is confirmed by the construction of their foundations. Foundations and load-bearing columns placed under the walls are separate elements. Accordingly, unequal settling of the foundations did not cause stresses in the building elements. Each architectural element is connected to the other. Reasons such as the light structure of the Ionic order, when compared to the Doric

[56] Grant-Hazel 2002, 441-443
[57] Stiros 1995, 725-736; Stiros 1996, 129-152.

order, krepis, and the thickness of the outer columns can be called innovations utilized against the damages of the earthquakes. Despite the flexible structure of the walls and columns, the weight of the superstructure is the main reason why temples collapse during earthquakes. However, tholos structures of the same culture are more perfect in terms of seismic stability than a rectangular structure. It can be said that the symmetry of round-designed structures is ideal. Foundations consist of closed deep rings designed separately under the outer columns and separately under the walls and inner columns.

Interestingly, the Greeks were aware of the importance of a solid foundation when building their earliest temples. The Temple of Hera at Olympia (6th century BC) was built on the bad alluvial ground carried by the river on the Peloponnesian peninsula. It was also built on a specially made platform due to the presence of groundwater close to the surface and frequent earthquakes. The Tegea Athena Temple in the Arkadia region (4th century BC) was also destroyed because they could not implement the earthquake-resistant improvements of the time. The reason is that even though the stones on the walls of the temple, which carry heavy loads, are connected, the building still has shallow foundations on the alluvial ground.

In ancient Greek engineering, placing sand, gravel or clay layers between the ground and foundation was a well-known method, as it was in Mesopotamia and Egypt. In fact, as stated, some of the Greek temples were protected by a basic insulation system. Thus, the structures could more easily cope with the problems arising from geotectonic movements. However, placing sand on building foundations and placing votive materials inside are also seen in Greek architecture (such as Ephesus, Delos, Akragas and Naxos). In these examples, sand was chosen for purification purposes, as in Mesopotamian examples. In fact, the coal used in the construction of the temple in Samos (Temple D), the ruins in the Pergamon Z building[58] and the frequent use of coal in constructions by Theodoros of Samos were all practices that had parallels in Mesopotamian rituals.

One of the best-studied examples of Greek engineering is the magnificent Doric building Athenaion at Paestum[59] (Fig. 16). It was built at the end of the 6th century BC. Deep excavations were made to reach the travertine bedrock into which the trenches were opened to lay the foundations under the columns and cella walls. These trenches on the bedrock were later filled with a 0.50 m thick layer of sand. The foundations were formed by laying large travertine plates measuring 1.85-2.35 m on the sand. A modern geotechnical analysis clearly shows that this foundation system is very well designed and is highly safe even in the event of a seismic load. As mentioned, this basic technique was used systematically not only at Paestum[60]

58 Radt 1994, 419-421.
59 Giuffrè 1988.
60 Pescatore – Viggiani 1991, 29-42.

(e.g., archaic Temple of Hera-550-540 BC), but also in the broader area, including Metapontum, where the earliest applications were found (e.g., Temple AI, 570-560 BC). The fact that both cities were Achaean colonies suggests that this basic practice was probably imported from the motherland, namely Greece[61].

The sand was also used in the foundations of structures such as the Artemision of Ephesus[62] and Samos Heraion[63], both built on marshy ground for earthquake protection.

The Temple of Artemis in Ephesus, one of the seven wonders of the Ancient World, which took one hundred and twenty years to build, also has an interesting infrastructure arrangement[64]. A swampy area was chosen for the location of the temple[65] (Fig. 13). On the other hand, to prevent the foundations of a large mass from resting on a loose and mobile bed, layers of coal were placed underneath, and fleece and wool were placed on top[66]. This anecdote may also have referred to a ritual performed before or during the temple's establishment. Because this expression also reminds us of the 'sacrifice of blessing'[67].

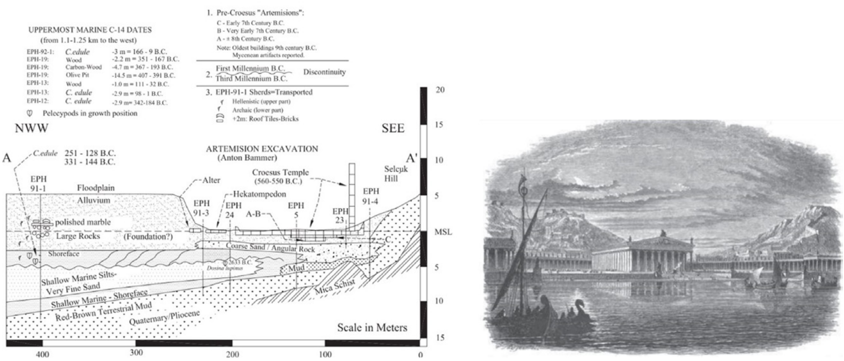

Fig. 13. left: Section of Artemisin according to excavations, (Kraft et al. 2007, Fig.5); right: Ephesus Temple of Artemis and harbor according to Falkener (Kraft et al. 2007, Fig. 7).

The precautions in these monumental temples were clearly taken against earthquakes. In particular, these layers of coal and wool are an early example of a seismic foundation isolation system. During the 6th century BC, Greek colonies on

61 Carpani 2014, 7.
62 Bammer 1984.
63 Kienast 1991; Kienast 2001, 38; Carpani 2017, 9.
64 Pliny, NH 2, 201, 36.95.
65 Kraft et al. 2007, 121-149.
66 Pliny, NH 2, 201, 36.95.
67 Schaber 1982, 19.

the west coast of Asia Minor had begun to build massive temples on a scale never before attempted in their major religious centres. The construction of Artemision started at the mouth of the Kraistos River between 550 and 540 BC. The sediments carried by the river, the swamp and the alluvial landscape formed due to frequent floods created technical problems that seemed impossible for engineers and architects in ancient times. Until then, foundation-laying methods were based on solid foundations that were constantly under the load-bearing elements (columns and walls). However, for the first time, a vast stone platform was built here, 112 m long, 57 m wide and approximately 1.15 m thick[68]. Accordingly, hundreds of tons of load on the temple superstructure are evenly placed on the foundations.

According to researchers, during the excavations, the 0.10-0.20 m thick clay layer mentioned by Pliny was discovered under the temple foundations[69]. This layer was spread evenly on the base and levelled. Ash and charcoal were detected at the bottom. Both clay and charcoal were chosen as waterproofing layers. It is noteworthy that the foundations are made of materials that are effective in preventing water ingress and also have shock absorbing properties. It is known from the statement of Diogenes Laertius (Lives II.103) that this feature of coal was well known in this period. The construction of the Heraion temple, whose chief architect was Theodoros, started a few years before Artemision (560-550 BC). Theodoros, who was also known in Ionia, probably suggested that this practice be carried out in Artemision.

Aside from the fact that Artemis of Ephesus was depicted with a mural crown on her head to protect the city in difficult times[70] and the relevant gods were worshipped to protect the ground and foundations against earthquakes[71], as in the improvements in the Roman Age prytaneion building[72], the Ionians knew that they had to deal with problems in a region where earthquakes were frequent[73]. However, they still built the temple in both the Archaic and Hellenistic phases in the same place rather than on a more solid ground. The reason for this is either religious or, as Pliny[74] stated, ground knowledge. Of course, Greek philosophers tried to

68 Bammer 1984; Bammer – Muss 1996; Carpani 2014, 7-8.
69 Hogarth 1908.
70 Rogers 2012, 6-7.
71 Rogers 2012, 237-238.
72 These so-called "Themelioi" gods may have helped guarantee the strength of the ground and building foundations against earthquakes. Rogers 2012, 305-306.
73 Perhaps in these difficult situations, they were pursuing beneficial knowledge rather than the gods. Such an approach to disasters like earthquakes or events that put society in trouble was not due to the lack of religiosity of the ancient people. On the contrary, it seems that the piety and pragmatic attitudes of the Ephesians and Ionians were a result of the general conditions of the harsh world in which the Ephesians operated. The Greeks and Romans had no choice but to resort to practical and beneficial action as their world was plagued by wars, droughts, earthquakes and plagues. For example, according to recent research, most people in imperial cemeteries around Rome died between the ages of twenty and forty, and very few people reached what we now consider middle age. see Catalano et al. 2001; Dysson 2010.
74 Pliny, NH 2.201, 36.95.

understand earthquakes[75] and interpreted them differently[76], the most interesting of which is that earthquakes are seen to be associated with large underground caves. Still, they must have seen the sedimentary layers as a precaution against the destruction caused by the earthquakes caused by underground forces. Despite this, we can discuss the foundation arrangement related to waterproofing rather than seismic problems. However, in the basic structure of the temple, clay is a solution, but wool alone is not the solution; it can perhaps be considered a binder. Thus, it is understood that the Ephesus Artemision was designed to float on muddy alluvial ground. However, some researchers argue that this idea is wrong[77].

In Samos, an Ionian colony, the Temple of Hera (Fig. 14) attracts attention with its enormous dimensions and by being built on swampy ground, like the Ephesus-Artemision. Geotechnical problems arose from the marshy ground here, too. Construction of the first major dipteral temple began around 575 BC under the direction of the Samian architects Rhoikos and Theodoros and was probably completed in 550 BC. As mentioned before, Theodoros further suggested placing a coal layer under the Artemision of Ephesus foundations. For this reason, he became famous as a genius of his time and went down in history as an 'expert in fundamentals'. However, shortly after the temple was completed, it was realized that its foundations were inadequate[78]. This is mainly due to the weight of the 12 m high columns and the roof standing on them, which creates severe pressure on the soil[79]. In the end, this pressure exceeds the carrying capacity of the soil by two times. Therefore, around 540-530 BC, the temple was dismantled and built approximately 40 m further west. This second dipteros, of even larger dimensions, was never finished, but the effort made in the foundations to increase the strength of the structure is remarkable. Here, the solid stone foundations consist of limestone slabs with a total height of 2.50 m and a width of 4 m at the bottom. This foundation rests on a 20 cm layer of gravel covering a 1 m deep trench filled with pure white sea sand (Fig. 14).

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75 Early historical records provide information on earthquakes dating back to 2000 BC. However, most of this information is of little value to modern seismologists. There are often exaggerated narratives about earthquakes. Some even attribute it to supernatural powers. However, some of the ancient philosophers such as Thucydides, Aristotle, Strabo, Seneca, Livius and Pliny, tried to express the natural causes of earthquakes within the earth by going beyond mythological narratives. In fact, Aristotle (ca. 340 BC) divided earthquakes into six types according to the nature of the place.

76 Ammianus Marcellinus, 17.7.9; See also Guidoboni 1982, 42-53.

77 Karwiese argues that the temple burned down after being struck by lightning. Karwiese 1991, 87-95; Karwiese 1995, 57-59; Herostratos was held responsible for the "crime" so that he would not be held responsible for Artemis' failure to protect her home. Knibbe proposes a different theory: The temple was demolished on the orders of the temple itself. Realizing that the old temple was sinking, the administration itself said that there was soft sand under its foundations and that a new temple should be built. "Angry" Herostratos was the fall man of the temple administration. Knibbe 1998, 88–89.

78 Kienast 1998, 111-131.

79 Kienast 1991, 125; Kienast 1998, 124-126.

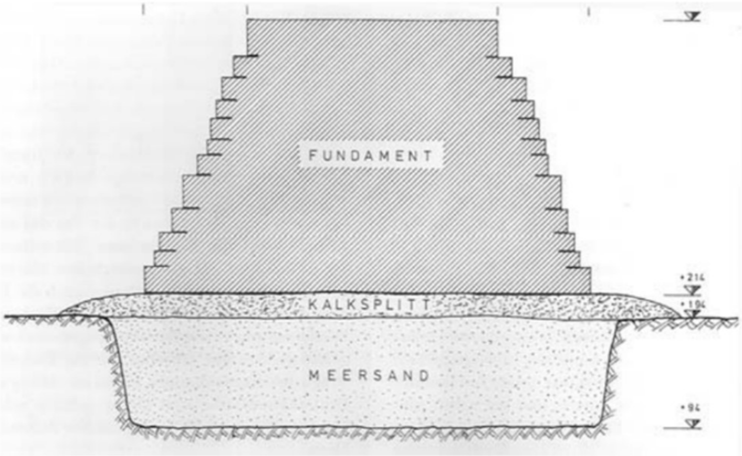

Fig. 14. Sand foundations of the Temple of Hera (phase III) in Samos. Schematic drawing (Kienast 2001).

Fig. 15. Black sand under the temple foundations of the Ptolemaic-Roman Period at Tell Timai (Bennett 2019, Fig. 4).

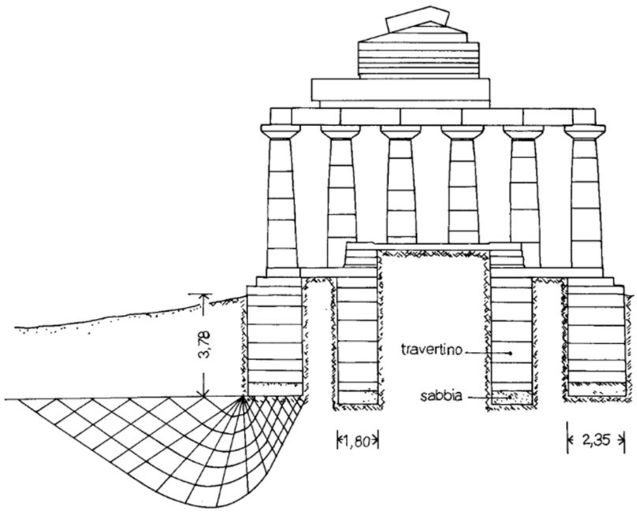

Fig. 16. Paestum Athenaion. Sand bed under foundations. (T. S. Pescatore–C. Viggiani 1991, Fig. 12).

Apart from the cults, another influence of Egypt on the architecture of Samos, along with dimensions and units of measurement, is the use of technically imported sand in the foundations. However, in Egypt, using sand in foundations was not only a construction method but also had cultic meaning. This idea is an essential element among the founding rituals in Egyptian architecture. It is unknown whether the foundation's failure in Samos was due to a gradual collapse process or a sudden disaster and possible seismic reasons. As a result, it is understood that the various materials such as clay and sand under the foundations of the temples of Samos and Ephesus did not come with alluvial floods, but were the result of a conscious application. Because the tradition of placing votive materials on the foundations, seen in Egypt, is also seen in Sardis, apart from Samos and Ephesus[80]. An extraordinary example of coal use in Sardis and the region can be seen above the ceiling of the Alyattes tumulus[81]. This application should be directly related to insulation. However, as in Ephesus and Samos, the use of sand, coal and ash in the foundations has both a ritual[82] and practical function.

The Temple of Apollo in Naxos, the Temple of Apollo in Bassae[83], the Temple of Athena in Troy/Ilion and the Temple of Zeus in Olbia[84] can also be added to that

80 Butler 1925; Gruben 1961; Hanfmann-Frazer 1975.
81 Ratté 1993, 3.
82 Sinn 1985, 132; Furtwängler 1984, 100.
83 Cooper 1996, 7-11; Carpani 2017, 10.
84 Wasowicz 1975, 89, 102, Fig. 69.

list. The famous Bassae Temple of Apollo (Fig. 17) was built in a remote area from the Arkadia mountains (today's northeastern Messenia) at an altitude of 1,130 m above sea level. It was built in the middle of the 5th century BC. The temple structure largely survives not only because of the location but despite the seismicity of the site. The temple's structural integrity testifies to its builders' ability to design and build an earthquake-resistant structure. Additionally, the temple is located on a hill, with poor, sloping ground, characterized by significantly weakened folded rock with low beds. The foundations were built with a mixed system of gravel soil held by retaining walls, with a mat foundation consisting of thick layers of limestone slabs and rock. This layer isolates the walls from the bedrock. The spread foundations of the columns were placed in this mass. Ancient builders placed a layer of soil of various thicknesses and densities between the *euthynteria* and the bedrock[85]. A clay layer was also found on the bedrock; in some places, the cracks on the bedrock were filled with the same clay. In fact, it caused the clay structure to deteriorate. According to the archaeological report, the successful survival of the temple is due to the quality of its foundations, which provide optimum pressure distribution, good drainage and a seismic foundation isolation design.

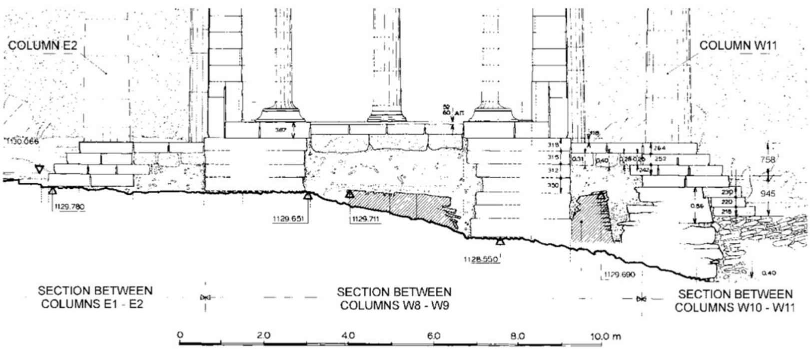

Fig. 17. Bassae Temple of Apollo Temple of Epikourios, section of the filling under euthynteria. (Papadopoulous 2010, Fig. 2).

Another example is the foundations of the temple of Athena in the city of Troy/Ilion, which had an antiseismic design on its walls in the Bronze Age[86] (Fig. 18). The foundations of the Hellenistic temple, situated at the top of the Troy mound, were built on a sand bed. Its construction started in the mid-3rd century BC. Since mounds like Troy are artificial hills, it is challenging to reach the natural solid ground; more precisely, it is not possible to reach until the bedrock. For this reason, ancient engineers, architects and builders built the temple on 5.40 m high massive

85 Papadoupoulos 2010, 248-251; Figs. 2,17-18.
86 Dörpfeld 1902.

foundations resting on a 3.70 m high sand bed. In this context, it can be said that there was a constant awareness in the city of Troy about loosening the bond between ground and structure from the Bronze Age to the Hellenistic Period.

A great example of developing technical innovation or technical skill and capacity can also be seen in the Greek colonies on the northern coast of the Black Sea. In particular, the excavations carried out in the ancient settlement of Olbia in today's Ukraine provide one of the most beautiful evidence of an imposing and original foundation application, the temple of Zeus. The city was founded by colonists from the Ionian city of Miletus at the end of the 7th century BC. While stone beds are not seen as frequent geological formations in and around this settlement, with unique geological features, clayey and loess soil beds are commonly attested[87]. Loess is known for turning into very fertile soil (it probably influenced the site selection of the city). Still, it is also the main reason for a very problematic foundation structure. Its most significant feature is that it causes crashes. Therefore, to increase durability, the place where the foundations will be built should not be saturated with water or should be kept away from moisture.

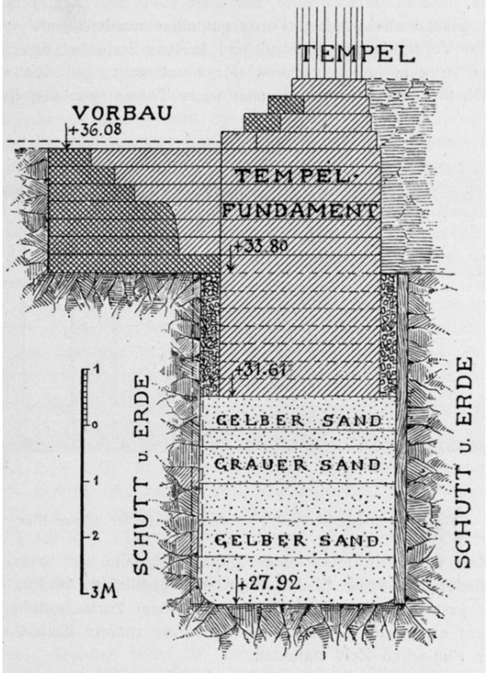

Fig. 18. Ilion Temple of Athena foundation, detail. Sand layers under foundations (Dörpfeld 1902, Fig. 85).

[87] Wasowicz 1975, 25-26; Carpani 2014, 11-12.

In this geography, very skilful mitigating measures were taken to balance the moisture content, or rather to increase the structural durability of the foundations, and a new method for building foundations was developed starting from the early 4th century BC. This is the use of soil layers moistened with water, mixed with ash, and compacted[88]. Ash and coal were turned into a solid block, which, in the end, formed a waterproof coating. A continuous drainage system is also provided in the foundations. All structures in the city, such as temples, agora, walls, etc., were built on this foundation arrangement, which proved extraordinarily strong. This man-made base was often used in cases where the construction was planned on weak soils.

One of the examples of earthquake-resistant foundations is found in Pontikapea, another Black Sea Greek colonial city[89] founded in the 6th century BC. As has been stated previously, much attention was paid to the foundation by the builders of ancient times. In the city of Pontikapea, when building foundation structures, builders encountered complex ground conditions. They had to erect buildings on hill slopes formed by layered sandstone rocks that easily gave way to settling and slides. First, a row of gravel sand was laid. The rectangular-shaped limestones of the first row, placed along the edge, were fitted together precisely. The second row, consisting entirely of similar rectangles, was placed on top of the first row, but this time flat on the bed. The third and fourth rows of stone blocks were laid on a layer of small stones. Small stones in the joints between the blocks help the foundation blocks to share the monolithic load and ensure that the blocks slide relative to each other in the event of an earthquake, which reduces earthquake loads.

A different application in the same geography was used in Chokrak[90] (Fig. 20). In this town, on the shores of a bay of the Sea of Azov, the foundations of a large building that may have been a temple were excavated. The ruins of this structure indicate that, according to historical data, a severe earthquake occurred in this region in the 3rd century BC. First, a thick layer of sand was placed, and then medium-sized natural stones were laid, followed by foundation blocks on a flattened minor stone backfill. The purpose of such a structure is to distribute the load evenly and reduce the effects of earthquakes.

88 Wasowicz 1975, .89, 102, Figs. 69-70.
89 Noonan 1973, 77-81.
90 Barbat – Bozzo 1997, 155.

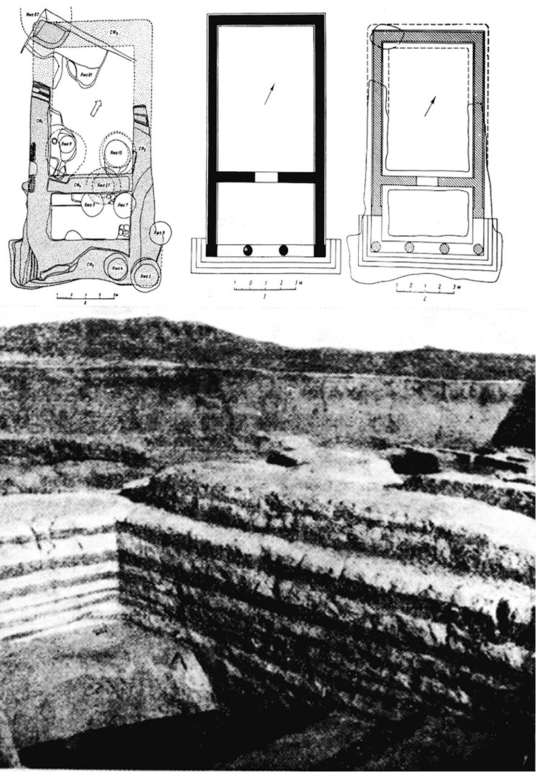

Fig. 19. Plan and foundations of the Temple of Zeus in Olbia (Wasowicz 1975, Figs.67-69; Carpani 2014, Fig. 20).

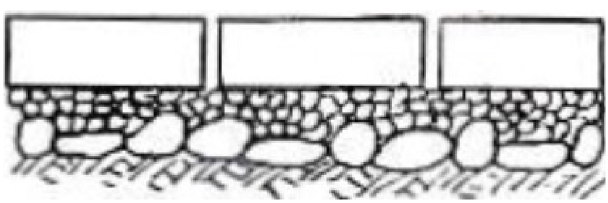

Fig. 20. Seismic insulation and foundation blocks from Chokrak (Kirikov 1992, Fig. 26).

As a result, there is clear archaeological evidence that different geographies such as the Middle East, Italy-Sicily, the Aegean and the Black Sea and the ancient cultures that prevailed in these regions developed an awareness of the problems arising from ground movements and the risks associated with them. Almost all of this evidence was obtained from archaeological excavation sites, and some of it was obtained from ancient texts.

To sum up, ancient Greeks implemented various structural improvements to build earthquake-resistant structures, especially temples. They used only beam-column designs, which represent an earthquake-resistant development. Most of the temples have rectangular or round, symmetrical mass arrangements in accordance with their geometric symmetry. There are seismic stability zones at the lower and upper elevations. The base binding is made in the form of a stylobate consisting of large blocks of hard stone connected with metal fasteners. The columns are directly supported by the stylobate, the upper floor of the three-step krepidoma. In the upper section, the binding is made in the form of double beams connected by clamps extending from column to column, known as architraves. Another earthquake-resistant development is that its entire structure consists of stone blocks fitted together precisely and attached with metal clamps and dowels fixed in place with lead. The contacting surfaces of the blocks are fully finished to provide greater friction. Connecting the blocks in this way increases the strength of the entire wall, preventing local stress concentration and, therefore, damage. In contrast, the increased friction between the blocks reduces the shaking amplitude of the entire building. In addition, the most remarkable earthquake-resistant measures are the comprehensive compression of ground beds and foundations made in the form of separate foundation elements under vertical load-bearers.

The Eastern Mediterranean was under Greek influence or in contact with Greece from the 4th century BC, and Asia Minor from the 8th century BC. However, Asia Minor combined Greek art with Persian, Parthian and Sasanian influences, bringing it to a further stage. One of the predecessors of this unity is the Halicarnassus Mausoleum. In terms of its arrangement, it is very similar to the tomb of the Persian king Cyrus the Great (built in the 6th century BC). Cyrus, referred to in the Bible[91], says in his decree regarding God's Temple in Jerusalem: "Let the foundation be laid for the reconstruction of this temple for sacrifice. Lay three rows of large stones and one row of beams. Let its height and width be sixty cubits (about 27 meters). "Let the expenses be covered by the palace."[92]. A foundation similar to the one described in the orders given for the temple is also found in the tomb of Cyrus[93].

For the stability of the tomb, a small rectangular (in plan) burial chamber was raised on a six-stepped pedestal platform. All elements of this burial vault are made of large limestone blocks. The pyramid-like base, consisting of steps decreasing in area with height, has made this tomb resistant to all earthquakes for more than 2500 years. In other words, Cyrus's tomb meets all the earthquake-resistant cons-

91 Isaiah 45.1.
92 Ezra 5.6.
93 Motamedmanesh 2021, .9-16.

truction principles. These are the principles of strict symmetry, low centre of gravity, appropriate dimensions, and a total height not exceeding 11 meters, except perhaps for weight reduction. More precisely, this tomb also copied the ancient Iranian temple architecture[94] (Fig. 21).

The Halicarnassus Mausoleum did not meet seismic resistance principles. First, it is known as one of the Seven Wonders of the World, not only because of its fanciful architecture but also because of its size. Secondly, the main reason is that the peripteral fragile colonnades and cella walls could not support the high pyramid-like body of the ceiling, and the structure was too heavy. As a result, earthquake-induced loads and their effects overloaded the foundation and deep foundation. According to archaeological research, the monument was destroyed by an earthquake. As seen in these examples, everything is vital to complying with earthquake resistance principles. As a result, Persian written sources show that similar to Greek and Roman thought, the royal architects were also seeking healing technical information, even though they saw the source of the earthquakes that caused destruction differently. Examples from Northern Iran[95], where wood was used in foundations, also prove that this awareness was formed in the early period.

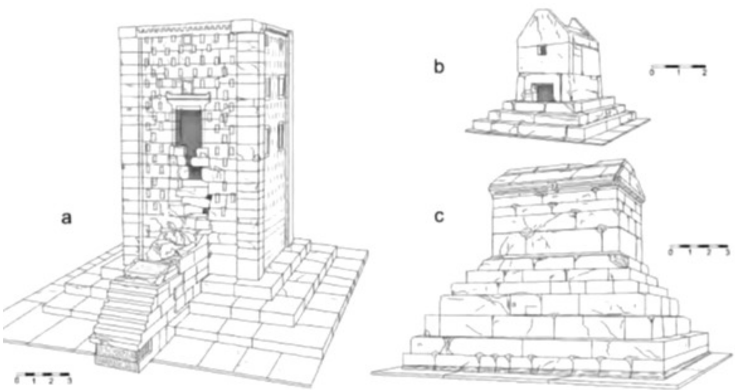

Fig. 21. Achaemenid structures sitting on a stepped podium: a. Pasargade, b. Bozpar, c. Kyrus' tomb (Motamedmanesh 2021, Fig. 2).

Diodorus of Sicily give another, more interesting preemptive example of these ancient sources[96]. According to him, Alexander the Great's magnificent hearse used a suspension system that did the job of the shock absorber system (actually not fully understood, but cleverly placed). Thanks to this system, the funeral-ceremony chariot, the work of Arrhidaeus, could travel through rough places without being affected by shocks.

94 According to J.Boardman, Cyrus's tomb is of Lydian-Ionian origin in terms of architecture. Boardman 2000, 53-60.

95 Nazidizaji et al. 2014, 63-82.

96 History 18-27.3-4.

The ancient buildings located in the old city centre of Istanbul and still standing today reveal the existence of some engineering concepts that have been adapted to their structures from the past to the present. Apart from monuments such as Hagia Sophia, located in earthquake-prone regions such as Istanbul, the Theodosius and Örmetaş obelisks (Fig. 22) are different examples of these concepts and applications[97]. Both monuments show the existence of seismic methods used in the past and that they have damping properties by transmitting earthquake forces through isolation levels. The stone layers under the Örmetaş monument have such a mechanism. As stated before, this system was applied to the tomb structure of the Persian King Cyrus the Great in the 6th century BC. The Örmetaş monument is placed on a marble base superimposed on three layers of orthostat stone. These three layers of stone served to absorb the earthquake waves that intensify at the first moment and cause less movement to be transmitted to the superstructure. There are many examples using the three-step arrangement, primarily in ancient Greek peripteral temples, which were structures with tall columns. The reason behind the widespread use of three-layered stones can be explained by their durability even after many centuries and various earthquakes. Therefore, it is emphasized that such foundations are the key to earthquake protection. In this layered system, the earthquake waves approaching the structure are first partially damped between the three-layered mortarless stones and later changed direction, preventing the earthquake's shock transitions direct effects.

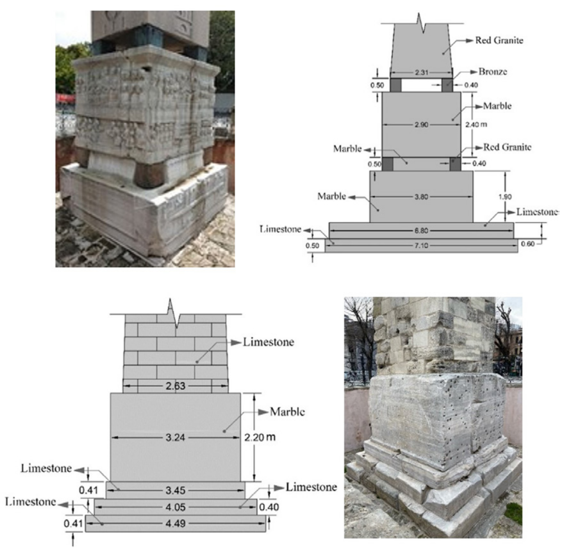

Fig. 22. Istanbul Obelisks. Upper: Theodosius Obelisk, bottom: Knitted Obelisk (Hoseyni et al. 2005, Figs. 2-4.).

[97] Hoseyni et al. 2022, 1-32; Bayraktar et al. 2012, 1-9.

The main idea in all the examples is to perfectly anchor the foundations of the structures that will shake with the ground in an earthquake. It can easily be seen that such an effort existed in ancient times. However, from time to time, they tried not to fix the structures to the foundation, but generally, they did the opposite.

In short, the need to build monumental structures on unfavourable foundation grounds is seen in every period. However, even if they fail, they have contributed to the development of ingenious applications that demonstrate both a good understanding of the foundations against geotectonic movements and the capacity for innovation. What's even better is that many of the techniques and regulations practised and described in antiquity are consistent with today's know-how. For example, soil improvement techniques to control moisture content in the construction base and improve the bed capacity of soil and foundation materials are widely used today. Among these, laying sand or clay bedding and artificial layers under the foundations is reminiscent of foundation isolation, also seen in modern anti-seismic techniques. These are activities to improve the earthquake performance of buildings. Thus, it confirms the robustness of many of the old methods described above, such as using pure sand layers and clay in the substructure, such as friction foundation insulation or soil liquefaction foundation insulation. In fact, not only the sand layer under the foundation but also the hydraulic insulation made to protect the walls from water and moisture is a seismic reinforcement. For this reason, a coating or a small drain is used to prevent water from entering under the wall and into the soil floor and filling the foundation. Although these interventions and applications may seem like small building elements, they play a significant role in a building's resistance to earthquake loads. In this sense, the earthquake resistance problem was solved by a series of structural techniques along with other multi-purpose measures. For example, a layer of sand placed under the foundation as a cushion can absorb earthquake shocks and additionally help to remove water from the structure.

Another problem is that the stronger and more solid the bond between the building and the shaking ground, the higher the earthquake loads occur in the building because the shaking is transmitted from the ground to the building more strongly. So, what will be the result of reducing these loads by weakening the bond between the ground and the building? For this purpose, various earthquake protection elements, such as sand layers and clay pillows, are used. This approach existed in ancient times and is actively used in many countries today, as it makes it possible to build affordable, effective and reliable earthquake-resistant structures. Perhaps it would be correct to call this current a passive earthquake protection system. This practice is the oldest method of protecting buildings from earthquakes. However, the Romans, who ruled the entire Mediterranean region, took the construction of buildings to a further stage with a building material of their own invention, a material that we call mortar (*Opus caementicium*).

CONCLUSION

From the Bronze Age until the Roman Period, it is seen that ancient engineers, architects, and builders first took into consideration the ground of the buildings and placed wood, sand, gravel or clay between the ground and foundations. Anatolian settlements provide sufficient examples of these practices. Similar foundation systems are seen in the Beycesultan and Acemhöyük palaces. In these examples, wooden logs were preferred in the foundations and between the ground and the foundation. The foundation timbers and the thick walls were designed and implemented to prevent tremors. Likewise, the presence of a thick layer of sand under the foundations of buildings in Egypt and Mesopotamia can be clearly stated in connection with a religious ritual. In Greek foundation engineering, numerous examples show some of the technical solutions used to confront geotectonic problems. Among these, the Artemision in Ephesus, one of the monumental archaic (6th century BC) temples on the western side of Anatolia and one of the Seven Wonders of the ancient world, and the Heraion in Samos, built in the same period, rest on ditches filled with clean sand. According to Pliny the Elder (NH. 36.95), who refers to an antiseismic solution, he states that the temple was built on marshy ground to protect it from earthquakes, and layers of coal and wool fleece were laid under the foundations to cope with the adverse conditions of the soft ground. Excavations have shown that a large foundation stone platform "floats" on a layer of clay mixed with coal. In other Greek temples, Paestum, a layer of sand was laid between the bedrock of the temple of Athena and its massive stone foundations. At Bassae, a different approach was used for the temple of Apollo, where a type of mat foundation consisting of thick limestone slabs and gravelly soil separated the platform from the bedrock. One of the most interesting examples of Greek temples comes from Olbia, a Greek colony on the northern coast of the Black Sea, produced with an exceptional technique. Local materials were used here in the temple of Zeus and other buildings dating back to the 4th century BC. Here, a new foundation-laying method was developed, consisting of layers of loess wetted and compressed alternately with ash and charcoal. A better example is the temple of Athena in Ilion, built on a 3.70 m high sand bed.

As a result, it is understood that the idea of loosening the bond between the ground and the structure and "separating the movement between the superstructure and the foundations" was known in ancient times. Although these technical solutions comply well with the basic principles of base insulation, this does not mean that early builders fully understood the potential antiseismic effectiveness of their techniques. Today, foundation insulation has been developed with a more innovative technology. However, it took over a century for this system to emerge as a mature and efficient technology, and it has not been implemented in many geographies. It can be accepted that the reason for this depends on the society's level of knowledge, priority needs, economic reasons, and technological and cultural development level. In fact, the cultural structure of the society and its ability to accept innovations is an issue that resists for various reasons depending on economic, political and social factors. However, the best approaches are either to import the latest technology or to benefit from your geography's proven traditional approach and construction experience. It should be known that earthquakes are the main reason that creates our geography, and others depend on this. With this awareness, the needs and studies for the development of antiseismic methods in a constantly moving piece of land need to be understood and accelerated at least as much as the people of ancient times.

Conflict of Interest

Within the scope of the study, there is no personal or financial conflict of interest between the authors.

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