Historical Aspects of Seismic Base Isolation Application

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AZADI GRAND HOTEL

Historical Structures

- Ancient historical structures have a very complex load carrying behavior due to the massive and continuous interaction of domes, vaults, arches and pillars.

- Typically, these structures are more massive than contemporary structures and that usually carry their actions primarily in compression.

- A better understanding of both gravity load transfer mechanism and lateral resisting system of such structures is the key issue for a comprehensive understanding of historical structures.

Historical Structures

- A great challenge in understanding the behavior of these structures is that major structures were designed not only for complex load carrying system, but also for architectural concepts and for enough light and proper acoustics.

- Foundation systems are the most critical components to ensure a long life for all historical structures. Without a proper foundation system, these structures can not survive for many centuries.

Historical Structures

- Ancient History
- Recent History

Application of Base Isolation Concept in Earthquake Resistant Construction of Historical Structures

Ancient History

- Construction on Multi-layer Cut Stones
- Pouring Sand or gravel under the Foundation

Application of Base Isolation Concept in Earthquake Resistant Construction of Historical Structures

Recent History

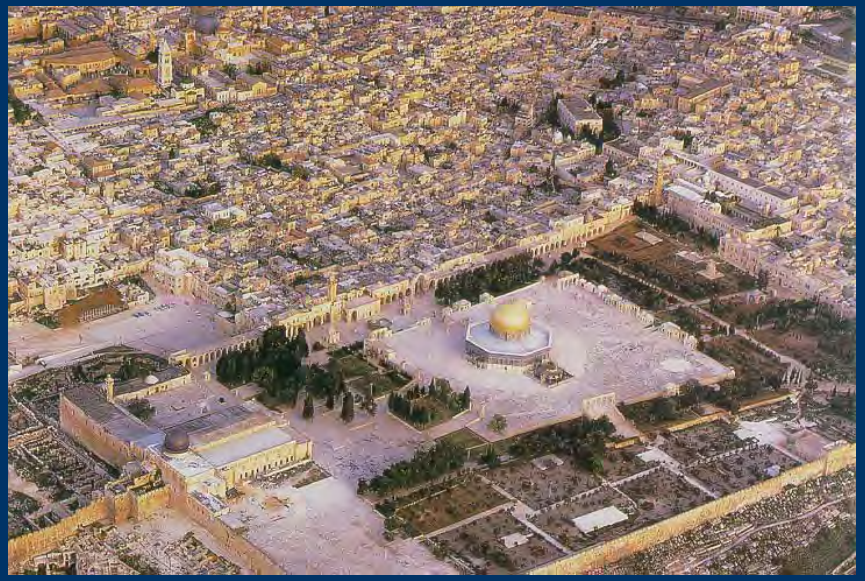
- Pouring Sand or Leaving a soft Layer under the Foundation
- Installing Pieces of Wood between the Ground and the Foundation

Aqsa Mosque

Sacred House (Jerusalem)

Ezra 6 of the Bible reads

"… 3 In the first year of King Cyrus, Cyrus the King issued a decree: *'Concerning* the house of God at Jerusalem, let the temple, the place where sacrifices are offered, be rebuilt and let its foundations be retained, its height being 60 cubits [about 27 meters] and its width 60 cubits; 4 with three layers of huge stones and one layer of timbers. And let the cost be paid from the royal treasury… 14 … And they finished building according to the command of the God … and the decree of Cyrus, Darius, and Artaxerxes [Ardeshir] king of Persia…"



Cyrus the Great Tomb

Pasargadae, southeast of Iran, built in 550 BC

- Several layers of smoothed stone without any mortar or sticky material between them actually form a kind of base isolation.


TURKEY
ARM.
AZER.
N Iran
Caspian Sea
TURKMENISTAN
Ashgabat
Tabriz
Orūmīyeh
Rasht
Qazvīn
Mashhad
SYR.
Tehran
Rey
IRAQ
Hamadān
Qom
Kermānshāh
35°
Baghdad
IRAN
AFG.
Eşfahān
Qomsheh
Yazd
Ahvāz
Ābādān
Kermān
Zāhedān
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PAK.
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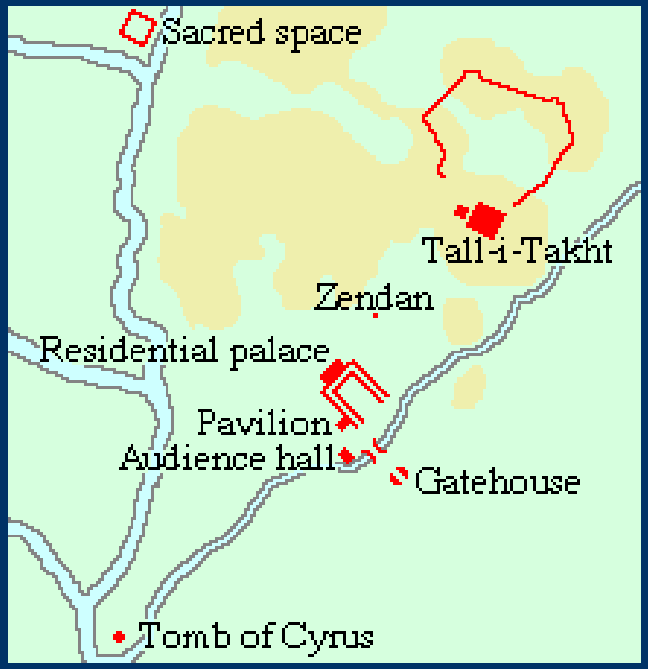
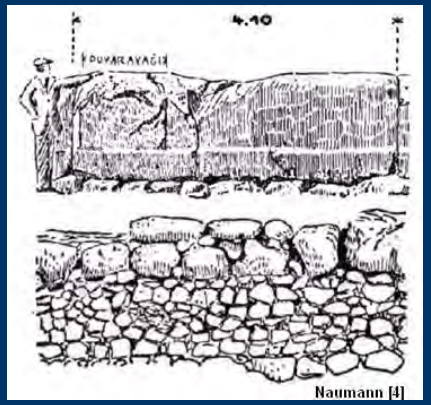

Sacred space
Tall-i-Takht
Zendan
Residential palace
Pavilion
Audience hall
Gatehouse
Tomb of Cyrus

Orthostat Stone Layers

- In earthquake prone areas, some flat small stones like pillow were laid to absorb the first shock of earthquake forces on the pre-prepared soil under foundations.

- Then, some big foundation stone layers were put over these small stones where normal construction of the walls was built.

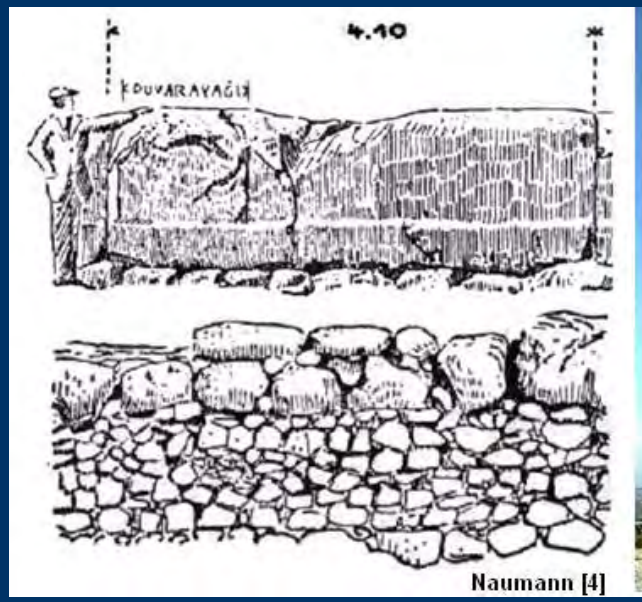


- The number of layers in most of the times was three and no mortar was used.

- These large foundation stones are called ‘Orthostat’ stones.

- Even though the stones are over each other without any mortar or sticky material, the mechanism is in such a manner that actually no sliding occur; or better say, they may slide a little but they come back to their original position following the earthquake.

- The fact is that we observe the structures still standing after many centuries without any movement of stones. If they had moved just a little, say less than even 1 cm in each strong earthquake, then, they should have moved tenth of centimeters during this long period.



Erechtheion Temple on the north side of the Acropolis of Athens in Greece (built between 421 and 407 BC).

Orthostat Stone Layers

Analytical investigations are being performed to verify why the stones remain standing in their original places. One of the reasons may be the upward component of earthquakes which has not been seriously taken into consideration up to now.

Foundation of Obelisks

An obelisk is a slender stone shaft with a pyramid-shaped top.

Obelisks on Hippodrome in Istanbul, Turkey:

- Ormetash (laid or woven stone)
- Dikilitash (vertical or standing stone)

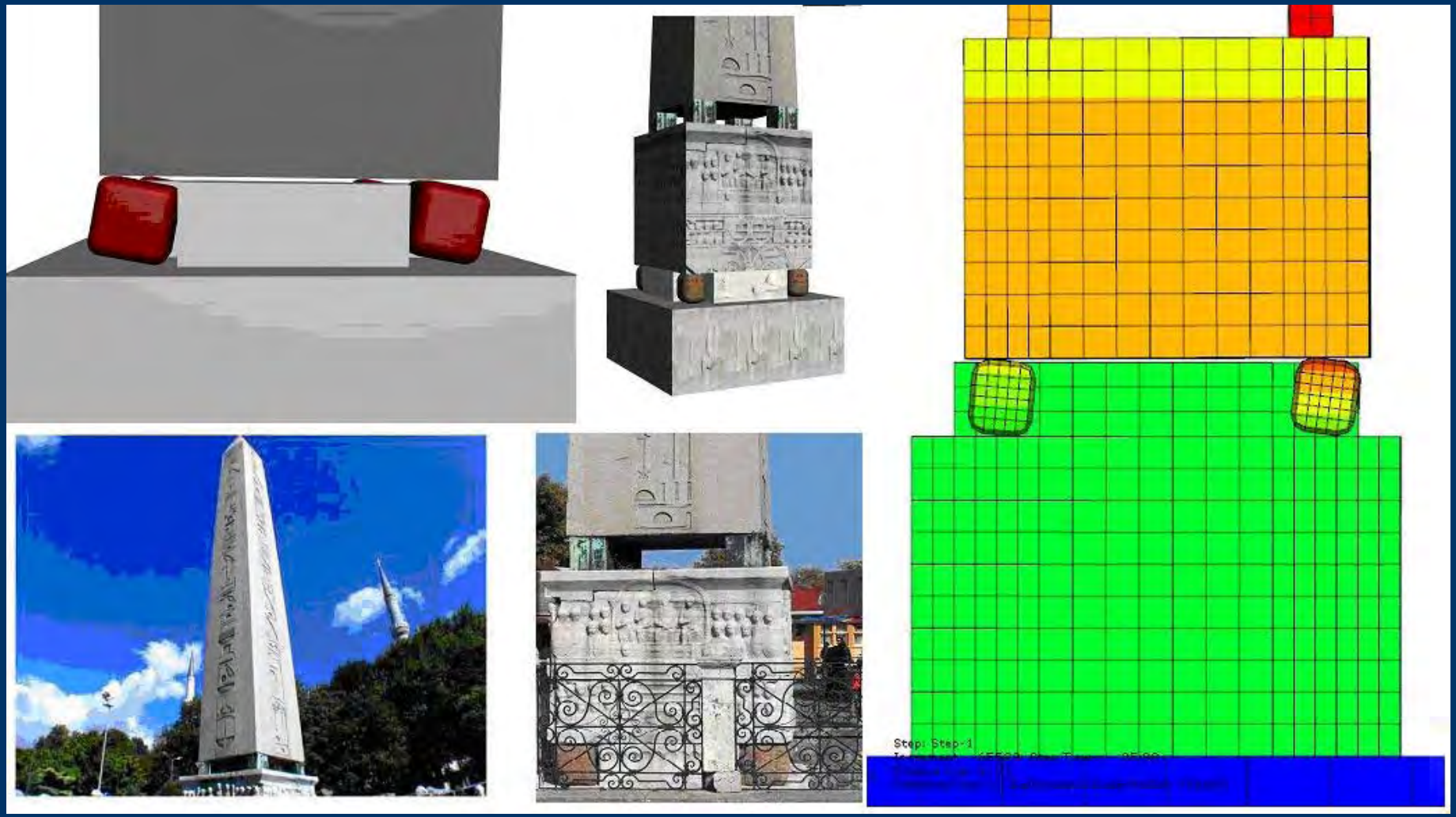
Ormetash

- A pier constructed of dry dressed stone of 32 meters (built in 4 AD)
- Placed on a marble base over three layers of orthostat stones

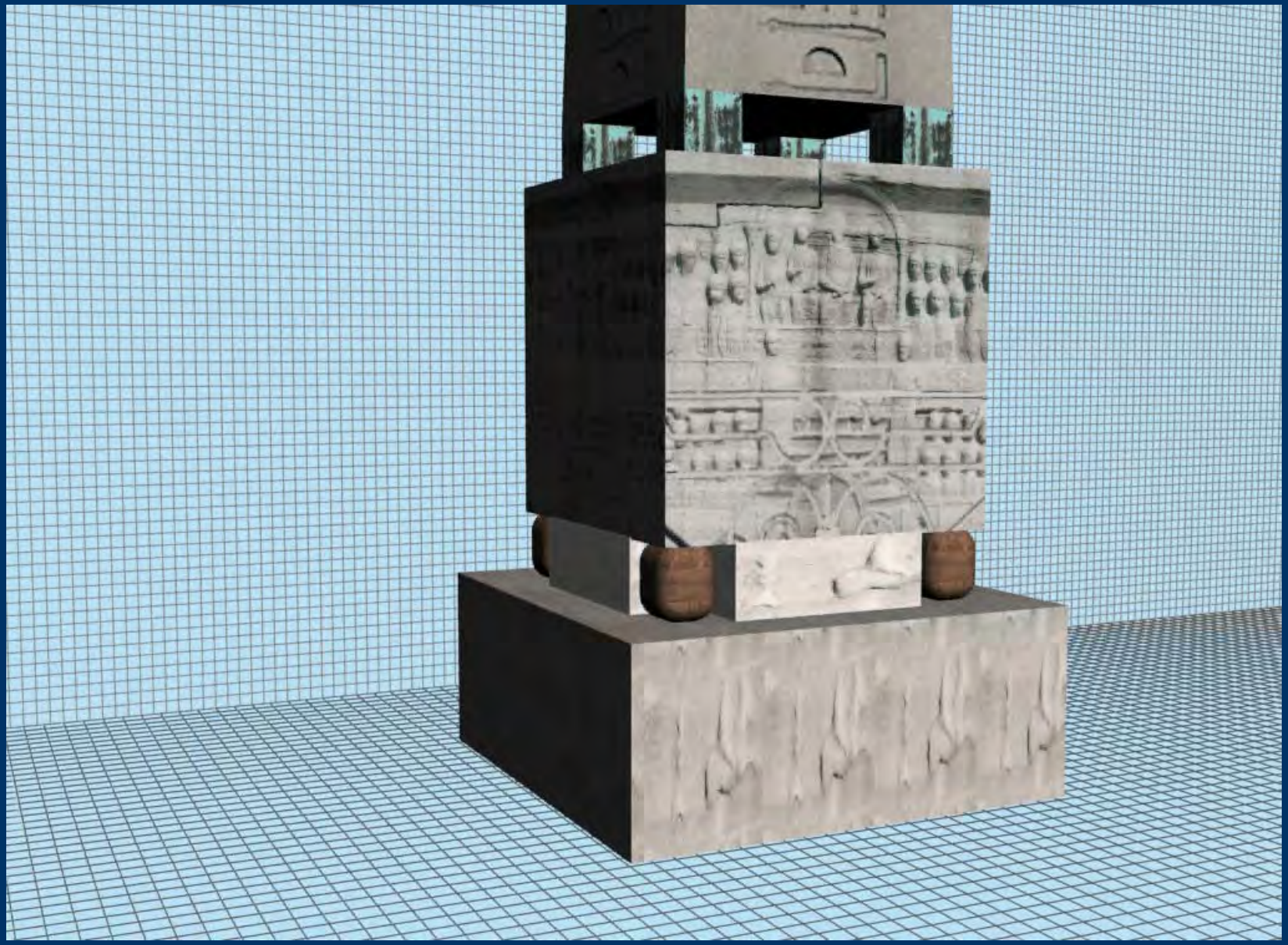
Dikilitash (Egyptian) Obelisk

- A block stone of 18.69 m high carved in Egypt in 1450 BC.
- Brought to Istanbul and erected during 379-395 AD.
- Placed on 4 square (50x50cm) bronze feet over a 3x3x3 meters cubic marble base that sits on marble orthostat stones.

Dikilitash (Egyptian) Obelisk



May collapse by an EQ with M>7.6 and 5 Km epicentral distance



Cleopatra’s Needle

New York

Paris

Recent History

Imperial Hotel

Tokyo, Built in 1921

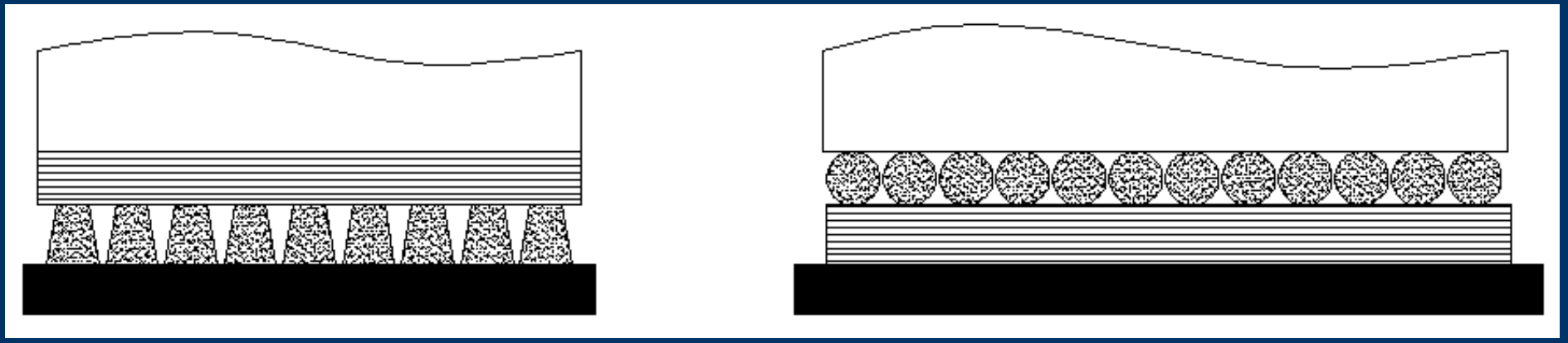
Founded on a shallow layer of firm Soil which in turn was supported by An underlying layer of mud.

Frank Lloyd Wright, 1977:

“merciful provision” of 60 to 70 feet (18 to 21 meters) of soft mud below the upper 8 foot (2.4 meters) thick surface soil layer which supported the building.

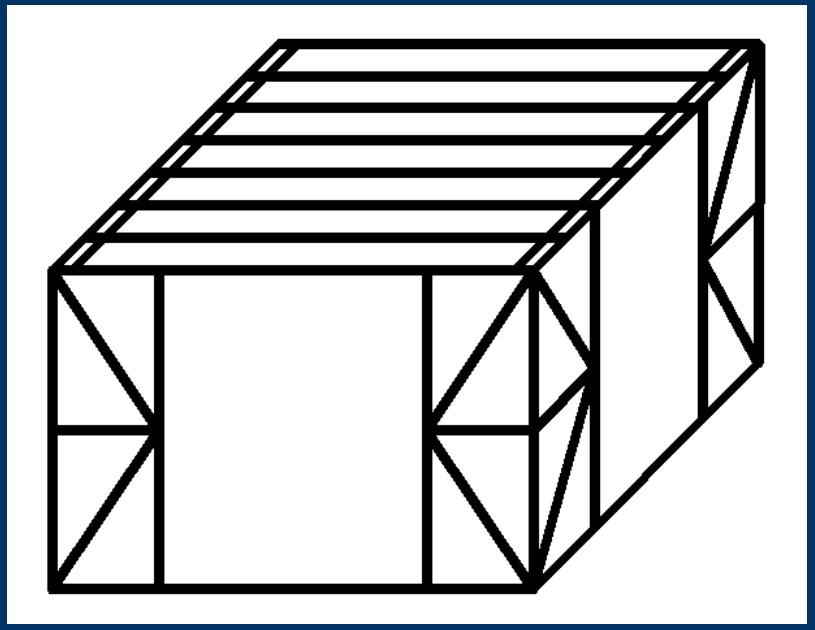
Masooleh, North of Iran

Masooleh



Two sides of a foundation constructed on layers of timber in many traditional buildings

Masooleh



Wooden tie beams and tie columns plus vert. and horiz. bracings at the corners provide an integrated structure.

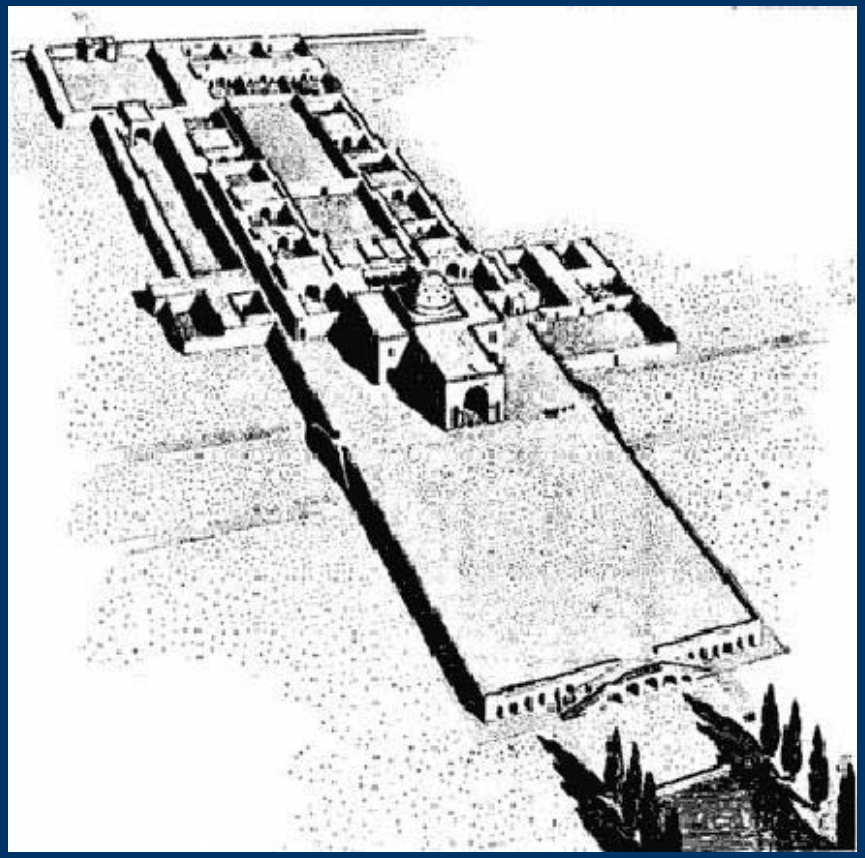
Lahijan, North of Iran

Use of pieces of woods between the ground and the foundation of traditional houses

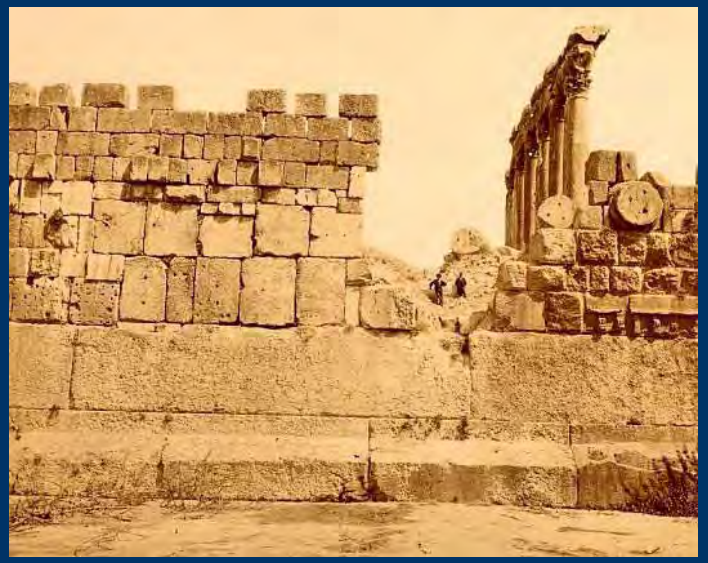
Medina (Algeria)

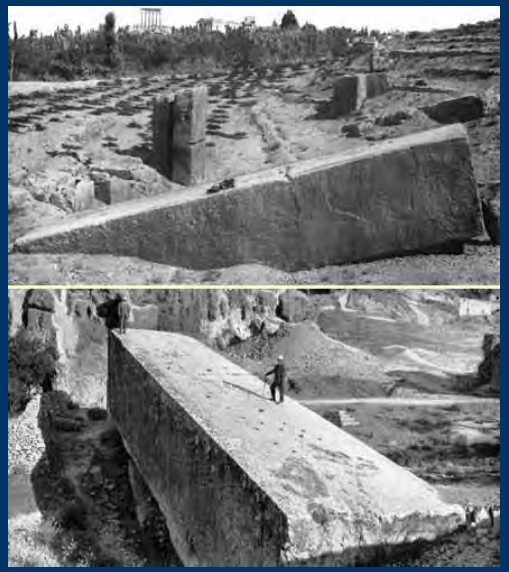
Khosro Castle (West of Iran)

built in 600 AD

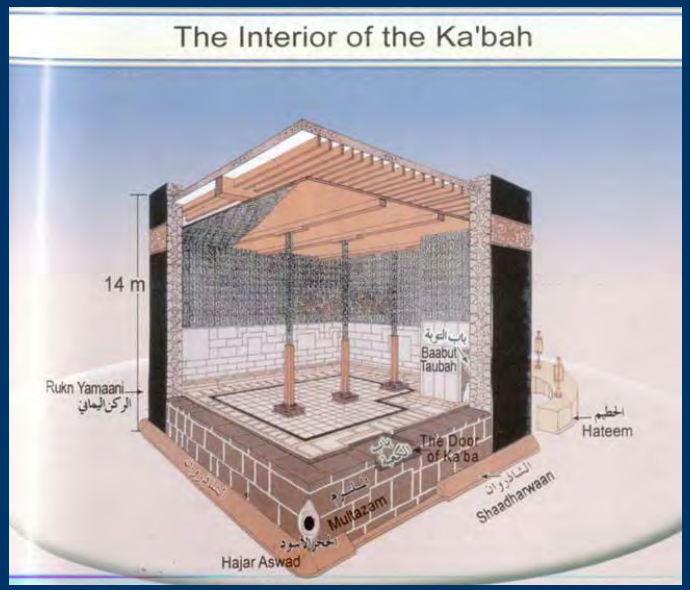


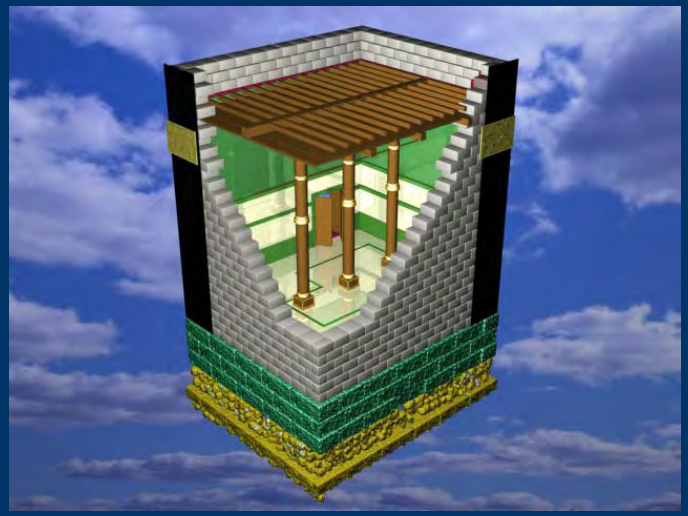
Baalbek (Lebanon), built in the first 300 AD





Ka’aba (Mecca, Saudi Arabia)

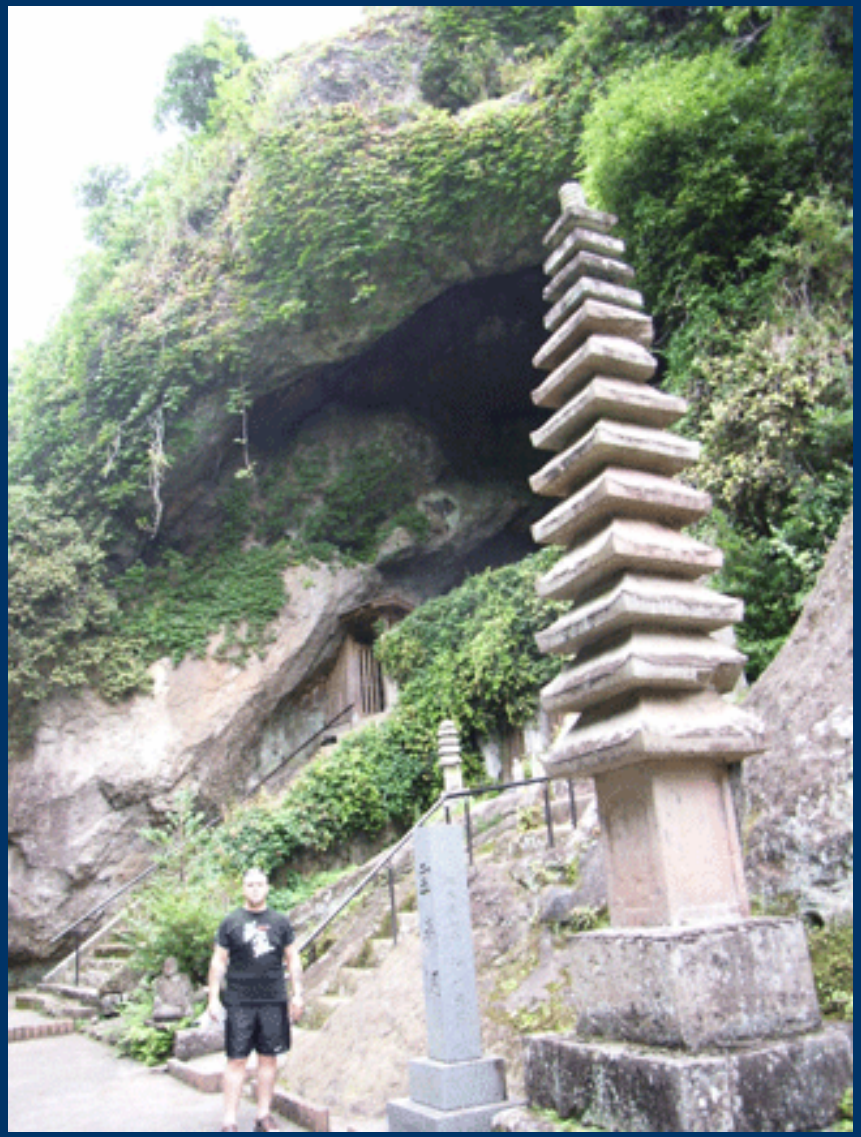




Anahita Temple (West of Iran)

Great Buddha (Kamakura, Japan)

Kumamoto, Japan



Conclusions

- earthquake engineering concepts have been applied since ancient times.
- Seismic base isolation was one of the concepts that was utilized for earthquake protection.
- Additional studies will unveil more details on this concept and other principles that our ancestors have applied to better cope with earthquakes and other natural hazards.
- If more analytical and experimental investigation proves the reliability and safety of the historical methods (e.g., Orthostad stone layers), can we use them today for some simple structures as an alternative to modern Base Isolators?