UNESCO Documentation and Advisory Services (UDAS) Project

Fourth Consultation Workshop for the Conservation Works of the Baalbak Jupiter Colonnade

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EXPERT REPORT

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Secretary-General, Iscarsah

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Introduction

Upon the creation of the Cultural and Heritage Urban Development (CHUD) project, works were proposed for Lebanese Historic cities and major archaeological sites. The BTAP Project, part of the CHUD, requested a preliminary study composed by ARS progetti in 2002. The project loan agreement for BTAP was finalized according to that preliminary study. Later, in 2010, the JV Planarch–BCD Progetti prepared further studies on which tender documents for the implementation of the works foreseen by the CHUD document were issued. Among the numerous interventions proposed is that which deals with the Jupiter Colonnade (belonging to the Baalbek Jupiter Temple). It is to be noted that the relevance of the Jupiter Colonnade as a major landmark of the Lebanese identity has been considered vital in its inclusion within the BTAP framework.

As with the rest of the monuments within the tender documents, a preliminary assessment (from the ground) was undertaken on the Jupiter Colonnade which led to the establishment of the tender dossier and the works proposals.

In 2017, the scaffolding was installed around the Jupiter Colonnade by the JV firm, Cooperativa Archeologia -Italian Costruzione-JV (CAIC). Testing, sampling and analysis of the material, on forms of degradation, and on the monument have been performed. The findings showed that the Jupiter Colonnade and its entablature are facing severe degradation problems resulting from the presence of steel inserted into the stone circa 1933 for consolidation purposes. This decay was observed during the design phase, yet its severity is more apparent upon close observation. Other pathologies, including microcracks, that could not be observed during the design phase have also been identified.

In February 2018, the Method Statement (MS) for the execution of works was prepared by CAIC, controlled by the Consulting firm, submitted to CDR/DGA and forwarded to three ICOMOS experts via UNESCO Beirut Office (Two experts in Historic Structural Conservation; Mr. Pierre Smars and Mr. Stephen Kelley and one expert in Surface conservation and archaeological management, Ms. Teresa Patricio. The objective of this particular UDAS workshop (UDAS-WS04) is to assist the DGA in addressing the issues of the Jupiter Colonnade, by organizing a four-day workshop in accordance to the following program:

DAY 1
Presentation to experts by 1- CDR PM: the general framework of the CHUD and BTAP project; 2- DGA: the Jupiter Colonnade issues from DGA point of view; 3- Consultant BCD progetti – Planarch JV: the studies and the suggested actions; and 4- Contractor Cooperativa Archeologia – Italiana Costruzione JV: The Method statement to implement the works with the available budget.

DAY 2
Site visit and review of the Jupiter Colonnade from the scaffolding in presence of the experts, DGA, and CDR, the consultant and the contractor staff.

DAY 3
Site visit and review of the Jupiter Colonnade actions and works as foreseen in the Method Statement in presence of the experts, DGA, CDR, the consultant and the contractor staff.

DAY 4
Feedback of the three experts on the materials presented and site visit.

Stephen J Kelley, Secretary-General of ISCARSAH, attended the UNESCO Documentation and Advisory Services (UDAS) 4th Consultation Workshop (UDAS - WS04) for the Conservation Works of the Baalbek Jupiter Colonnade held on 26 to 29 March 2018. The purpose of my participation was to review the structural aspects of the proposed project. My consultation was enhanced by written materials that were provided to me before and during the Workshop that provide historical context, information on past repairs, and diagnostic procedures and proposed treatments to the Jupiter Colonnade that are part of the present project.

Awesome in their size and mesmerizing in their richness of decoration, the ruins of Baalbek are Lebanon's premier attraction. The earliest evidence of settlement in Baalbek dates to at least to the end of the 3rd millennium BCE, and during the 1st millennium BCE a temple compound dedicated to the worship of Baal was established here. The principality was incorporated into the Empire of Alexander the Great and became part of the Seleucid Empire. However, it was during the Roman era that the magnificent temples of Baalbek were constructed.[1]

Baalbek World Heritage Site

From the UNESCO website we know the following about the importance of the Baalbek Sanctuary Complex as well as the Jupiter Colonnade. The complex of temples at Baalbek is located at the foot of the south-west slope of Anti-Lebanon, bordering the fertile plain of the Bekaa at an altitude of 1150 m at Latitude N34 0 25.45 and Longitude E36 12 17.78. It was inscribed on the World Heritage List in 1984. Its colossal constructions built over a period of more than two centuries, make it one of the most famous sanctuaries of the Roman world and a model of Imperial Roman architecture. Pilgrims thronged to the sanctuary to venerate the three deities, known under the name of the Romanized Triad of Heliopolis, an essentially Phoenician cult (Jupiter, Venus and Mercury).

The importance of this amalgam of ruins of the Greco-Roman period with even more ancient vestiges of Phoenician tradition, are based on its outstanding artistic and architectural value. The acropolis of Baalbek is comprised of several temples. The Roman construction was built on top of earlier ruins which were formed into a raised plaza, formed of twenty-four monoliths, the largest.

[1] ***Beirut*** by Jessica Lee, Footprints Handbooks LTD: Great Britain 2014

The Temple of Jupiter, principal temple of the Baalbek triad, was remarkable for its 20 m high columns that surrounded the cella, and the gigantic stones of its terrace. Baalbek became one of the most celebrated sanctuaries of the ancient world, progressively overlaid with colossal constructions which were built during more than two centuries. Its monumental ensemble is one of the most impressive testimonies of the Roman architecture of the imperial period.

Outstanding Universal Value

Baalbek is deemed to have Outstanding Universal Value for the following criteria:

Criterion (i): The archaeological site of Baalbek represents a religious complex of outstanding artistic value and its majestic monumental ensemble, with its exquisitely detailed stonework, is a unique artistic creation which reflects the amalgamation of Phoenician beliefs with the gods of the Greco-Roman pantheon through an amazing stylistic metamorphosis.

Criterion (iv): The monumental complex of Baalbek is an outstanding example of a Roman sanctuary and one of the most impressive testimonies to the Roman period at its apogee that displays to the full the power and wealth of the Roman Empire. It contains some of the largest Roman temples ever built, and they are among the best preserved. They reflect an extraordinary amalgamation of Roman architecture with local traditions of planning and layout.

Integrity

The serial nomination consists of the Temples of Jupiter, Bacchus, Venus and Mercury, and the Odeon - all the key attributes of the sanctuary. The entire town within the Arab walls, as well as the south-western quarter extra-muros between Boustan el Khan, the Roman works and the Mameluk mosque of

Ras-al-Ain, provides the essential context for the key attributes.

Authenticity

Despite extensive restoration in the 1960s and the 1980s, and the impact of armed conflict which brought unplanned development, the overall authenticity of the site has remained intact thanks to the efforts of national and international bodies. To safeguard the vestiges, the Directorate General of Antiquities (DGA) has carried out consolidation and restoration work on the various monuments, especially on the inside of the Qal'a site that comprises the Temples of Jupiter and Bacchus. Nevertheless, the authenticity of the property is highly vulnerable to changes that affect the detail of its structures and the overall majesty of its setting.

Protection and management requirements

Conservation and management of the property are ensured by the DGA which controls all construction and restoration permits. The Law on Antiquities No 166/1933 provides for several important protection measures for the ruins located within the protected area. Cooperation between the Directorate General for Urban Planning and the DGA facilitates expropriation concerning the land surrounding the archaeological area.

A protection and enhancement plan which is under preparation, aims at ensuring an improved presentation of these unique vestiges and the development of a new protection system for the site that respects international charts. Cooperation with specialists for the restoration of historical monuments is essential. The plan must also treat the question of improved coordination methods between the different bodies involved in the property.

Another master plan for the city, under consideration, is aimed at protecting the surrounds of the site and controlling urban development that threatens the archaeological site, the urban zone located within the Arab walls, as well as the south-west quarter (extra-muros) located between Boustan el Khan and the Roman quarry (Hajjar el Hubla).

Temple of Jupiter Technical History

Work on the Temple of Jupiter started around 60 BCE and was nearing completion toward the end of the reign of Emperor Nero in the 1st Century ACE.[2] The temple was already in use although the decorations were still being carved during a visit by Emperor Hadrian around 130 ACE.[3] The Jupiter Temple was erected on a massive substructure for a pre-Roman sanctuary. It is assumed that the Romans, being sophisticated with foundation systems, were comfortable with the foundations beneath the existing substructure.[4] Jupiter Temple measured approximately 95 m in length and 34 m in width. It was enclosed by 54 unfluted Corinthian columns - 10 columns at each end and 17 on each side.[5] Each column was composed of three enormous blocks placed on a base approximately 2.5 m high and was surmounted by a highly ornate Corinthian column with magnificent sculptured architraves, frieze and cornice.[6] The construction of perfectly cut stones and interconnected with metallic clamps and towels set in lead was not reliant upon mortar.[7]

Very little is known about the construction of the roof but would have been composed of wood trusswork.

In the 2nd Century A.C.E. a series of enlargements were initiated including the great court complex adjoining the Temple of Jupiter to the east, The Temple of Bacchus and the Temple of Venus. In the 3rd Century the hexagonal court and the Propylaea were constructed.[8] Refer to Figure 1.

Human Actions

As part of the adoption of Christianity as the religion of the Holy Roman Empire, Emperor Justinian (527-565) dismantled eight columns of the Temple of Jupiter to adorn the Hagia Sophia in Constantinople.[9] These are red porphyry columns and not from the exterior Colonnade.[10] Over the years, stones from the site were recycled into a Byzantine basilica that was constructed in the courtyard to the east (now completely gone).[11] See Figure 2.

Abu Ubaidah ibn al-Jarrah attacked Baalbek, still an opulent city at the time, after the Moslem capture of Damascus in A.D. 635. Stones from the site were utilized during the following period in the construction of an Arab fortress.[12] See Figure 3. Baalbek subsequently became a source of conflict between the various Syrian dynasties and the caliphs of Damascus and Egypt, and the city was sacked in 748. In 1090 Baalbek passed to the Seljuks and, in 1134, to Genghis Khan. It was captured by Saladin in 1175. In 1400 it was pillaged by Timurlane, and in 1517 it passed with the rest of Syria to Ottoman dominion.[13] Under Ottoman rule Baalbek fell into obscurity. During this stretch of time, earthquakes frequently occurred in that area, and these contributed more than human actions to the ruined condition of the monuments.

German explorer Martin von Baumgarten wrote the book ***Peregrinatio in Aegyptum, Arabiam, Palaestinam, & Syriam*** (1594) based

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[2] ***Beirut*** by Jessica Lee, Footprints Handbooks LTD: Great Britain 2014
[3] ***Beirut*** by Friedrich Ragette, Noyes Press: New Jersey (1980)
[4] Ibid.
[5] ***History of Baalbek*** by Michael M Alouf 16th edition, American Press: Beirut (1944)
[6] Ibid.
[7] ***Beirut*** by Friedrich Ragette, Noyes Press: New Jersey (1980)
[8] ***Beirut*** by Jessica Lee, Footprints Handbooks LTD: Great Britain 2014
[9] http://www.pheniciens.com/cites/baalbek.php?lang=en
[10] https://www.lessingimages.com/viewimage.asp?i=150309+6+&cr=4&cl=1
[11] http://www.pheniciens.com/cites/baalbek.php?lang=en
[12] Ibid.
[13] ***The Encyclopædia Britannica: A Dictionary of Arts, Sciences, Literature and General Information*** Volume 3 Cambridge University Press, 1910

upon his 1507 travels, and it was the first modern account of the ruins at Baalbek. However, the ruins were brought to European attention by Pierre Belon in 1555 during his travels in the Levant. The ruins were much damaged by the earthquake of 1759 and remained untouched until the beginning of the 20th century.[14]

In 1751, two English architects, Robert Wood and James Dawkins, visited Baalbek and their plans and drawings revealed to Europeans the magnificence of the ruins, Figure 4. According to Wood, Baalbek was at that time a small town with a population of 5,000 inhabitants.[15]

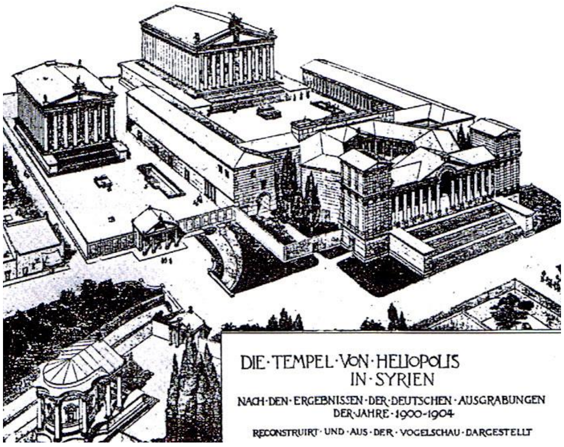

Figure 1 - *Reconstruction of the Baalbek sanctuary complex as envisioned by the researchers of the German Mission (B. Schulz). Aerial view from the southeast.*

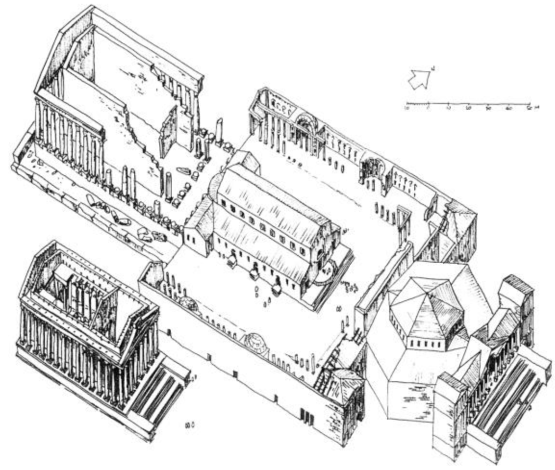

Figure 2 *- Reconstruction of the Baalbek sanctuary complex during the Byzantine Period (**Baalbek** by Friedrich Ragette (1980) Noyes Press). Aerial view from the southeast. Note the Christian basilica which was located in the courtyard.*

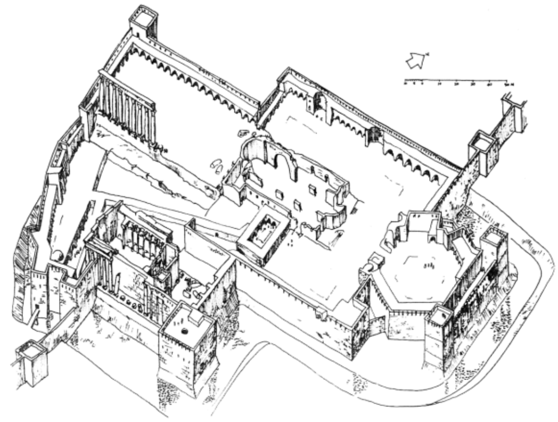

Figure 3 *– Reconstruction of the Baalbek sanctuary complex site during the Arab Islamic Period (**Baalbek** by Friedrich Ragette (1980) Noyes Press). Aerial view from the southeast. The temples and basilica are in ruins and the site has become a fortification.*

[14] Ibid.

[15] ***History of Baalbek*** by Michael M Alouf 16th edition, American Press: Beirut (1944)

Figure 4 – *Sketch of the Baalbek site as viewed from the west by Robert Wood, circa 1751. The Jupiter Colonnade is depicted with nine columns. Three of the columns, those to the west, collapsed during the 1759 earthquake as well is that portion of the stone lintel that they supported.*

Natural Disasters: Earthquakes

Earthquakes, such as those listed below damaged or destroyed many of the structures and temples of Baalbek and destruction was no doubt more severe than any of the human actions described above.

The Dead Sea Transform fault system is composed of multiple parallel faults that run 1,000 km from the northern end of the Red Sea along the Jordan Rift Valley to the Taurus Mountains complex in southern Turkey. The fault system forms the transform boundary between the African Plate to the west and the Arabian Plate to the east. Both plates are moving in a general north-northeast direction, but the Arabian Plate is moving faster, resulting in the observed left lateral motions along the fault.[16] The left-lateral fault zone has produced pull-apart basins that form the Dead Sea and the Sea of Galilee. The main strand of the fault system passing through Lebanon is the Yammouneh Fault, Figure 5, which is the source of many of the earthquakes in the region.

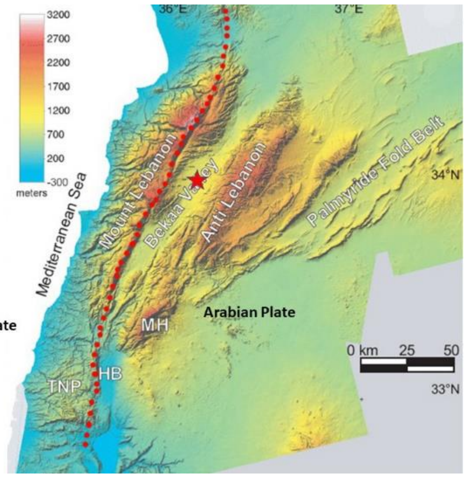

Figure 5 – Topographical map of Lebanon showing the location of the Yammouneh Fault (dotted red line) and the location of Baalbek (red Star) relative to the fault.

551 Beirut Earthquake

The 551 Beirut earthquake occurred on 9 July with an estimated magnitude of about 7.6 on the moment magnitude scale and a maximum felt intensity of X (*violent*) on the Mercalli intensity scale. It triggered a devastating tsunami which affected the coastal towns of Byzantine Phoenicia, causing great destruction and sinking many ships. There is little in the way of detailed descriptions of the damage caused by this earthquake in contemporary accounts. The earthquake was felt over a wide area from Alexandria in the southwest to Antioch in the north.[17]

1170 Syria Earthquake

The 1170 Syria earthquake occurred early in the morning of 29 June 1170. It formed part of a sequence of large earthquakes that propagated southwards starting with the 1138 Aleppo earthquake, continuing with the 1157 Hama, 1170 and 1202 Syria events. The estimated magnitude is 7.7 on the moment magnitude scale, with the maximum intensity of X (*extreme*) on the Mercalli intensity scale. Severe damage was widespread from Antioch

[16] https://en.wikipedia.org/wiki/Dead_Sea_Transform

[17] https://en.wikipedia.org/wiki/551_Beirut_earthquake

in the north to Tripoli and Baalbek in the south.[18]

1202 Syria Earthquake

The 1202 Syria earthquake struck on 20 May 1202 with an epicenter in southwestern Syria. A magnitude of M_s = 7.6 has been estimated with damage up to XI on the Mercalli intensity scale. The greatest damage was reported from Mount Lebanon, Tyre, Acre, Baalbek, Beit Jann, Al-Samyra, Nablus, Banyas, Damascus, Hauran, Tripoli and Hama.[19]

Near East Earthquakes of 1759

The Near East earthquakes of 1759 were a series of devastating earthquakes that shook a large portion of the Levant in October and November of that year. This initial event given a magnitude rating of VIII (*severe*) to IX (*violent*) on the Mercalli intensity scale. This was followed by a more significant earthquake (IX) on November 25 that destroyed all the villages in the Bekaa Valley. The ruins of Baalbek was badly damaged.[20] Three columns of the Jupiter colonnade fell in the earthquake of 1759.[21] This damage is easily confirmed by review of pre-earthquake drawings ascribed to Wood.

[18]https://en.wikipedia.org/wiki/1170_Syria_earthquake

[19]https://en.wikipedia.org/wiki/1202_Syria_earthquake

[20]https://en.wikipedia.org/wiki/Near_East_earthquakes_of_1759

[21] ***The Encyclopædia Britannica: A Dictionary of Arts, Sciences, Literature and General Information*** Volume 3 Cambridge University Press, 1910

Modern Era Archaeological Work

Scientific interest for the safeguarding of the remains of the temples of Baalbek began to develop in the 19th Century. A British mission, "Palestine Exploration Fund", undertook a first mission in 1873. It was an unsuccessful mission without accomplishment.[22]

German Mission

Kaiser Wilhelm II visited Baalbek in November 1898,[23] and after obtaining the Sultan's authorization, the Kaiser sent a mission to Baalbek. Dr. R. Koldewey, drew a map of the extent ruins and proposed a scheme of excavations while en route to Baghdad.[24] Following this scheme a group of scholars and architects led by Professor Otto Puchstein visited the site.[25] These excavations which included site cleaning and some anastylosis were begun on August 1900 by Puchstein with architects B. Schulz and D. Krencker[26] and completed in 1904.[27] Photos of the Jupiter Colonnade from this time are shown in Figures 6 through 8.

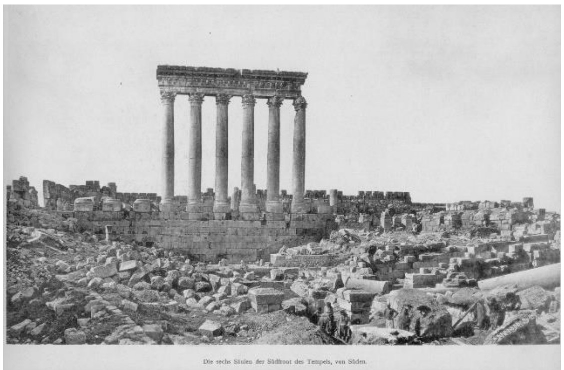

Figure 6 *– View of Jupiter Colonnade as seen from the south prior to cleaning the site. Photograph taken during the German mission, circa 1900.*

Figure 7 *– View of the Jupiter Colonnade as seen from the south. Characteristic damage of the frieze in the middle of the stone lintel can be seen. The eastern portion of the stone lintel (right) extends no further than the centerline of the column. Photograph taken during the German mission, circa 1900.*

[22] Ibid.

[23] The Dolphin, Vol. 3 Issues 105 American Ecclesiastical review, 1903

[24] ***Beirut*** by Friedrich Ragette, Noyes Press: New Jersey (1980)

[25] History of Baalbek by Michael M Alouf 16th edition, American Press: Beirut (1944)

[26] The Dolphin, Vol. 3 Issues 105 American Ecclesiastical review, 1903

[27] History of Baalbek by Michael M Alouf 16th edition, American Press: Beirut (1944)

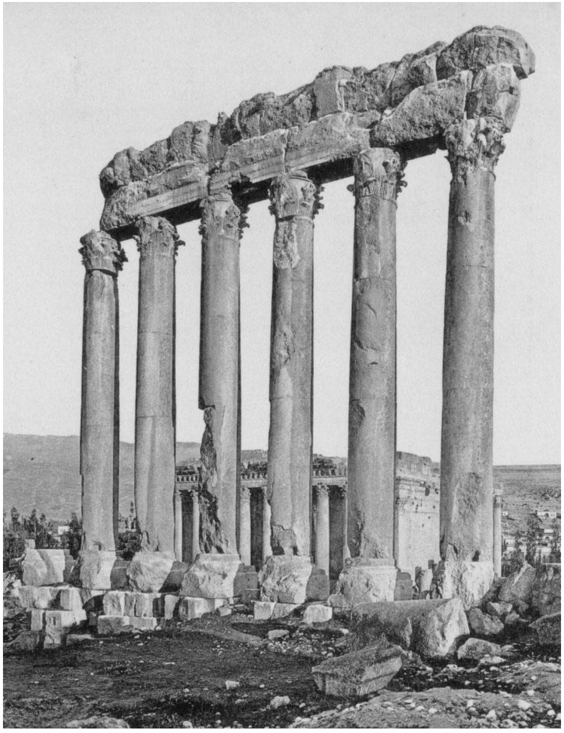

Figure 8 *– View of the Jupiter Colonnade as seen from the north. The unconsolidated stone lintel reveals the extensive amount of stone loss and the tenuous nature of the stone lintel bearing on the easternmost column (left). In addition extensive damage can be seen emanating from the base of several of the columns which is most likely resultant from the rocking of these columns during seismic actions. Photograph taken during the German mission, circa 1900.*

French Mission

After the first World War and the installation of the French mandate in Lebanon, French missions to Baalbek were commissioned.[28] The curator of the site persuaded Charles Virolleaud, a well-known French archaeologist and at one time the director of the Haut-commissariat Département d'archéologie, the necessity of repairing the remains of the Jupiter Colonnade. In June 1930 the work of clearing the debris, reinforcing and rebuilding was done under the directions of the architects, Mr. François Anus and Mr. Pierre Coupel, in accordance with the plans of the instructions of the eminent archaeologist Mr. Seyrig, then director of the archaeological department.[29] Refer to Figures 9 through 20.

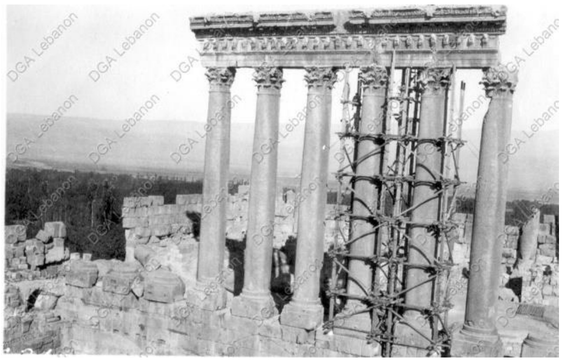

Figure 9 *– View of the Jupiter Colonnade as seen from the south with wooden scaffolding in place. Photograph taken during the French Mission, circa 1930s.*

Figure 10 *– View of the Jupiter Colonnade as seen from the north with wooden scaffolding in place. The wooden scaffolding was localized and moved rather than covering the entire Colonnade.*

[28] Ibid.

[29] Ibid.

Photograph taken during the French Mission, circa 1930s.

Figure 11 *– View of the Jupiter Colonnade as seen from the southeast with wooden scaffolding in place. A suspended wooden scaffolding hangs from the top of the stone lintel to facilitate work on the architrave and frieze. Photograph taken during the French Mission, circa 1930s.*

Figure 12 *– Work in progress at the base of one of the damaged columns. Ferrous metal rods have been set in drilled holes in the column stone, and the exterior face is filled with limestone laden mortar. The cavity behind the face is believed to be filled with concrete. Photograph taken during the French Mission, circa 1930s.*

Figure 13 *– View of the underside of the stone lintel on the north side where extent extensive stone loss is being replaced with reinforced concrete. Photograph taken during the French Mission, circa 1930s.*

Figure 14 *– Staple shaped ferrous anchors embedded in slots that span a vertical crack on the south side of one of the columns. Photograph taken during the French Mission, circa 1930s.*

Figure 15 *– Holes to receive ferrous metal rods in the stone lintel are being drilled by hand. Photograph taken during the French Mission, circa 1930s.*

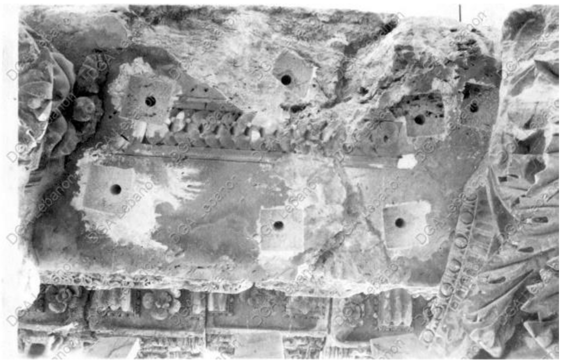

Figure 16 *- The underside of the stone lintel to the west that is cracked in two. Vertical rods with through plates that are embedded in the underside of the stone extend up through the stone and are believed to be connected to the reinforced concrete cap on top of the stone lintel. Photograph taken during the French Mission, circa 1930s.*

Figure 17 *– The reinforcing for the concrete cap is in place. The concrete Over the westernmost span is thickened probably to add additional strength to support the broken stone lintel below. Photograph taken during the French Mission, circa 1930s.*

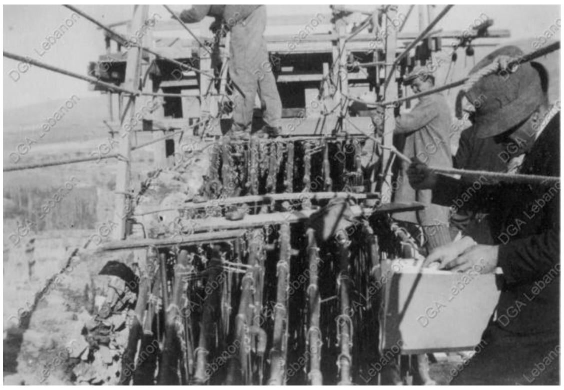

Figure 18 *– Close of view of the reinforcing of the concrete cap at the westernmost span as seen from the west. Vertical bars that are bolted into horizontal plates are believed to be the bars that support the lintel shown in figure 16. Photograph taken during the French Mission, circa 1930s.*

Figure 19 *– View of the reinforced concrete after it has been poured as seen from the west. Control joints in the concrete cap mimic the joints between the stones of the frieze upon which it has been cast. The concrete cap was finished by hand without formwork so that it would shed water. Metallic anchors protrude from the top to assist in access and repair work that may be planned in the future. Photograph taken during the French Mission, circa 1930s.*

***Figure 20** – View of the newly consolidated Jupiter Colonnade after the scaffolding has been removed as shown from the southeast. The concrete cap with its thickened portion and the westernmost span can be seen as well as the building up of the stone lintel on the east (right) to further consolidate the bearing of the stone lintel on the easternmost column. Photograph taken during the French Mission, circa 1930s.*

Cursory Non-Intrusive Assessment

Much sophisticated assessment and analyses have been performed by others. Since my time on site was short I will keep my comments brief. These following comments are from observations on the monument, of stones that have fallen from the monument and other structures in the sanctuary complex.

The stone of which the Jupiter Colonnade is composed is a crystalline limestone from the nearby quarry (Figures 21 and 22). A visit to the quarry revealed that the quarry workers were aware of stratification weaknesses in the stone and took the stratification into account during quarrying procedures (Figure 23). Limestone was used extensively throughout the sanctuary complex and thus it is easy to comment on its mode of decay. Degradation occurs mainly by disaggregation of the calcite grains (Figure 24) and alveolarization (Figure 25).

Figure 21 *– A small sample of the limestone of which the Jupiter Colonnade is composed taken from the quarry. The stone is white in color when cleaned but has a characteristic light ochre color as it weathers.*

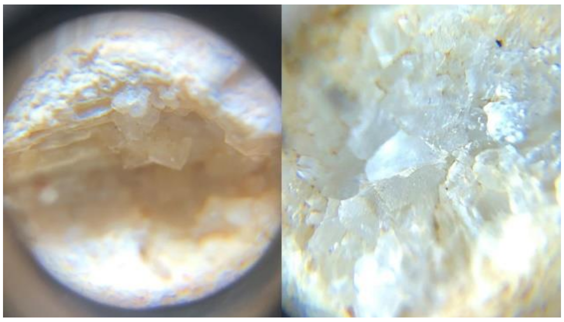

Figure 22 *– Microscopic view of the stone sample showing the crystalline nature of the calcite.*

Figure 23 *– The large stone at the quarry that was hewn and never moved reveals that the stone was hewn between weakened strata and the surrounding deposit. The workers in the quarry were cognizant of natural weaknesses in the limestone.*

Figure 24 *– Disaggregation of the limestone as seen on the steps leading up to the temple of Bacchus.*

Figure 25 *– Alveolarization of the limestone on the face of the column shaft just below the capital.*

Figure 27 *– Some of the molten lead within the stone lintel (between architrave and freeze stone units). Has been exposed on the north side.*

The stones of the column bases and shafts are set on three metallic pins at each interface and these pins are laid out as an equilateral triangle (Figure 26). They also seem to have been set in molten lead (Figure 27). It was noted that at one of the interfaces between the column base and shaft that the stone had decayed due to what appeared to be freeze thaw cycling (Figure 28). Many of the places where pins were set to span cracks in the column were evident and were in fair condition (Figure 29). There were several areas noted where corrosion of ferrous anchors were damaging the stone (Figure 30).

Figure 28 *– Close up view of the north side of one of the column shafts where it rests on the base. This is an area where the stones have been damaged possibly due to rocking during seismic actions. It appears that this damage may be exacerbated by freeze thaw decay.*

Figure 26 *– View of one of the ends of one of the fallen column shaft stones. The three drilled holes would have received metallic anchors to secure one stone top of the other. The metallic anchors would have been set in molten lead.*

Figure 29 *– Area where staple shaped metallic anchors were embedded spanning a vertical crack in one of the capitals.*

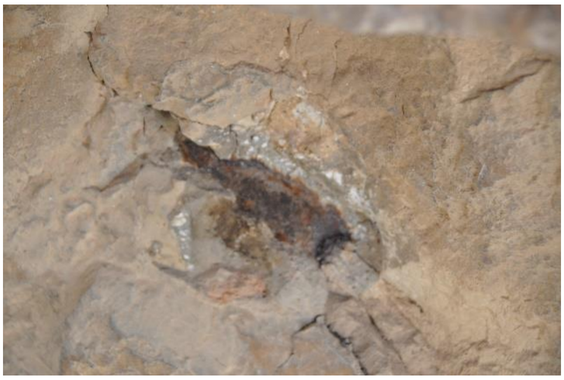

Figure 30 *– An area where an embedded metallic anchor has corroded and damaged the stone. Such damage was viewed in numerous areas.*

The Corinthian capitals are each composed of a single stone, and it is believed that they were partially carved after they were set atop the column shafts (Figure 31). The six capitals have ornate carving on the south side only (exterior side) and not on the north (interior side). I will not speculate on the reasons because it is beyond the scope of my peer review. There were numerous repairs using metallic pins evident to the capitals there were added during the 1930s work (Figure 32). In my opinion at least one of these pins, composed of wrought iron, is original, and was a repair done by the builders during initial construction (Figure 33). This is not unusual and is still common practice for builders on a structure to perform minor repairs on the scaffolding.

Figure 31 *– One of the Corinthian capitals as seen looking westward. Carving is highly ornate but is only present on the south side of the Capitol.*

Figure 32 *– Close up view of one of the Corinthian capital scrolls revealing its delicate nature and deep carving. Metallic anchors added by the French Mission can easily be seen because they have been painted with blue paint.*

Figure 33 *– Close up view of metallic anchor which appears to be wrought iron and square and profile, and not the carbon steel and circular and profile of which the French Mission anchors are composed. This anchor is believed to be from the Roman era and installed as a repair during the initial construction of the temple.*

Atop and straddling the columns is the stone lintel. The stone lintel is composed of the architrave surmounted by a frieze. The remains of the architrave are 5 stone units that span from midpoint to midpoint of the capitals and a portion of a stone unit on the west end. The remains of the frieze are composed of 10 stone units and a partial unit on the east end (Figure 34). A cast bronze anchor set in lead was exposed on the Jupiter Colonnade which connected two architrave stone units together (Figure 35). There are other nonstructural metallic anchors on the Colonnade in the architrave which date from the time when the

Jupiter Temple was afunctioning temple. I will not discuss these anchors as they are beyond the scope of my peer review.

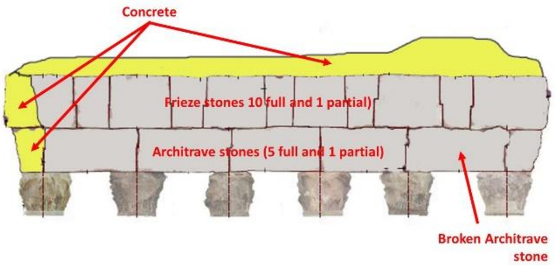

Figure 34 *– Diagram of the stone lintel atop the Jupiter Colonnade as seen from the north.*

Figure 35 *– Roman era cast bronze anchor set in lead that has been exposed due to previous damage on the north side of the stone lintel in the horizontal joint between the architrave and frieze stones.*

Inspection of portions of the stone lintel that are on the ground reveal intricate nature of carving as well as the manner in which the frieze stone units interlocked on the backside (Figures 36 and 37). Also evident that the stones of the architrave and freeze were ornately carved on the south side (exterior) only much like the capitals below. In addition, there is much stone loss on the north side that was consolidated with stonework backed up by concrete and tied to the stone with steel reinforcing. In addition a large portion of the entire stone lintel at the east side was also replaced with stonework and concrete.

Figure 36 *– A unit of the frieze that has fallen to the ground. Note the high degree of ornamental carving, much of which was put in place after the stone was set atop the Colonnade.*

Figure 37 *– Side view of the frieze unit showing the toothing of one stone to the other. Small square holes either used to receivd metal towels, to hoist the stone into place, or both.*

Atop the stone lintel is the concrete grade beam which was installed by the French Mission (Figure 38). A curious aspect of this grade beam is its precise effect on the long term behavior of the Jupiter Colonnade. We know that this beam is structural and that three compromised architrave stone units have been suspended from it via metallic anchors with end plates (Figures 39 through 41). We also know that the concrete was meant to form a waterproof cap that would successfully shed water off the top of the stone lintel (Figures 42 and 43).

***Figure 38** – View of the concrete cap looking eastward. The concrete is smooth and rounded in order to shed water to the original guttering system on the south and off of the stone lintel on the north.*

***Figure 39** – View of the underside of one of the architrave stones that has been suspended from the reinforced concrete cab above. Through plates, recently painted blue, were inset into the stone and then covered with mortar.*

***Figure 40** – View of the underside of the westernmost architrave stone which had been compromised by a large crack.*

***Figure 41** – View of the underside of another one of the architrave stones that has been suspended from the reinforced concrete cap above.*

***Figure 42** – The original guttering system within the stone frieze. The concrete cap allows water to drain into this guttering system which has downspouts that lead to the mouths of carved lions in the south side of the frieze.*

***Figure 43** – Welded wire fabric was placed in the concrete cap near the surface to control shrinkage cracks in the concrete and increase its water shedding abilities.*

However, there is a formed break in the continuity of the beam which prevents it from forming a continuous tie across the top of the stone lintel (Figure 44). It is a compelling question to me as to how much strength the concrete beam adds to the Jupiter Colonnade as a whole and whether a further enhanced continuity effect would be better?

***Figure 44** – Formed break in the concrete cap towards the west end of the cap. Little is known about the steel reinforcing within the concrete other than it must be present above the architrave stones that are suspended and is discontinuous at this break.*

Discussion on BTAP2 team Work

It is my understanding that the goals of the project are the following: "restore the restoration" that was implemented by the French team from 1931 to 1933; and to structurally strengthen the Jupiter Colonnade to counteract static loads only, i.e. the Jupiter Colonnade will not be retrofitted to counteract seismic loading.

Review of Studies Performed to Date

According to the ISCARSAH Principles, the uniqueness of older buildings with their complex histories, requires the organization of studies in steps that are like those used in medicine. *Case history*, *diagnosis*, *therapy* and *controls*, corresponding respectively to the search for significant data, categorizing damages, choosing treatments, and monitoring the effectiveness of those treatments. I have placed my comments relative to these steps. In this manner I am providing an organizational outline into which one can place all actions to date.

Diagnosis

Diagnosis is identifying the nature and causes of deterioration and decay, and the opinion derived from such an investigation. Physical investigative techniques and include non-invasive and minimally invasive methods. Laboratory analysis on material properties has been comprehensive in many cases.

The BTAP2 consultants and contractors (BTAP2) have performed an enormous task of diagnosing numerous issues with the Jupiter Colonnade of Jupiter and developing considered opinions on therapy. My following critique of their protocols are meant to be constructive in nature and in no way should be interpreted as unfavorable.

I like to consider diagnostic techniques that span from sensory and non-invasive to invasive to laboratory evaluation and finally to structural analysis. I will place my comments in this order.

Sensory Non-invasive Survey

With the aid of the scaffolding which completely covers the Temple of Jupiter and provides close-up access to each of the six columns and both sides of the stone lintel, BTAP2 have been able to perform a comprehensive hands-on survey. A laser scanner survey was also implemented to define a correct mapping of the surfaces and of their relevant decays which is a wonderful took for clear communication.

If they have not already done so the laser scan survey can also be used to record leans and warps in the monument. A study of the present laser scan materials by Pierre Smars indicates that the westward columns lean westward and the eastern columns lean eastward (Figure 45). This is not surprising as even the smallest seismic shock can open joints between units that will immediately be filled with falling pieces of stone so that the joints cannot return to their previous state. This is a reiterative process which will only make the joints grow wider over time. This phenomenon is causing the lean in the columns. The leans of the columns both in the east-west and north-south orientations as well as any warps in the stone lintel should be clearly quantified to obtain a greater understanding of the behavior of the Jupiter Colonnade.

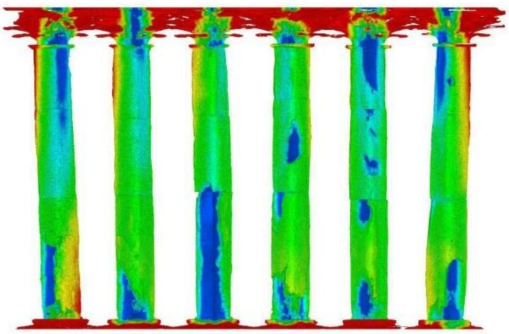

Figure 45 *– Laser scan view of the Jupiter Colonnade as seen from the north. Inclinations are exaggerated by a factor of five revealing the outward lean of the end columns (study by Pierre Smars).*

Magneticometric Survey

The discovery of the distribution of ferrous metal anchors using a magnetic metal detector revealed that these anchors are mainly located at the north side of the Colonnade that has more vertical cracking damage (Figure 46). The oxidation of these anchors has been identified as a cause of further cracking damage. In addition, oxidation of anchors within the delicate and fragile stone carving of the Corinthian capitals (Figure 47) has been recognized as accelerating present damage. The makeup of these anchors seems to have not been determined as they are referred to as both iron and steel by different writers. They were installed during the French Mission of the 1930s and this time frame would indicate that the anchors are composed of steel rather than cast or wrought iron. Steel oxidizes in lamellar fashion and the corrosion product is more expansive manner than either cast or wrought iron. It is an essential step to perform a metallurgical examination of removed anchors to determine their nature.

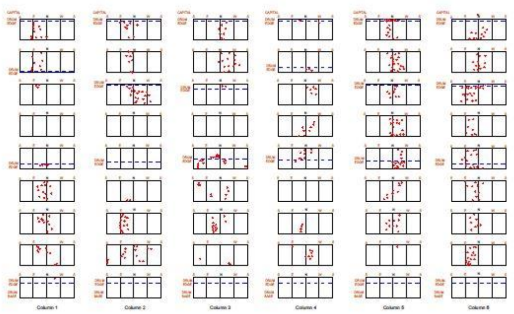

Figure 46 *– Results of the metal detector survey and the six columns showing that the anchors are typically on the north elevation where the damages greatest.*

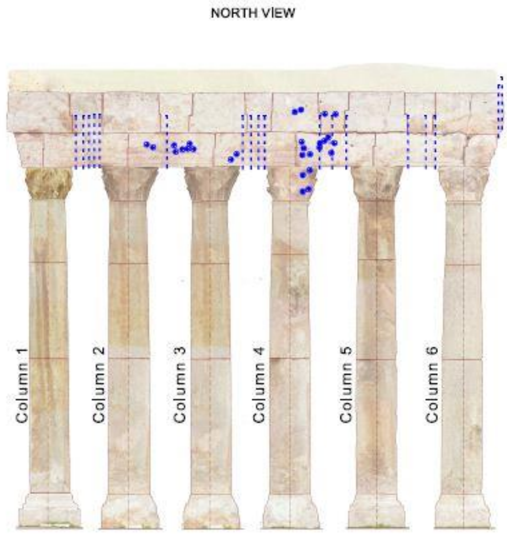

Figure 47 *- View of the metal detector survey shown on the north elevation of the laser scan. Anchors in the Corinthian columns in the stone lintel can be seen. In addition vertical anchors that support the stone architrave in three locations can be seen.*

Petrographic Examination

Petrographic macroscopic and microscopic observations performed at the Dipartomento de Ingegneria Civile, Ambientale, Aerospazials, dei Materiali (DICAM) has led them to characterize the building limestone as a carbonate sedimentary rock of bioclastic fine grain with a supported grain structure and a matrix composed of micrite and microcrystalline calcite. This petrographic description is in keeping with the observed dissolution characteristics of the quarried stone that has been directly exposed to the elements for up to 2000 years. Visible diffused microcracking has been observed on the stone cores that were removed from the monument which indicates that the cracking is more than just surficial.

Core Removal and Endoscopic Examination

Thirteen cores were extracted from previously repaired stone damages at column bases, column drums and stone lintel (Figure 48). The cement reintegration material was examined visually to obtain a measure of its condition, and the results indicated that the samples were in fair condition with some voids and honeycombs. Fortunately testing with phenolphthalein revealed that there is no carbonation in the concrete. It was also observed that reinforcing within these materials was not corroded. In addition, 38 holes were drilled into the column bases, shaft and stone lintel for the purposes of endoscopic evaluation to observe the state of the reintegration material and the original stone. Though voids are found in the reintegration material there were no voids between this material and the stone.

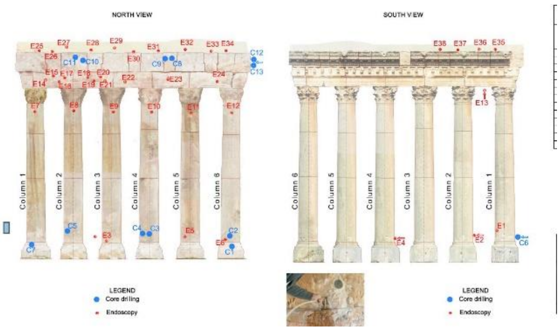

Figure 48 *- View of the north and south sides of the Jupiter Colonnade showing the locations of core samples and endoscopic pilot holes.*

Laboratory Examination

Extraction and testing of six cores was carried out by Geoscience Engineering & Laboratory Services (GELS) at the request of BTAP2 (Figures 49 and 50). The purpose of the investigation was to determine the compressive strength, modulus of elasticity and specific weight of the structure under investigation and included samples of stone and reintegration material from the column bases, columns shafts and the stone lintel. This testing revealed that the cement has a similar compressive stress as the stone and both have similar specific weights. There is typically a good bond between the cement, aggregate and stone, but the concrete mixture is sometimes poorly graded with isolated honeycombing. Concern has been expressed with the compatibility of the stone and cement, but no obvious effects of the incompatibility were observed.

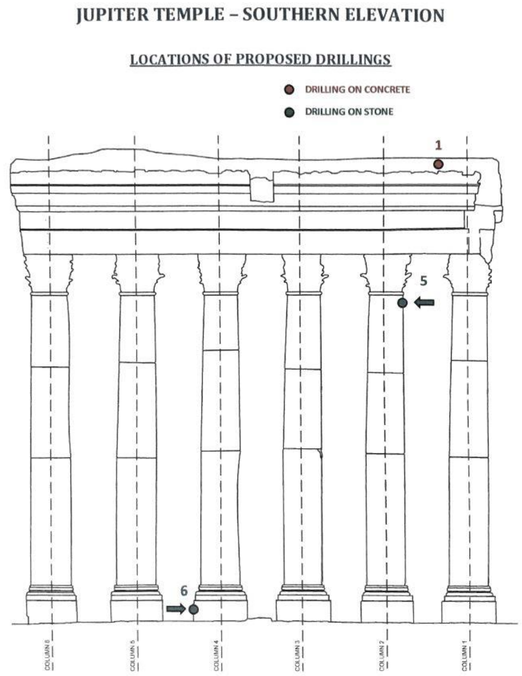

Figure 49 *– Locations of core sample removal for laboratory evaluation on the south elevation of the Jupiter Colonnade.*

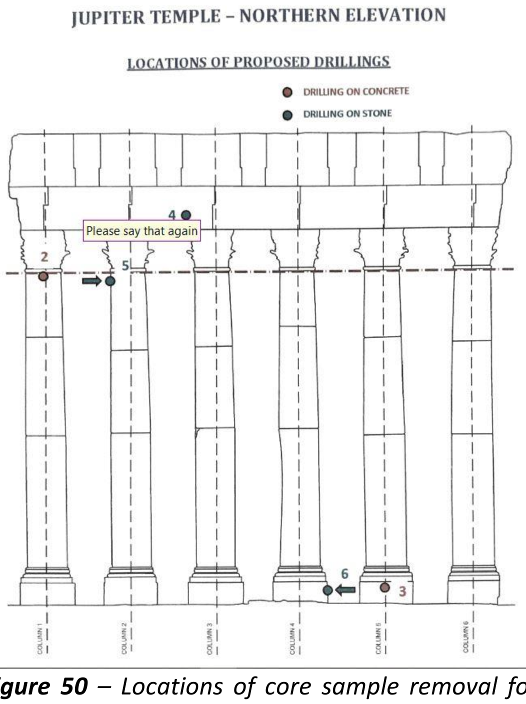

Figure 50 *– Locations of core sample removal for laboratory evaluation on the north elevation of the Jupiter Colonnade.*

Accelerated Weathering Testing

A single test of compressive strength determination of freeze-thaw cycled stone was successfully carried out. The aim of the test was to identify and quantify any variation of the mechanical characteristics of the stone after 20 cycles of freeze-thaw. When the accelerated weathering was completed a smaller core was extracted from the specimen and tested in compression. The comparison of stone strength between before and after freeze thaw cycling revealed a sizable reduction in strength. This test, though insightful, was performed on only one sample which is inadequate to establish a trend. More accelerated weathering testing is recommended on stone and concrete samples.

Structural Modeling

Structural modeling was carried out in 2008 using finite element method (FEM) three-dimensional modeling techniques. This structural analysis which was not performed by BTAP2 was of limited usefulness due to the deceivably simple monument construction. From study of the seismicity on the area and particularly the nearby Yammouneh fault line, seismic movements will be in the north-south direction due to the African Plate to the west and Arabian Plate to the west both moving in a general north-northeast direction, but one moving faster than the other. Inspection of the present locations of the large stones of portions of the Jupiter Colonnade that have already collapsed indicate that they fell southward. Large losses of stone on the northern side of the column shafts at their base are assumed to have occurred due to rocking of the columns, a phenomenon which is readily seen in the computer model (Figure 51). The remaining Jupiter Colonnade is weakest in the north-south direction. It must be accepted that the Jupiter Colonnade, if not seismically retrofitted, is vulnerable to collapse during a seismic event. Therefore, the DGA accepts this risk in not including seismic retrofit as part of the project.

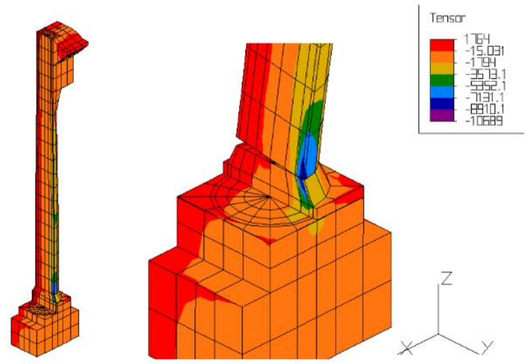

Figure 51 *– Previous three-dimensional structural computer modeling studies showing the buildup of compressive stresses at the base of the column shaft (in blue) due to rocking of the Colonnade in response to seismic loading.*

Long Term Monitoring: Long-term monitoring of the Jupiter Colonnade is essential and should be part of the planning process going forward. The recently completed laser scan, as stated by BTAP2 is a valid tool for a long-term monitoring program. This monitoring program should be further developed and implemented as part of the present project.

Further Diagnoses Recommended

Other than further studies that have been recommended above I would also include the following studies. One aspect of the Jupiter Colonnade that is not fully understood is the concrete cap that was installed atop the stone lintel by the French Mission.

1. Perform metallurgical studies on the ferrous metal pins to verify that they are indeed carbon steel.
2. Perform further accelerated weathering tests on the stone and the concrete to determine if the reduction of strength is a trend.
3. Not enough is known about the metal reinforcing in the concrete beam atop the stome lintel other than the thickened area above the cracked stone architrave unit. It can be assumed that there is metal reinforcing above the other architrave stones that have been reinforced. However, the formed separation in the concrete cap

indicates that the beam was not meant to form a continuous tie across the top of the lintel. Further intrusive inspection is warranted in this contemporary element to determine the sizes, numbers and conditions of the reinforcing steel in areas where little is known about the reinforcing steel. Such an inspection would include selective removal of concrete, would not affect the authentic portions of the monument, and could be easily repaired.

4. Ambient vibration testing should be performed on the monument to obtain an understanding of how vibrations pass through the monument and find weakened areas. Such testing would include the temporary installation of seismometers at selected points within each column and along the stone lintel. Such testing may answer the question of whether the present concrete beam should be further reinforced.

Therapy and Control

Therapy includes remedial treatments (consolidation, conservation, strengthening, etc.) in response to the diagnosis. Control is the means of verifying and regulating the efficiency of an enacted therapy through monitoring and cyclical examination.

In general, it is my opinion that BPAT2 team is moving in the correct direction and consolidation of the monument within the established agreements of the goals of the project. It is understood that the present project, when completed, will leave the Jupiter Colonnade in a state where it is vulnerable to collapse during a significant seismic shock.

I would like to provide the following commentary on the proposed treatments:

1. The present strategy of painting these pins where they are exposed will not be effective. Anchors corrode on embedded surfaces and will not corrode on exposed surfaces. From experience I can attest the following: steel corrodes much more readily where it is buried in mortar or stone in comparison to where it is exposed; and the corrosive expansion of carbon steel anchors will destroy the stone into which it is embedded. I strongly recommend that consideration be given to removing these pins in the column shafts in all cases where this can be performed without causing significant damage. Once removed the pins can be replaced with stainless steel, nonferrous, or nonmetallic anchors of similar size and profile. I agree that extraction of these pins at the column capitals would be too damaging and should probably not be attempted at this time.
2. The concrete cap on the stone lintel should be made waterproof. Open cracks, joints, voids and the like on all faces of the architrave should be filled to mitigate infiltration of water. Corrosion of ferrous pins occurs in the presence of water in the architrave can serve as a protective canopy for many of these pins in the capitals directly below.

The BTAP2 team has suggested that the laser scanner product be used as an instrument for monitoring the changing condition of the monument in the future which is a great use for laser scan surveys. I recommend that this team formally propose the method of control for which the laser scan can be used.

Reporting

The BTAP2 teams have performed a lot of fine diagnostic work. The presentation of this body of work can be much more useful if organized and presented in an Explanatory Report. This report would specifically define the subjective aspects involved in the assessment, such as uncertainties in the data assumed, and the difficulties in a precise evaluation of the phenomena that may lead to conclusions of uncertain reliability. Much of the present data is not immediately accessible without some digging, much of it is not dated and some of the samples examined have no clear provenance.

This proper presentation would speak to future generations into which hands the care of this monument will be placed. Imagine if such reporting had been pulled together and archived by the German and French missions so that we would have that data readily accessible today?

It is not necessary to rewrite present reports but rather to use them as appendices to the explanatory report. The explanatory report need not be lengthy but should be written with one voice and adopt all the appropriate terminologies when discussing the Jupiter Colonnade. As an example below is a suggested outline for an Explanatory Report.

Structural Studies

- Non invasive surveys
- Invasive surveys
- Field testing
- Laboratory testing
- Monitoring
- Explanation of Diagnosis

Surficial Studies

- Non invasive surveys
- Invasive surveys
- Field testing
- Laboratory testing
- Monitoring
- Explanation of Diagnosis

Recommended Therapies

- Priority 1 - Emergency
- Priority 2 – Perform within a year
- Priority 3 – Perform within five years