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Conservation of Heritage Structures in Turkey: Practice and Difficulties

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Abstract Conservation studies in developing countries might have additional problems to those that are being experienced by leading developed countries. The problems and difficulties mentioned here do not reflect the common practice in Turkey and mostly list rare cases for information purposes. Countries located in Asia and Middle East have rich structural heritage, in number and significance, which are sometimes even a few millenniums old. On the other hand, often times financial or bureaucratic constraints make the conservation studies more difficult, while technical problems remain to be an issue. It is quite interesting that sometimes having available financial support for conservation studies turns out to be the main source of problem, since quick and not well thought interventions end up damaging hundreds of years old surviving structures, rather than conserving them. Other most common application problems include use of Portland cement in humid environments causing salt contamination (which is now widely being avoided), infilling and freezing cracks that used to work as seasonal water table movement based motion or thermal expansion joints that are cyclic in nature, covering the structure to protect but forming unintentional green house effect – micro climates forming fungus, improper drainage to cause support settlements, removing earth fill or structural members to cause structural movements and cracks, strengthening parts of a flexible structure only to make it more rigid and cause to attract more earthquake forces, disable its energy dissipating mechanisms, applying improper chemicals, using incompatible material or irreversible techniques etc. are just a few to mention. The problem solution strategies in conservation studies should include internationally accepted conservation rules. Multi disciplinary teams are always recommended since combination of various expertise areas are mutually needed in conservation studies; architects, geotechnical and structural engineers, geology and material science specialists, archeologists, art historians are among the most important team members. Analytical modeling and simulations, on-field non destructive testing, instrumented monitoring (SHM), and small scale field treatment tests are recommended to be merged and used in conservation studies, because conventional methods or commercial repair/treatment materials available over-the-counter may not always suitable for a given specific case. Reversibility, minimum intervention, and respect to authenticity should be among the main principles to avoid serious conservation problems.

Keywords: Turkey, problem, opportunity

Introduction

Conservation of heritage structures is a delicate practice which is evolving and improving in time. This paper discusses some common problems experienced in Turkey mostly from a structural engineer's point of view. The *practice and difficulties* explained here may also be experienced by other countries, although sometimes with a few decades time shift. The purpose of this paper is to give brief description of major conservation studies in Turkey while touching on a few commonly observed and experienced difficulties on conservation studies. The problems and difficulties mentioned here do not reflect the common practice in Turkey and are mostly rare cases provided for information purposes.

Conservation studies in developing countries might have additional problems to those that are being experienced by leading developed countries. Countries located in Asia and Middle East have rich structural heritage, in number and significance, which are sometimes even a few millenniums old. On the other hand, often times financial or bureaucratic constraints make the conservation studies more difficult, while technical problems may still remain to be an issue. It is quite interesting that sometimes having available financial support for conservation studies turns out to be the main source

of problem, since quick and not well thoroughly thought interventions may end up damaging hundreds of years old surviving structures in the next following few years, rather than conserving them. Other most common application mistakes used to include the use of Portland cement in humid environments causing salt contamination (which is now widely being avoided), infilling and freezing cracks that used to work as seasonal water table movement based motion or thermal expansion joints that are cyclic in nature, covering the structure to protect but forming unintentional green house effect – micro climates forming fungus, improper drainage to cause support settlements, removing earth fill or structural members to cause structural movements and cracks, strengthening parts of a flexible structure only to make it more rigid and cause to attract more earthquake forces, disable its energy dissipating mechanisms, applying improper chemicals, using incompatible material or irreversible techniques etc. are just a few to mention. The problem solution strategies in conservation studies should include internationally accepted conservation rules. Multi disciplinary teams are always recommended since combination of various expertise areas are mutually needed in conservation studies; architects, geotechnical and structural engineers, geology and material science specialists, archeologists, art historians are among the most important team members. Analytical modeling and simulations, on-field non-destructive testing, instrumented monitoring (SHM), and small scale field treatment tests are recommended to be merged and used in conservation studies, because conventional methods or commercial repair/treatment materials available over-the-counter may not always suitable for a given specific case. Reversibility, minimum intervention, and respect to authenticity should be among the main principles to avoid serious conservation problems.

The potential problems and difficulties that are described here do not reflect the common practice. Exceptional applications and circumstances may develop in any country and rules / regulations may be adjusted to minimize such events. On the other hand, having too many constraints and requirements in the rules & regulations might make the work too slow or impossible to maneuver.

Practice

Conservation of heritage structures in any country is a broad subject which cannot be covered by a single paper. Claiming to have a complete overview of the conservation practice in Turkey would be too ambitious and disrespectful to various researchers and practitioners in various fields of the conservation. This paper tries to give a structural engineer’s perspective who has been involved in various conservation studies in Turkey, became a partner in interdisciplinary conservation teams, and made consultancy work to the ministry and private companies on various projects. A few significant examples are provided below with limited coverage and there are many other important studies which unfortunately remained not mentioned.

Sivas Divrigi Great (Ulu) Mosque One of the major historic heritage structures in Anatolia is the Great Mosque located in a small town Divrigi in central Anatolia in Sivas province. The mosque was built in 1228-1229 century during the Anatolian Seljuk by Ahmet Shah and his wife Melike Turan, who had initiated an additional hospital construction adjacent to the mosque. Divrigi Ulu Mosque is the only structure in the world heritage list of UNESCO among all 9 sites listed from Turkey (UNESCO list).

The conservation studies regarding Great Mosque and Hospital of Divriği targets primary concerns regarding the removal of the gallery behind the east wall (Fig. 1) as well as preservation of the beautiful stone carvings (Fig. 2). Furthermore, the west façade is inclined towards the garden indicating possible opening in the vaults. The east wall lower sections exhibit excessive salt contamination as well as critical bulging towards interior. The salt formation is coming from the reinforced concrete single storey gallery on the east side. The melting snow and rain water is not properly discharged from the east wall, which seeps into the gallery and to the lower elevations of the east wall. The historic structure is one of its kind in Turkey due to the extensive studies regarding structural health monitoring. The monitoring studies will include underground inclinometer and ground water level sensors, crackmeters, wall and minaret tiltmeters, accelerometers, temperature and humidity measurements, laser based displacement sensors, surveillance cameras for security and observation of atmospheric conditions. About 60 critical points on the structure will also be

monitored using better than 1mm accurate optical measurement system on a monthly basis to obtain the current geometry to investigate previous structural deformations as well as possible recent movements. Finite element modeling studies will reveal the vulnerability of the structure to new earthquakes as well as effects of east gallery removal by computer simulations. The one year monitoring of the structure will follow controlled demolition of the gallery, which might be immediately stopped if any critical movement in the structure is detected. The data acquisition system will give alerts by sending SMS messages if any sensor gives out of boundary readings. The accelerometers will record synchronous acceleration data from all channels if any earthquake movement is detected. The tilt, crack width, deflection, and similar data will also be recorded at full speed during an earthquake and their values will be compared for before and after an earthquake event, which will enable rapid condition assessment.

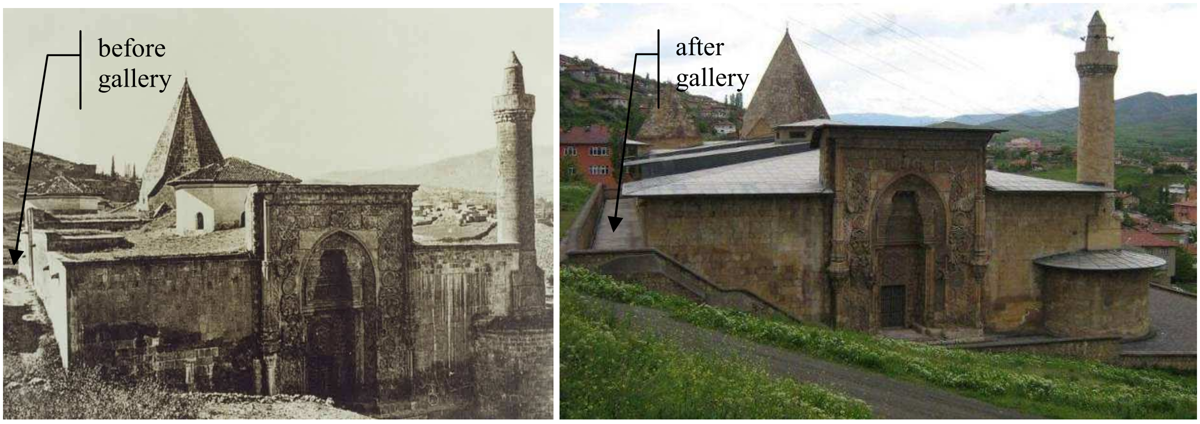

Figure 1: Sivas Divrigi Great (Ulu) Mosque general view before and after the gallery

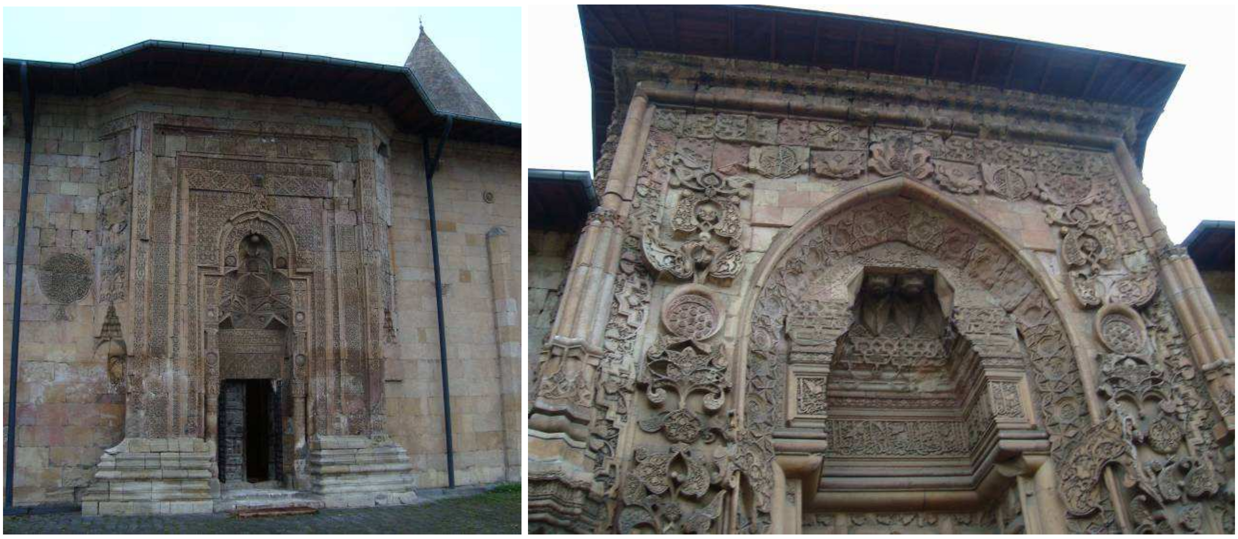

Figure 2: Sivas Divrigi Great (Ulu) Mosque stone carvings on the walls

Nemrut - Commangane Nemrud is an archaeological site in Adiyaman, located in the eastern part of Turkey, noted with the large-size monumental statues (8 to 10 m tall, having approximately 3.5 m x 3.5 m base area) which are more than two milleniums old. The site is located at 2150 meters altitude at the crest of Nemrud Mountain and composed of two main terraces in the East and West of a central tumulus, where the monuments lined up side by side facing the west and east. The site carries the signs of dispute between two opposing powers of that time, the west and east (Greek and Persian) and a mediator civilization (Commangane) in between, which is interestingly similar to the position of Turkey now being a bridge between Europe and Asia, facing both directions and civilizations.

The monuments are composed of seven layers of large stone blocks which are not interconnected with shear keys, metal locks, or mortar. The 7^{th} layer consists of the heads only, which used to be located over a small ditch located over the shoulder level (Fig. 3) but all has been fallen down. The monuments, which are composed of big limestone blocks without mortar or interlocking mechanisms, placed on the East and West terraces show considerable differences in terms of damage level for physical integrity. The east terrace statues are in better structural condition except for the fallen heads while the west terrace statues are almost completely demolished except for the first two layers. The Nemrud monuments were discovery in 1881 by Otto Puchstein and Karl Sester; and various works have been carried out by Osman Hamdi Bey and Osgan Efendi (1882), Karl Humann and Otto Puchstein (1882), Karl F. Dörner (1954-1958; 1984), Theresa Goell (1956-1973), Sencer Şahin (1987-1989), Herman A.G. Brijder and Maurice Crijns (2001-2003). A recent and comprehensive project is being led by Dr. Neriman Sahin Guchan at METU, which involves detailed documentation, evaluation, development of case specific solutions for conservation, strengthening, site planning including the surrounding cities and other structures in the area including bridges, caves, monuments, etc. The Nemrud monuments are especially important and at the core of the current studies.

The site is only a few kilometers away from the East Anatolian Fault (EAF) which is seismically active and can generate large earthquakes. The structural evaluation consists of nonlinear analytical modeling and simulation of previously recorded earthquakes acting on the structures (Fig. 4). Other loads such as snow load and blast load are also being investigated since the heavy snow accumulated at the skirts of the tumulus may impose large lateral loads. Blast loading is also among alternatives since large craters were found on the tumulus, reminding tomb thieves and treasury hunters using explosives to reach a possible tomb at the core of the tumulus. The results indicate that explosives are not likely to cause of the damage since tons of TNT is needed. Snow and earthquakes can both damage the statues. The conservation studies will be shaped based on the results of evaluation; demountable winter barriers and stabilizing each layer against earthquakes are among the possible interventions.

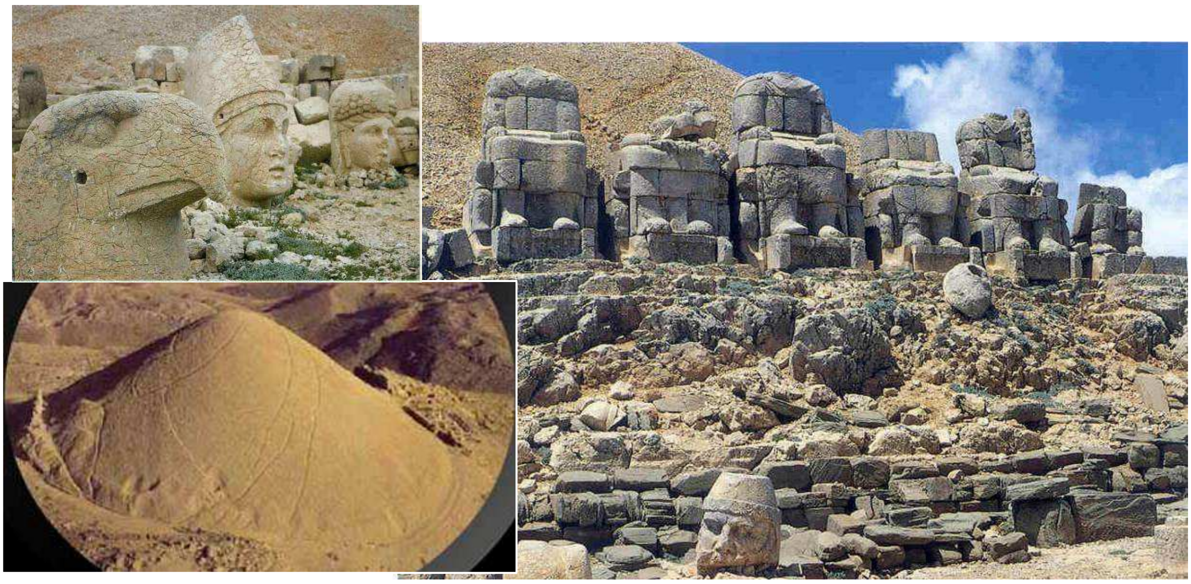

Figure 3: Nemrud monuments, west and east terraces from left to right

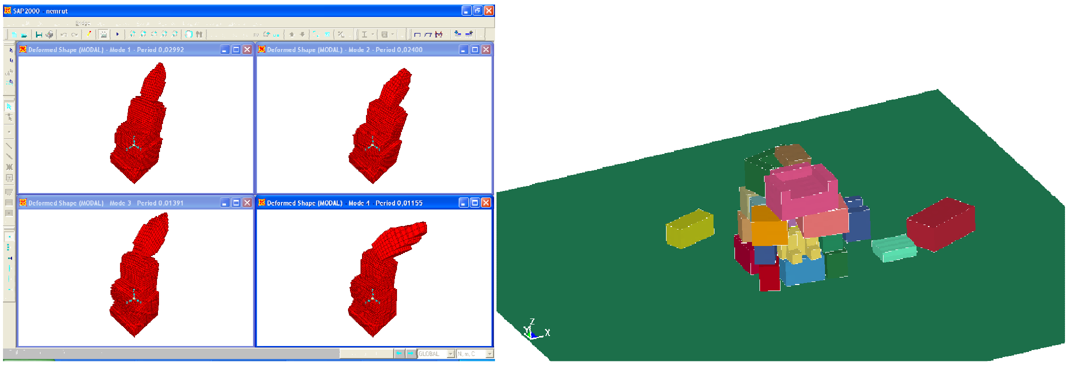

Figure 4: Linear and nonlinear modeling of Nemrud monuments

Hasankeyf Area and Zeynelbey Mausoleum Hasankeyf is a historic settlement area located by the Tigris (Dicle) river in Batman, Turkey which is famous with its rich historical structures. In spite of heated national and international debates regarding the construction of Ilısu dam, the construction has started in 2006 and the area will be flooded by the dam's reservoir in about 5 to 10 years of time form today. The most important structures in Hasankeyf area can be listed as The Old Tigris Bridge (1116), Small Palace (Ayyubids), Great (Ulu) Mosque (1325), Great Palace (Artukids), El Rizk Mosque (1409), Süleyman Mosque, Koc Mosque (Ayyubids), Kizlar Mosque (Ayyubid), Zeynel Bey Mausoleum (15th century), second and upper gates (Fig. 5). All structures suffer multiple problems mostly related to aging, lack of proper maintenance, and vandalism. The most common reflection of aging is the degradation and loss of stones and loss of wooden members in the walls. Environmental effects such as vegetation on the walls and roof, rain and snow weakening the material by erosion as well as less frequent freeze & thaw cycles can also be counted among time based damaging agents. The mortar between stones is mostly clay based sometimes with lime mixture. The lack of maintenance causes the stones to fall out of their place as the mortar between stones are washed away and wooden lintels deteriorated in time.

Most of the inhabitants have low level of income; therefore, not fully comprehend the value of the historical heritage. Stealing wood for fire and stones for building homes is quite common. Treasure hunters give a lot of damage to the historical structures as they dig corners of buildings, relocate the keystone of arches hoping to find gold hidden at those places. There are many rumors about rich people of the past hiding gold and silver coins at the roof or inside the walls of these historical structures. They believe that there used to be a mint in the area and some gold coins were fallen into the cracks on the rocks. Unfortunately, digging around for earthenware jug full of gold is a recreational event. Use of dynamite for fish hunting in Tigris River is also common, which would generate small scale earth tremors that vibrate near-collapse structures. Writing graffiti and scratching names on the walls of historic structures is also common. The security personnel on the area are only one or two people, outnumbered by the number of visitors on a very large visit area. In the spring of 2007, a group of visitors dancing on the roof of the Great (Ulu) Mosque caused collapse of one of the vaults causing serious injury of one person.

Besides of all the negative developments regarding Hasankeyf, Ministry of Culture is taking the site very seriously and recently there has been multiple restoration projects executed in parallel. Zeynelbey mausoleum is one of the important structures being strengthened in Hasankeyf (Fig. 6). The exterior dome of the mausoleum suffered a series of vertical serious cracks. The 3D FE modeling and simulations indicated tension zone at the mid height where cracks are the largest. Proposed circumferential post-tensioning was accepted and recently applied as an emergency intervention to prevent collapse of the dome. The tension forces in the cables are continuously being monitored. Feasibility studies to transfer Zeynelbey's Mausoleum to higher elevations are currently being investigated. Lifting the structure using a number of electronically controlled hydraulic armed carts and maintaining perfect leveling and low level of vibrations during the transportation is a possibility.

The salvaged structures are planned to be relocated as a whole or in parts and preserved at a higher elevation outside the dam's reservoir.

Figure 5: Hasankeyf region,and thermal insulated roof structure

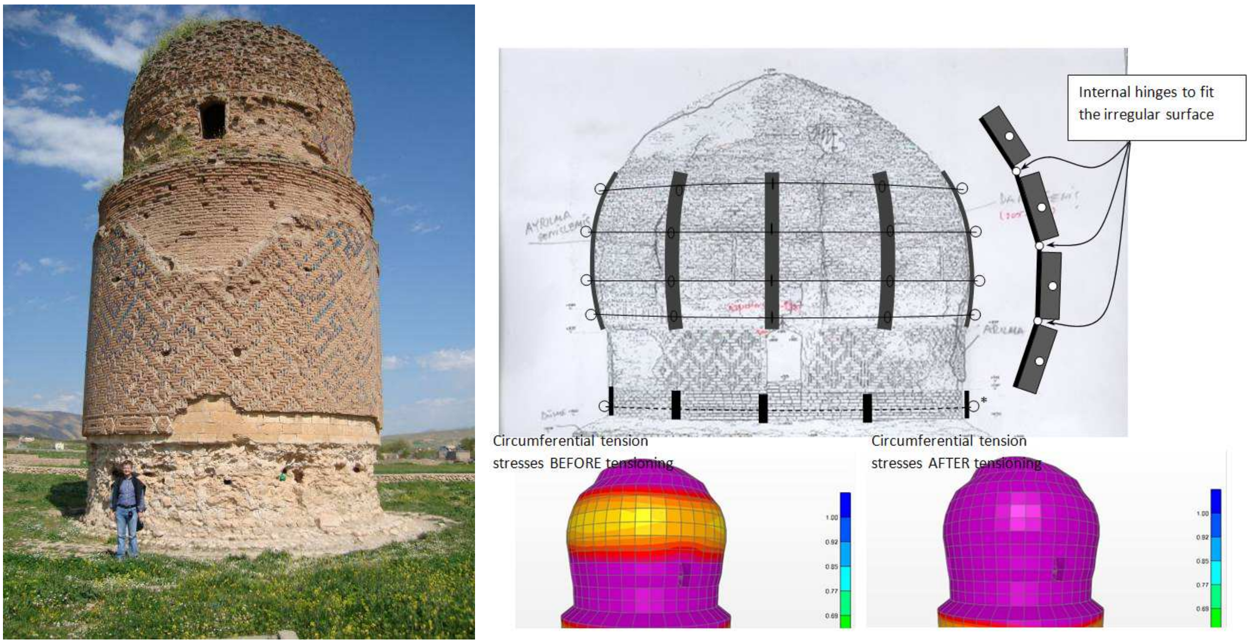

Figure 6: Zeynelbey Mausoleum,and analytical modeling to indicate tension zones

Temple of Augustus The Temple of Augustus, being one of the most important monuments of Roman age, is located in Ankara, Central Anatolia, capital of Turkey. The temple is also known as Monumentum Ancyranum. Available information about the construction date of the temple goes back to years 30-25 B.C. After the conquest of Galatia (Asia Minor) by the first Roman Emperor Caesar Octavian Augustus, Ancyra (ancient name of Ankara) became the ruling center of Roman province. Referring to the glory of Caesar Octavian Augustus, a magnificent marble temple was built. Among the other Roman monuments, the Temple of Augustus has a special place; the inscriptions on its walls are unique, which were copied from the original inscriptions engraved on bronze pillars used to exist at the entrance of the mausoleum of Augustus in Rome. This inscription is called as Res Gestae Divi Augustus and it was engraved on the walls after the death of Octavian Augustus

according to his will. The inscription is about the deeds and testaments of the emperor. Since the original inscription does not exist anymore, the importance of the temple has significantly increased. (Akurgal 1993)

The monument has an H shaped plan which is about 28m×11.5m in size and has a height of approximately 11m. Hacibayram Mosque (1428) is interestingly constructed adjacent to the Temple of Augustus sharing the same roof level at the west corner of the monument, in a way highlighting the sacred meaning of the area and sharing two different beliefs in one corner (Fig. 7).

The current condition of the structure is giving warning signals since two walls existed in the original temple are missing today; the dark and shaded lines in Fig. 7 indicate the walls that were lost over time which caused the north wall to get dangerously tilted towards inside (Fig 8). An emergency support mechanism was proposed, designed, and currently under construction, which would be holding the wall if it becomes unstable until a comprehensive restoration work is planned and conducted. The restoration work will mainly cover a) structural issues; a roof that will not mask the significance of the monument but protect from rain, snow, and ultraviolet at the same time provide structural stability by forming a diaphragm action over the walls; will have platforms at every 2m to provide working platform for future restoration works. b) stone conservation; encryptions on the walls that are in Roman and Greek suffer from acid rain and general aging; proper protective measures will be first tested on similar stones on the field, then small areas on the temple, and finally on a large scale provided that the compatibility and success of the stone treatment is proved. c) site presentation including the surrounding park as well as information panels.

Two tiltmeters are being planned to be installed on the dangerously tilted wall to investigate if the tilting is progressive in nature. The supporting structure is planned not to touch the temple's wall, but be there to hold it if an unstable condition is reached. The supporting roof will be demountable, which should not touch the wall; otherwise, demounting would not be possible in the future since the two structures would start to lean on each other transferring forces. Removal of equilibrating forces may result in structural instability.

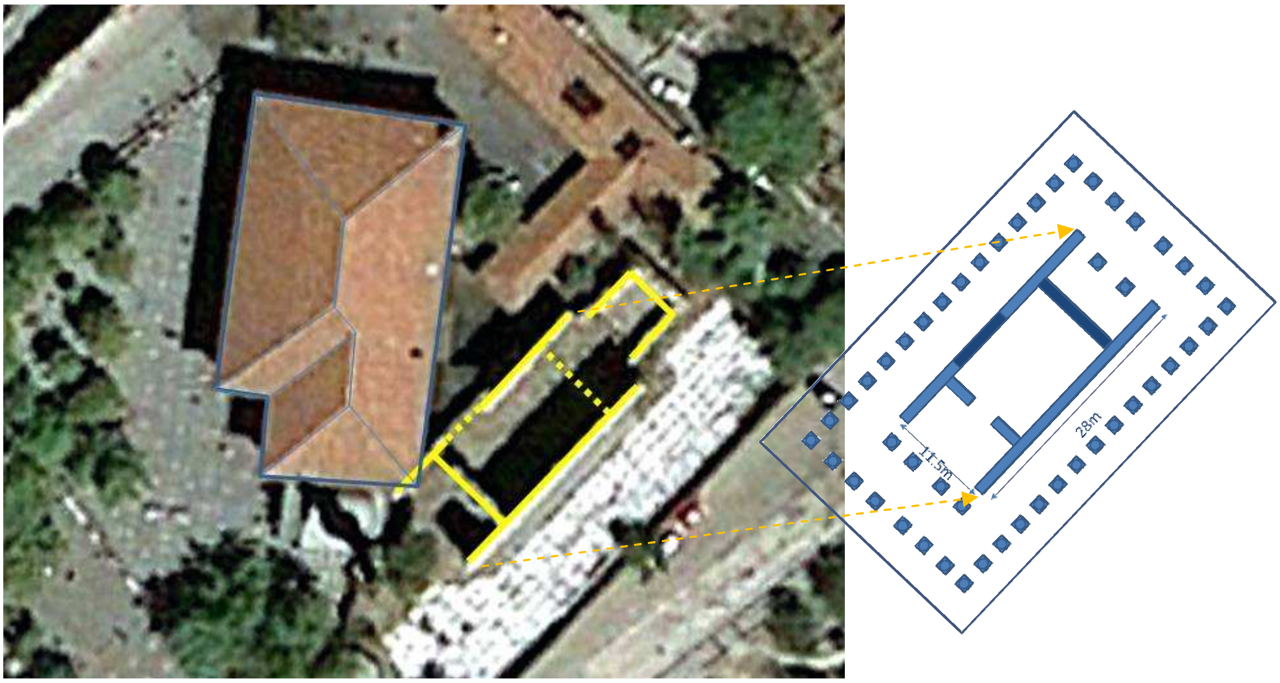

Figure 7: Satellite view of Temple of Augustus and adjacent Hacibayram Mosque

Gordion and Cappadocian Gates The ceramics findings and historical records indicate that settlers migrating from the Balkans in Europe first settled in Anatolia around Eskisehir city hundred or more years following the destruction of the Hittite Empire (1200 BC). Phrygian king Midas is quite famous primarily known from Greek historical records, also appears on the rock inscriptions in Gordion. Constructed around 900 BC, the Early Phrygian Gate is composed of multiple leaf dry stone

masonry. The outer limestone wall shows extensive cracking, spalls, open joints, and bulging. After its excavation in 1950s, the gate has been exposed to environmental conditions. What's more important is that there is soil pressure at the back fill of the wall while about 10m deep wall is not supported on the outer side (Fig. 9). The excavation work and preservation studies are mainly carried out by UPenn (USA - Dr. Frank Matero) teamed up with researchers from METU (Turkey). The bulging wall is now continuously being monitored by three digital LVDTs which are remotely connected to a PC at METU using GSM modem. Furthermore, 3D surface scans of the walls taken last summer will be digitally compared after one year against similar measurements that will be taken in the summer of 2010. Previous injection of lime based mortar at the joints showed limited use and additional measures are being planned such as removal of static pressure behind the wall or anchorage.

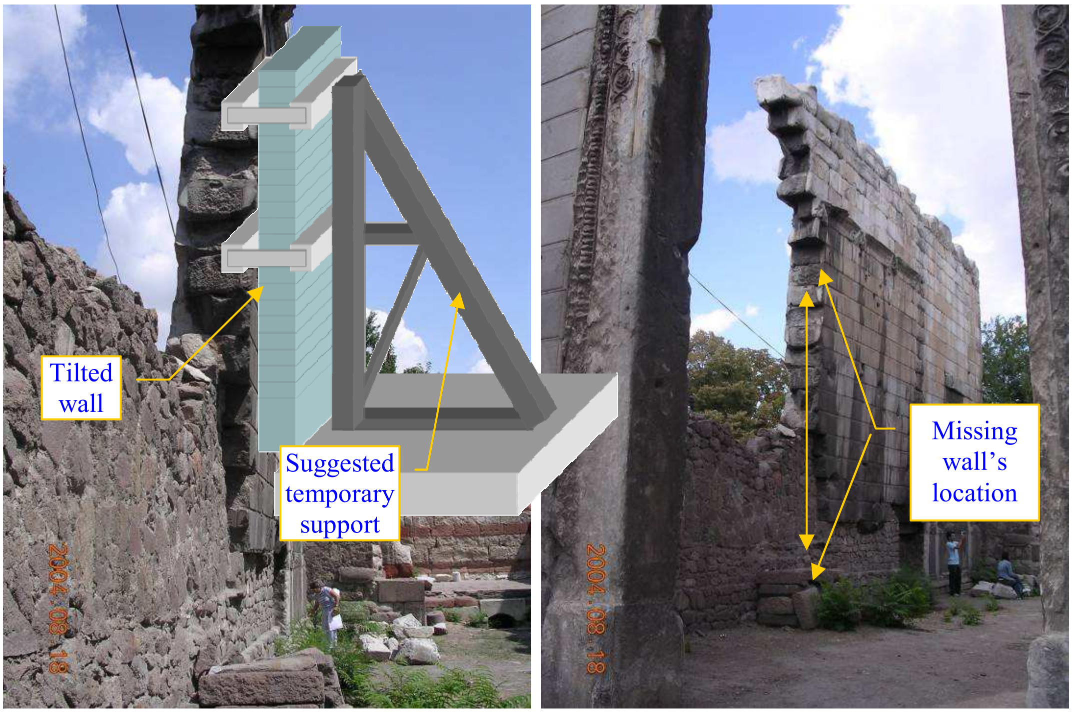

Figure 8:Tilted north wall and emergency support system

Cappadocian gate is located in Yozgat on Kerkenes dag (Fig. 10). The ancient city is the largest pre-Hellenistic site known on the Anatolian Plateau dates back to 7^{th} century BC, covering 2.5 km^2, enclosed by 7 km of strong defensive wall which can be seen from space. The city was burnt and its inhabitants enslaved by Croesus, the Lydian king of Sardis in 547 BC (Summers 2003). Restoration studies are successfully guided by Dr. Summers since 1993. The excavations studies have been recently interrupted with stability concerns regarding of the Cappadocian Gate and a number of dry masonry walls. Similar to the case of the Gordion gate, the dry masonry walls started bulging as they are exposed to environmental conditions.

Difficulties and Problems

Conservation of heritage structures is different and more difficult compared to modern structures. The difficulty mainly arises from the fact that historic structures are unique in many aspects. The authenticity of historic structures does not permit major alterations. The material properties cannot always fully determined, while usually heterogeneous characteristic of the used material changes at different parts of the structure. Previous interventions on historic structures are usually not well documented, which would sometimes cause different material and construction techniques used at different parts of a heritage structure. The aging process is not the same as well for all parts of a structure since dampness from the footing and roof levels, sun exposure, vegetation growth on

different parts varies. All variations and uncertainties in a historic structure is larger compared to modern civil engineering structures; therefore, evaluation, discritization, analytical modeling is difficult. Interventions on a historic structure needs to be reversible and compatible with the existing material and structural system which is not direct and simple in many cases. Additional problems may rise from the fact the site might be difficult to reach, too dangerous to work on (pending collapse), or economical constraints can jeopardize the restoration works. The difficulties and problems are further elaborated below under headings of technical and non-technical issues.

Figure 9: Gordion Gate bulging and gage installation studies

Figure 10: Cappadocian Gate general view; bulging and partial collapse

Technical Issues Restoration/conservation work that would be conducted on a historical structure has to obey a number of technical rules. The use of Portland cement in the 20th century restoration projects was a common mistake which resulted in salt contamination provided that material gets in contact with water or excessive humidity. The current practice has widely abandoned except for a few occasional small uncontrolled cases.

The current practice in conservation of historical structures has a number of primary rules such as use of original or compatible materials. The requirement comes from a logical stem that if incompatible materials are used, the existing and added parts would have difficulty working together under loads and various external effects. For example, if thermal expansion coefficients of two materials are different, these two materials composed together would generate forces on each other during daily and seasonal temperature changes. Steel has thermal expansion coefficient of about 11$\mu\varepsilon$/C, so does limestone and marble in the range of 8-12 $\mu\varepsilon$/C. Mortar in general has 7.3 to 13.5 $\mu\varepsilon$/C, brick masonry 5.5$\mu\varepsilon$/C, and masonry 4.7 to 9$\mu\varepsilon$/C, while Carbon Fiber Reinforced Polimer (CFRP) has very low or negative thermal expansion coefficient in its longitudinal direction (-1 to 0

με/C). On the other hand, expansion coefficient of CFRP has been reported as 22 με/C in the transverse direction (Burkart). UV exposure would also reduce its strength.

Current conservation studies in Turkey started to use CFRP on a trial basis although the long term performance is not well known and there are many indications of pessimistic performance. The CFRP application often times violate “reversibility” criterion in addition to the “compatibility” requirement since the material is glued on the surface using epoxy which is a sticky stiff substance that penetrates into the existing material. The elastic modulus of the CFRP is about 5 times and strength is about 10 times that of steel. Epoxy is usually in contact with stone or mortar and again much more stiff and brittle. The glass transition limit (T_g) of common cold-curing epoxy adhesives show is about 55°C in the first heating and can be accepted to be. CFRP epoxy is about 80 C degree after which it becomes soft; such level of heat can easily be attained at the roofs and domes of structures under direct sun exposure. The contact surface between the existing historical and new strengthening material should be large in order to successfully transfer forces between the two, especially if the new strengthening material has a considerable high strength. If CFRP wraps are placed on historic heritage, the wraps would satisfy large contact area requirement; however, would cover the exterior surface of the structure totally destroying its value and authenticity. If the CFRP is placed as rods which are concentrated at the mortar layer between stones, it is quite possible that large forces by CFRP rods exerted on small areas of mortar would exceed bearing capacity of the material and cut into it. If those problems related to CFRP use could be resolved, CFRP has advantages of high tensile strength, light weight – consequently ease of application, and corrosion resistance. New materials and technologies should be given a chance to be used in historical heritage conservation studies, but always with precaution. Current practice in Turkey mostly relies on lime based mortar and steel reinforcement. Mild steel with low strength and cables with lower elastic modulus is generally preferred.

Non-technical Issues Conservation studies of historical heritage structures may constitute further difficulties due to non-technical issues. One of the most common problems in Turkey is the bidding system for conservator companies taking a certain restoration job from the government (Directorate of Wakfs or Ministry of Culture). The lowest bidding company is granted for the job and the actual expenses of the project might be sometimes higher than that. The contractor might therefore try to use cheaper material, hire incompetent workers for lower cost, or cannot complete the conservation job causing further delays of oftentimes time critical conservation work.

Conservation studies need to accommodate interdisciplinary teams including architects, art historians, structural and geotechnical engineers, geologists, etc. The team members and workers should also be experienced working on historical structures. Otherwise, improper interventions may be proposed and/or actual conservation conducted on site would not be up to the required standards.

The conservation studies in Turkey usually follow the three ‘R’s, which are a) measured drawing (Rölöve), b) Restitution, and c) Restoration steps. Measurement or surveying step is the first step and basically the documentation of a historic structure by using elevation, plan, and critical cross section views, including structural members, visible cracks, previous interventions, decorations, vegetation etc. Each documentation prepared about a historic structure has to be submitted and approved by The Cultural and Natural Heritage Protection Committee (Kültür ve Tabiat Varlıklarını Koruma Kurulu in Turkish), which is connected to the Ministry of Culture and determines the suitability and applicability of a project or drawing in Turkey. The actual field work can only be conducted after being given proper approval and permit. Respecting authenticity and preserving the structure in its current condition except for maintaining overall structural stability and necessity are the major requirements of the committee. Projects prepared by architecture based restoration companies are usually supported by advice and analyses carried out by academicians in the universities. The consultancy work provided by academic personnel has to go through the DOSIM or AGUDOS which are internal revenue offices in the universities. The university overhead and taxes are very high in the order of 50 – 70% of the total payment; therefore, the companies have to pay about three times the fee that they would like to pay for a consultancy work.

The Cultural and Natural Heritage Protection Committee has branches in various cities; nevertheless, overload of projects submitted for evaluation and approval is overwhelming. The

approval process of the projects may take a long time possibly causing critical delays. In a broader sense, bureaucracy is probably a common problem for many countries as well as for Turkey. Slow decisions for emergency situations are not desirable.

TUS (technical application responsibility) permit is owned by a person in charge of carrying out the restoration work following the approved projects, in accordance with the technical specifications, body of current law, scientific rules, with high quality, sound, and safe manner. However, illegal renting the TUS permit to third parties is sometimes encountered, which would not serve its intended purpose.

Ownership of the historical structures is mainly shared between the Directorate of Wakfs (Vakiflar Genel Mudurlugu) and Ministry of Culture and Tourism in Turkey, which might sometimes cause complicated situations like sharing different parts of a historical site by different institutions. Municipalities may also share ownership of some historical structures within the cities, but the ownership is regulated by law and can be passed from one institution to another one.

The conservation studies regarding a historical heritage structure starts and progresses in time. The control mechanism of the ministry involves a number of experienced key personnel who would need to travel the sites with conservation studies and inspect the carried out work is following the approved plans of restoration. The problem is that there are too many restoration sites and a small number of experienced control personnel who are always traveling at various locations in Turkey. The travel budget of the control institution may sometimes experience shortage to make things worse. The head of a department or directors may experience frequent shift of positions while the actual experienced personnel remains in position. The new directors are not always as experienced as the personnel in the conservation studies which might cause some minor problems.

Lack of financial support for a conservation study is a common general problem for many countries. On the other hand, it may also be a catastrophe to find some funding from an exterior source such as a private bank, a large company with good intentions or an international funding agency. Once a financial support is found, the conservation schedule is generally rushed and immediate results are sought since the funding agency usually has a fixed agenda and wants to see immediate results. The mechanics and state of equilibrium that the historic structure has built over centuries can sometimes not well understood and haphazard, disorganized interventions can be proposed and applied. The funders do not seem to understand that there is a stepwise scientific approach to each unique structure with unique combination of problems. Observation (monitoring), lab tests, field tests, application of various methods on a small scale on site and observing the response are among a example few slow steps that needs to be taken one at a time. Such observation, evaluation, testing, and curing process may take many years. A low budget forcing a quick conservation study may end up damaging a valuable historical structure which has survived for centuries.

Conclusions

Conservation of heritage structures in Turkey is a large and well organized practice. The proposed plans of conservation and restoration are controlled at the plan stage up to the standards of internationally accepted rules. The large number of heritage structures, overload on personnel who are in charge of controlling plans and practice, economical constraints on the practitioners are the major difficulties experienced in Turkey. Possible mistakes due to lack of information, qualification, and experience should be overcome by better organization of works and funds.

All variations and uncertainties in a historic structure is larger compared to modern civil engineering structures; therefore, evaluation, discritization, understanding, and analytical modeling is more difficult. Interventions on a historic structure needs to be reversible and compatible with the existing material and structural system which is not direct and simple in many cases. Additional problems may rise from the fact the site might be difficult to reach, too dangerous to work on (pending collapse), or economical constraints can jeopardize the restoration works.

The interventions on historic structures should be well investigated and applied with care. Use of incompatible materials and irreversible applications should be avoided. Non-technical issues may

sometimes become as important as the technical difficulties for the conservation of historical structures. Economical problems such as lack of funding may sometimes be better for a heritage structure, if a funding would force not well thought and fast conservation/restoration work that may end up further damaging it which has survived for centuries on its own. Proper and continuous maintenance is very important and sometimes evacuated heritage structures for conservation purposes end up being deteriorated and damaged beyond comprehension in a short time since the evacuated occupants could no longer be maintaining the structure.

Monitoring should be an integral part of understanding the behavior of a historical structure; a serious looking damage may not be that important whereas a hidden problem can be very important for the structural integrity and safety of a structure. For example, a large crack may be a natural expansion joint whereas injecting and filling it may end up damaging other parts of a structure due to seasonal temperature changes exerting large forces on the structure. If the monitored state of a "problem" is stationary over time, perhaps the best approach is "do nothing".

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