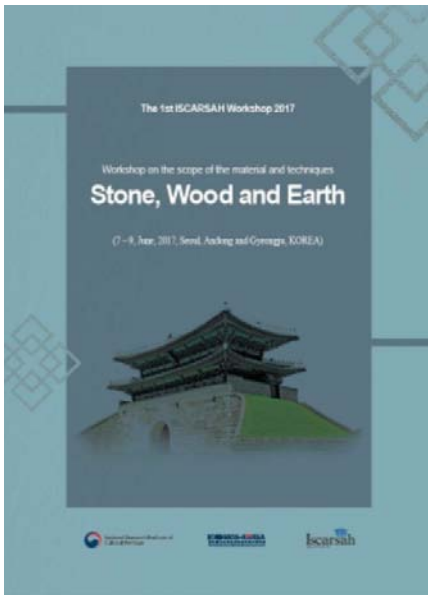
Iscarsah
International Scientific Committee on the Analysis and Restoration of Structures of Architectural Heritage

15-16-17

newsletter
April-December
2017

ICOMOS
International Council on Monuments and Sites
Conseil International des Monuments et des Sites

ISCARSAH Meeting, Seoul.



The information Book.

Sungnyemun Gate, Seoul.

Report 2017

Görün Arun, President of ISCARSAH

In 2017, we made two meetings; in Seoul, Korea on June 6th, 2017 and in Delhi, India on December 9th, 2017 during ICOMOS General Assembly.

2017 ISCARSAH meeting was in National Palace Museum of Korea in Seoul. On 7th June, there was a very nice welcome dinner at the President Hotel (Mozart Room) in Seoul. During the dinner, performance of Young Jeongjae Gukak Hui was very interesting.

During 7-9 June, ISCARSAH, ICOMOS Korea and National Research Institute of Cultural Heritage (NRICH) organized a workshop on "The Scope of the Material and Techniques of Stone, Wood and Earth" on World Heritage Sites in Korea.

Three heritage sites: Sungnyemun Gate, Heunginjimun Gate and Juhamnu Pavilion of ChangDeokGung Palace e in Seoul, two heritage sites; Seven-story Brick Pagoda at Beopheungsa Temple Site and Imcheonggak House, Andong, five heritage sites; Cheomseongdae Observatory, Dabotap Pagoda of Bulguksa Temple, Three-story Stone Pagoda of Bulguksa Temple, Wolseong Archeological Palace Site and Jjoksaem Archeological Site in Gyeongju were chosen for workshop visiting places. 10 expert members including ISCARSAH members were invited to Korea to take part in the workshop.

Korean colleagues had prepared very nice book of information about the history, drawings, the tests they made and the results of the tests on the monuments and sites to be visited. To read the information before visiting to the sites was very useful.

Every evening of the visits, there was a time for discussion about the views of the colleagues on the problems and/or solutions they observed.

On 7th of June we visited Sungnyemun Gate, Heunginjimun Gate and Juhamnu Pavilion of Changdeokgung Palace in Seoul.

Sungnyemun Gate, a wooden two-story south gate of the fortress of Joseon, was first built during 1396-1399. This is known by its another name Sungnyemun Gate. The gate was renovated in 1448 and later between 1961 and 1963. The building had severe damage to its entire structure by an arson attack in 2008. The gate restored in 2013 was reopened to the public.

Heunginjimun Gate, a two-story wooden gate at the east of Seoul fortress wall, was first constructed in 1398. This is also known as Dongdaemun Gate. This is the only gate of the wall to have a semi-circular barbican built both for defensive purposes. The gate was repaired in 1453 and 1869.

Juhamnu Pavilion of Changdeokgung Palace is one of the three palace pavilions built around Buyongji Pond in the rear garden of Changdeokgung Palace. This two-story wooden building was designed as royal library to store the king's writings at the lower story and as observation of the natural beauty of the surrounding at the upper story.

On 8th of June, we travelled to Andong and visited two heritage sites; Seven-story Brick Pagoda at Beopheungsa Temple Site and Imcheonggak House. And travelled to Gyeongju to overnight.

Seven-story Brick Pagoda at Buddhist Beopheungsa Temple Site is 17 m tall and it is the largest and oldest brick pagoda in Korea. The pagoda's base stands on a single-story platform, and is made of firmly cumulated bricks. It is estimated that the brick pagoda was built by imitating the appearance of wooden pagodas.

Imcheonggak House, a wooden house complex was constructed in 1515. During the construction of the Central Railway Line, some fifty buildings of

INDEX

Report 2017
Görün Arun (President of ISCARSAH) 1

Scientific reports
Christos Tsatsanifos, *Building in Ancient Cities: Geotechnical Engineering Challenges* 3
Maria Bostenaru Dan, Marina Mihăilă, Alex Dill, *Romanian Contribution to COST TD 1406 "Intelligent Management of Heritage Buildings"* 23
Orestes Modesto del Castillo del Prado, *Las Escuelas nacionales de Arte y su importancia en la vida de la República de Cuba* 28
Marek Skłodowski, Mónica Alvarez de Buergo, Gonzalo Barluenga, Rafael Fort, *Assessment of mechanical properties of the historical bricks of Burgos gate in Alcalá de Henares in Madrid* 32
In-Souk Cho, *ISCARSAH Workshop Korea 2017 Report* 37

Iscarsah

International Scientific Committee on the Analysis and Restoration of Structures of Architectural Heritage

website:
http://iscarsah.org

facebook:
https://www.facebook.com/pages/ISCARSAH/263710868630

linkedin:
http://www.linkedin.com/groups/ISCARSAH-Structures-Architectural-Heritage-3930057

Newsletter n. 15-16-17
April - December, 2017
ISSN 2306-0182

Editor: María Margarita Segarra Lagunes
Via Emanuele Filiberto, 190
00185 Roma (ITALY)

email: structurescommittee@gmail.com

the servant's quarters and various attached houses were torn down. Gunjajeong Pavilion of Imcheonggak House was designated as a treasure.
On 9th of June, five heritage sites; Cheomseongdae Observatory, Dabotap Pagoda of Bulguksa Temple, Three-story stone Pagoda of Bulguksa Temple, *Wolseong Archeological Palace Site* and *Jjoksaem Archeological Site* in Gyeongju. In the afternoon, we travelled back to Seoul and attended the Farewell Dinner of the workshop in another heritage site, Mungyewon in Seoul.
Cheomseongdae Observatory, 9 m high stone cylindrical body with a platform, and a square top, is the oldest astronomical observatory in Asia and is widely regarded as a precious cultural heritage.
Dabotap Pagoda and *Seokgatap Pagoda* of Bulguksa Temple are National Treasure.
They are similar in height (10.29 m and 10.75 m). It is presumed that the pagoda was built in 751 during the construction of Bulguksa Temple. Three-story stone Pagoda of Bulguksa Temple and Dabotap Pagoda are National Treasure. The three-story body of this stone pagoda stands on a two-story platform. Due to the large crack in upper basement stone appeared suddenly in December 2010, the pagoda was totally dismantled and restored from 2011 to 2016.
Wolseong Archeological Palace Site constructed in 101 A.D. was the capital fortress where the royal palace of Silla was once located. Since Dec. 2014, excavation and related research is underway by Gyeongju National Research Institute of Cultural Heritage (GNRICH). Total area of excavation is 222,528 m^2. Until today, lots of building sites, wall, moat and relics were excavated.
Jjoksaem Archeological Site is located in the east side of Tumuli Park where there are cemeteries of Silla royal families. Jjoksaem tomb is stone-piled wooden chamber tomb built above ground.
The ISCARSAH members prepared reports or articles on the places visited. NREC is going to translate these articles into Korean language and publish them in the NREC Journal and as a book of reports in 2018.
This year ICOMOS General Assembly (GA2017) was in India Habitat Center in Delhi, during 7-15 December 2017. In this occasion, 9th of December morning ISCARSAH meeting took place. During the meeting, Mehrdad Hejazi proposed to make one of the 2018 ISCARSAH Meetings in Iran accompanied by a training on Heritage Structures. In the afternoon of 9th December, 2nd ISCARSAH, ICORP and CIPA joint meeting and symposium took place. In the joint meeting, after each Scientific Committee introduced themselves; oral and poster presentations were made. On 10 December, the group joined the Reception dinner of the 2017 GA offered by Aga Khan Trust. The reception was in Sanscriti Museum, Anandagram. Quwwali Music Performance was the highlight of the evening.
Next year we hope to meet in different heritage sites in Iran.

Imcheonggak House; Jjoksaem Archeological Site.

Jjoksaem Archeological Site.

2nd ISCARSAH, ICORP and CIPA joint meeting, Delhi (India).

Building in Ancient Cities: Geotechnical Engineering Challenges

XVI Prague Geotechnical Lecture (May 26, 2008)
Academy of Science of the Czech Republic

Christos Tsatsanifos
Managing Director, Panagea Consulting Engineers LTD
pangaea@otenet.gr

1. Introduction

«My first contact with the ancient city of Sparta, buried under the new city, comes from my childhood. I was at the first year of the elementary school when a marble vase was found during the excavations for the foundation of a new building at the field next to our house. In a very short time the head of the Archaeological Service arrived and he started to caress it, like being his erotic companion. The intensive excavation stopped and a slow and careful excavation started by the workers of the Archaeological Service. And in a few days the ruins of a building of the roman era, according to the specialist, appeared. The site remained as a field for a long time after, to the delight of the children of the neighbourhood, who were playing there. I recall that I wondered at that time, with my childish thought, why the ancient people were burying these wonderful things under the ground. The answer came a few years later from my teacher, who was talking to our class for the "privilege" of the new Sparta to have been built over the ancient one. He was also talking about her past history, the catastrophic earthquakes, which buried her under the ground and about her historic phases, which are depicted from the archaeological excavations' findings […].

Today, after many many years, I confess that I am not in a position to say if it is a "privilege" of having the new Sparta built over the ruins of the old city. For certain the Spartan land hides in her bowels a very important part of her historic past and I believe that it is our duty and concern to bring it up "to the air". However this common effort should not be an obstacle to the progress and growth of the city of Sparta» (Matalas, 1994).

The above paragraphs are the preface of the Mayor of the city of Sparta at the proceedings of the conference held there in 1994 under the title *New Cities over Old Cities – The Example of Sparta*. However, these words could be the words of many Greeks, all over the country, including the author. The majority of the major Greek cities have been built over the ancient ones, some of them over a series of old cities (modern over medieval, medieval over Byzantine, Byzantine over ancient, ancient over prehistoric, prehistoric over Neolithic etc.).

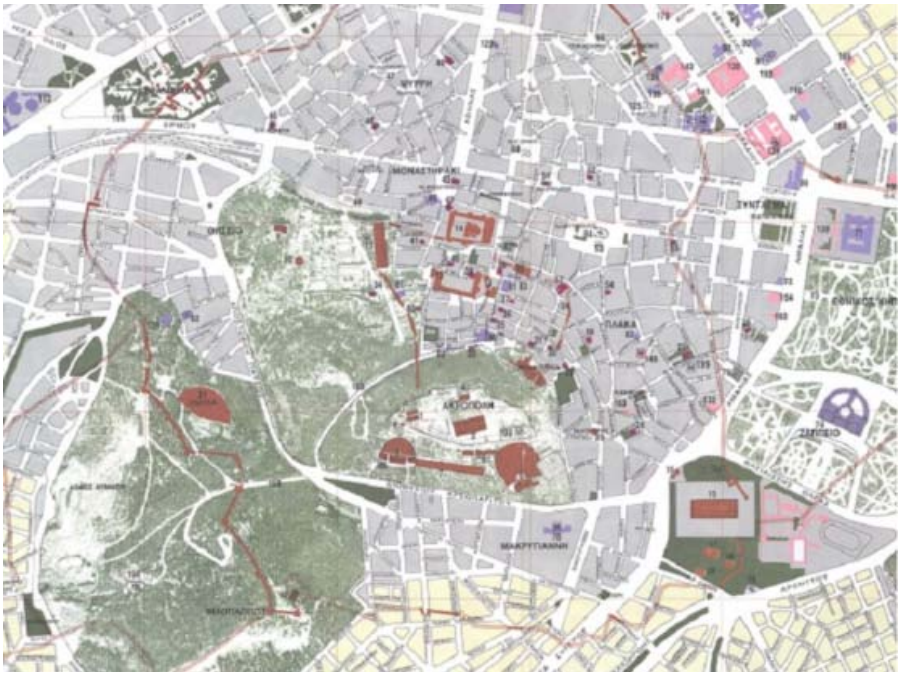


Fig. 1. Major archaeological sites in the centre of Athens.

The existence of antiquities in the ground environment in urban areas makes it unfavourable for the developer, mainly for two reasons: Firstly because there is a demand that the archaeological resource, if significant, be preserved in situ and secondly because the need for construction of new buildings and other structures next to existing monuments and historic buildings pose, most of the times, significant construction difficulties. In both cases innovative engineering solutions are required to overcome these difficulties.

Athens, a large modern city with a history of more than 5,200 years (starting in prehistoric period, around 3200 B.C.) and one of the largest economical, political and cultural centres of antiquity, holds into its substratum an archaeological treasure. Fig. 1 shows the major archaeological sites in the centre of Athens and among them the walls of the city constructed in the 5th century B.C. by Themistocles. Experience has shown that practically there is no square metre within the walls where shallow excavations will not find ancient ruins.

Any excavation in the centre of Athens is supervised by the archaeological service and, depending on the significance of the ruins and the cost of the land expropriation (if they are found in a private property), decision is made whether they should remain in situ, either in the open air or in the basement / ground floor of the new building to be visited, or can be moved or can be thoroughly backfilled and build on top of the fill without destroying them. Of course, there are many cases

where the construction of the new building was completely cancelled because of the significance of the antiquities found.
It is obvious that in the case where the antiquities are kept visit able under the new buildings, the role of the geotechnical and structural engineers is very significant, since they have to design the foundations without destroying the antiquities and the immediate superstructure in a way that permits the nice display of the antiquities. Similarly, the construction of a new building next to a monument or a historic building requires elegant geotechnical design in order to avoid damaging the monument. Finally, the preservation, the restoration or the rehabilitation of an old structure poses many challenges to be solved by the geotechnical engineer.
The geotechnical interventions in the process of building in ancient cities range from simple measures as thorough backfilling the antiquities, to complex applications as micro piling and fore poling under the antiquities or ground movement control using integrated hydraulic jacks to push back retaining walls. In this paper the general principles of intervention in ancient structures and a quick review of the methods for the geotechnical intervention in monuments are presented, as well as examples of the contribution of geotechnical engineering for solving problems related to preservation, restoration and rehabilitation of monuments and historic buildings in ancient cities, some from the authors' experience, some from the literature.

2. General principles of intervention in ancient structures. The authenticity principle for the foundations

The principles on the conservation and restoration of monuments were initially set at the 1st and 2nd International Congresses of Architects and Technicians of Historic Monuments held in Athens (1931) and Venice (1964) respectively, which adopted the so called *The Athens Charter* and *The Venice Charter*.
The Athens Charter introduced the word anastylosis as defining the conservation method that intends to keep the authenticity of the monuments: «In the case of ruins, scrupulous conservation is necessary, and steps should be taken to reinstate any original fragments that may be recovered (anastylosis), whenever this is possible; the new materials used for this purpose should in all cases be recognizable».
Later on, in *The Venice Charter* it was stated that «The process of restoration is a highly specialized operation. Its aim is to preserve and reveal the aesthetic and historic value of the monument and is based on respect for original material and authentic documents […] Where traditional techniques prove inadequate, the consolidation of a monument can be achieved by the use of any modern technique for conservation and construction, the efficacy of which has been shown by scientific data and proved by experience». In other words, anastylosis is nothing more than a reassembly of «existing» but «dismembered parts» which could be put together again provided that the material used for integration is always identifiable. Furthermore, «its use should be the least that will ensure the conservation of the monument and the reinstatement of its form» (Dimacopoulos, 1985).
The authenticity principle was concluded in *The Nara Document on Authenticity*, drafted by the participants at the Nara Conference on Authenticity in Relation to the World Heritage Convention, held at Nara, Japan, 1-6 November 1994. Accordingly, the authenticity should be determined in a manner respectful of cultures and heritage diversity to include any variation of the regional tradition of conservation of heritage.
According to *The Athens Charter* and *The Venice Charter* and *The Nara Document on Authenticity*, reconstruction is to be «ruled out *a priori*». However, reconstruction is extensively used for the «restoration» of ancient monuments in some parts of the world.
Generally, the authenticity has been discussed for the superstructures of historic monuments and not for their foundations. Interventions on the foundations have not usually been deemed necessary, while, some times, the foundations were not considered as one of the elements that constitute historic monuments.
However, there are many examples where either the type of the foundation was developed in some special way according to regional characteristics, or the foundation itself was historic heritage. In these cases, the type of the foundation might be preferred to keep its originalities.
Based on the authenticity and anastylosis principle, one could argue that also in the case of foundations only repositioning of all of the original material is allowed for the restoration of monuments, however minute in size, to which only a limited number of new pieces, always identifiable should be added as absolutely necessary for the operation.
However, over the years of the life of the monument, disrupting agents introduce changes in the prevailing geotechnical conditions of the site. «Natural agents like torrential rains, flooding or earthquakes, even tsunamis in coastal areas, may reduce shear strength or increase applied stress leading to bearing capacity failures. Antropic agents can be equally disrupting and are mainly related to man – induced changes in water content within soil masses like leakage from cisterns, sewage water supply lines, construction of dams or channels, or, among others, excavations in neighbouring sites, construction of buildings in the vicinity or tunnelling under the monument» (Ovando-Shelley, 2005).
Hence, the complete compliance with the authenticity and anastylosis principle is not always possible and major interventions have to be made in order to strengthen the foundation of the monument.
In his draft on the TC19 Guidelines - General Principles of the Interventions, D' Agostino excellently presents the necessary procedures for the interventions on the monuments' foundations having in mind the authenticity and anastylosis principle (D' Agostino, 2005). He states: «[…] it is necessary to analyse the global stability of the soil-structure unit, and of its immediately surrounding area. If the results are not satisfactory, stabilization measures need to be taken. Such stabilizations measures, however, should not modify the soil-structure relation and they must respect any archaeological finds that may be present.
Interventions on the foundations will have to seek to be uniform throughout the load-bearing area, with preference being given to the conservation of the existing foundation structures. In general, with a view to the best possible soil-struc-

ture relation, and assuming that there are no archaeological finds, it is preferable to consolidate the foundation system applying modern geotechnical engineering methods of analysis and techniques.
The use of piles or micro-piles is to be avoided as they significantly alter the construction design and the state of stress of the underpinned structure and they require the introduction of extraneous structures for the distribution of loads into the ancient ones. Moreover, a different behaviour is induced between the underpinned zones and those where the original foundations have been saved, and this has often proven to be the cause for future structural damages. And finally, using piles definitively alters the location of the building itself and conceals forever any archaeological find that were to be present.
Where there are archaeological items and the foundations are in need of support (or reinforcement), the existing structures will have to be underpinned. Great care needs to be exercised in perfectly identifying the portions to be underpinned, and in carrying out the excavations».

3. Methods of Geotechnical restoration of monuments

The main reasons for which the restoration of a monument is required are either the uneven settlements, which the monument may have presented, or the low bearing capacity of the foundations, compared to the loads which will be applied.
Stabilization measures concerning either the subsoil or the foundation of the monument may be attained by means of one of the following methods (or combination thereof) (Ulitsky, 2005):
• Repair of the existing foundation, which contain imperfections or defects.
• Strengthen the existing foundation body by its extension or addition of new footings and shear beams connecting the footings. In this way the existing foundation could also stiffened and the foundation bearing area is increased.
• Increase the footing level of the foundation.
• Provide a slab underneath the monument or a box-type foundation in the underground area of the monument.
• Provide additonal supports.
• Underpin the foundations by means of oscillated piles or bored piles constructed through the body of the foundation.
• In case of pile foundations extend the pile caps or rafts to provide additional bearing capacity and stiffness.
• Improve the subsoil (cementation, silication, chemical and electro-chemical strengthening, high pressure grouting capable of stabilising the soil mass, deep soil mixing, etc.).
In addition to strengthening measures, further stabilization measures could include:
• Underexcavation.
• Induced changes in the pore water pressures by local injection of water or by electro-osmosis.
• Isolation or separation trenches between new and existing building monument.
From the above methods only those of strengthening of the foundation body, increasing of the foundation bearing area, increasing of the footing level of the foundation, underexcavating and using isolation or separation trenches seem to comply with the authenticity and anastylosis principle. The rest, in one way or another, alter either the soil conditions or the original soil-structure system.
Poulos (2005) proposed the division of the methods for correcting the uneven settlements of monuments-'buildings' foundations into two broad categories:
i. **"Hard"** methods, which rely on the application of some form of direct force to the building, like:
- Application of force by anchor stressing;
- Application of additional loading;
- Cutting of piles, in the case of deep foundations;
- Jetting of the soil beneath the pile tips;
- Jacking of the foundation on the "low" side;
- Fracture grouting.
ii. **"Soft"** methods, which rely on processes which produce corrective foundation movements by inducing appropriate ground movements, like:
- Soil extraction;
- Dewatering;
- Compensation grouting;
- Removal of soil support;
In any case, in treating the foundations of monuments, it is advisable to follow the general recommendations provided by *The ISCARSAH Charter* (International Scientific Committee for Analysis and Restoration of Structures of Architectural Heritage) of ICOMOS (International Council on Monuments and Sites) (ISCARSAH, 2001):
• Each intervention should be in proportion to the safety objectives set, thus keeping intervention to the minimum to guarantee safety and durability with the least harm to heritage values.
• The design of intervention should be based on a clear understanding of the kinds of actions that were the cause of the damage and decay as well as those that are taken into account for the analysis of the structure after intervention; because the design will be dependent upon them.
• The choice between "traditional" and "innovative" techniques should be weighed up on a case-by-case basis and preference given to those that are least invasive and most compatible with heritage values, bearing in mind safety and durability requirements.
• Each intervention should, as far as possible, respect the concept, techniques and historical value of the original or earlier states of the structure and leaves evidences that can be recognised in the future.
• Intervention should be the result of an overall integrated plan that gives due weight to the different aspects of architecture, structure, installations and functionality.
The authenticity principle can be somehow violated in the case of interim or temporary remedial measures. For example, ballast, applied on certain areas in a monument or next to it to introduce corrective settlement to compensate inclinations and tilts, is conceived as a temporary solution (e.g. at the Tower of Pisa and at many buildings in Mexico City) (Almatzi, et al. 1997).
Finally, Iwasaki (2005) proposed to consider the following factors in the process for the evaluation and selection of the intervention method: cost, easiness, reliability and authenticity.

4. Case studies. Building next, over or under antiquities and historic buildings

4.1. Antiquities and Historic Buildings and the Athens Metro Construction

The design and construction of an

Fig. 2. Filling material of the Well No. 68 along the Line 3 of the Athens Metro.

Fig. 3. Exhibition of antiquities in the Athens Metro Stations.

underground Metro system in a city as Athens is certainly a complicated project with much more difficulties than usual. So, special design and construction solutions must be considered, due to the existence of precious archaeological remains over and underground.

To avoid as much as possible meeting antiquities and to minimize their influence in the construction activities, the Athens Metro tunnels were and are excavated at a depth below the "archaeological depth", i.e. below the depth up to which antiquities are anticipated (usually ranging from 10 m to 15 m). So, the expected problems are restricted mostly to the locations of the stations.

The geotechnical investigations were designed having in mind the problems and restrictions arising from the expectance of antiquities, however, due to their density near the ground surface, there were numerous cases of problems created due to their presence, as these described hereafter.

The main obstacles that the tunnels met were various ancient cavities, originally wells or cisterns, the filling material of which tumbled onto the tunnel floor as soon as it was disrupted. In antiquity, after the cavities had stopped being used, they became a dumping ground for useless everyday objects, which probably originated from the clearing of surrounding areas. The usual solution to this problem was the filling of the cavities with concrete, after removing all the findings.

For example, during the construction of the tunnel from the Acropolis Station and to ensure the safe passage of the large tunnel-boring machine used, a pilot tunnel was dug.

Starting from the station, it divided into two sections, which were approximately 300 m long each and headed north and south. The work was executed by conventional means and under archaeological supervision.

On their route, the excavation crews came across the Well No. 68. As soon as the tunnel reached the well, the material, that was filling it, fell into the tunnel. It contained a great number of pots, intact or in pieces, primarily of the Byzantine era (Fig. 2). 133 almost intact pots were gathered (stamnia, laginoi, phlaskia, amphorae, oinochoes), as well as hundreds of shells from other clay pots, small bone objects and fragments of sculpture and of architectural members. Additionally, loom weights, pieces of oil lamps, bones, shells etc. were found.

A thorough archaeological investigation followed and then the cavity was filled with concrete for the safe passage of the TBM.

During the excavation of all the central stations of the Athens Metro antiquities were found. In all the cases except one a thorough archaeological investigation preceded the main excavation and the antiquities found within the limits of the excavation were moved to the museums, while some of them are displayed in glass showcases in the stations (Fig. 3), sometimes as they have been found *in situ*. In the case of the *Kerameikos* Station, due to the density of the antiquities and their significance, the location of the station as well as the alignment of the tunnel was changed.

Regarding the problems associated with historic buildings over the tun-

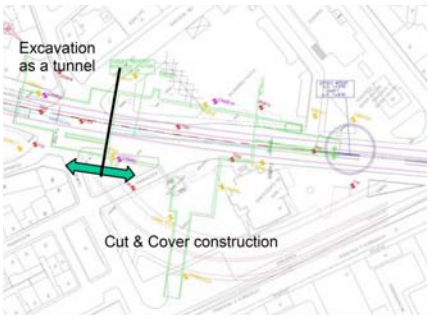


Fig. 4. Ground plan of Athens Metro *Peristeri* Station.

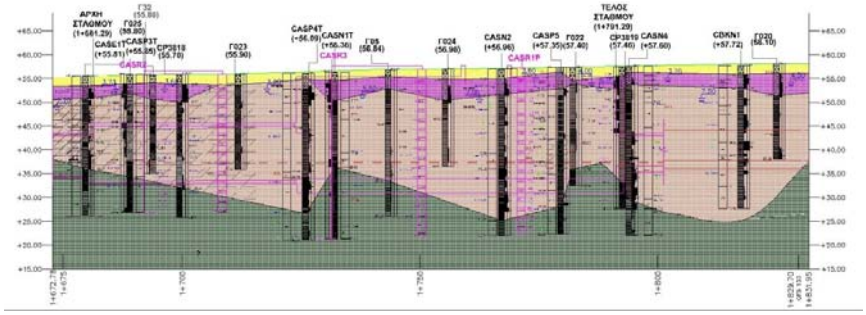
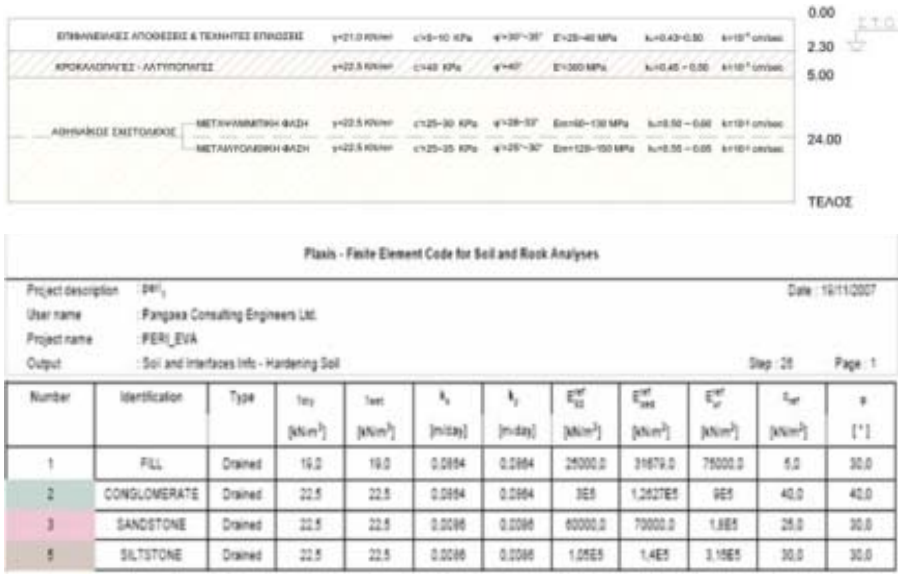


Fig. 5. Geological section along the *Peristeri* Station (Yellow: surface deposits, Magenta: conglomerate – breccia, Pink: Athenian Schist – Sandstone phase, Deep Green: Athenian Schist – Siltstone phase).



Number	Identification	Type	γ_{unsat} [kN/m³]	γ_{sat} [kN/m³]	k_x [m/day]	k_y [m/day]	E_{50}^{ref} [kN/m²]	E_{oed}^{ref} [kN/m²]	E_{ur}^{ref} [kN/m²]	c_{ref} [kN/m²]	φ [°]
1	FILL	Drained	19.0	19.0	0.0864	0.0864	25000.0	31679.0	75000.0	5.0	30.0
2	CONGLOMERATE	Drained	22.5	22.5	0.0864	0.0864	3E5	1.2627E5	9E5	40.0	40.0
3	SANDSTONE	Drained	22.5	22.5	0.0086	0.0086	60000.0	70000.0	1.8E5	25.0	30.0
5	SILTSTONE	Drained	22.5	22.5	0.0086	0.0086	1.05E5	1.4E5	3.15E5	30.0	30.0

Fig. 6. Geotechnical section along the Athens Metro *Peristeri* Station.

nels or close to the stations, the main concern was to minimize the deformations due to the excavation of the tunnel or of the station to the acceptable level for each structure. The structural engineers had estimated these deformations and the geotechnical engineers had to design either the tunnel lining or the support of the walls of the stations' open excavation to result in smaller deformations.

An example of a complex, in geometry, station next to a historic building, with a combination of support methods is that of the *Peristeri* Station at the north-west extension of Line No 2.

Fig. 4 shows the plan of the excavation, Fig. 5 the geological section along the station and Fig. 6 the geotechnical section used for the design of the support of the excavation's walls.

The geological and geotechnical sections were based on the results of detailed geotechnical investigations consisting of boreholes (their locations are shown), *in situ* tests (standard penetration tests and pressure meter tests) and laboratory tests.

In the process of evaluating the results of the investigations, the modulus of deformation, obtained from the pressure meter tests, were compared with its estimations based on the procedure using the Geological Strength Index – GSI, as proposed by Hoek and Diederichs (2006).

The relationship between the rock mass deformation modulus E_{rm} and GSI is based on a sigmoid function. They have proposed two forms of the relationship.

The simplified equation depends on GSI and D (disturbance factor to account for stress relaxation and blast damage) only and it should only be used when no information in the intact rock properties are available.

The more comprehensive equation includes the intact rock modulus, which, if not available, could be estimated from the intact rock strength σ_{ci} and a modulus reduction factor MR, $E_i = MR \cdot \sigma_{ci}$.

Simplified Hoek and Diederichs equation:

$$E_{rm} = E_i\left(0.02 + \frac{1 - D/2}{1 + e^{((60+15D-GSI)/11)}}\right)$$

Hoek and Diederichs equation:

$$E_{rm}(MPa) = 100\,000\left(\frac{1 - D/2}{1 + e^{((75+25D-GSI)/11)}}\right)$$

It has been found that in rock masses like the Athenian Schist, a flysch formation, depending on the assumption on the values of Ei or σci to be used, the rock mass deformation modulus could extremely vary. Hence, the estimated deformations of the structure to be constructed or the retained neighbouring structures may vary considerably.

The Athenian Schist in this specific location appears as a rock mass of very poor to medium quality (GSI ranges from 10 to 60), while there are locations where it is completely altered ("soily"). The question that arises is what is considered as intact rock in such case and how can we measure the E_i or σ_{ci} of this intact rock. It was suggested that when dealing with heavily weathered and/or heavily fragmented rock masses the MR or σci should be taken from the literature. Applying values of σ_{ci} and MR from the literature led to big discrepancies between these estimations of the rock mass deformation modulus and the pressure meter's measurements. On the contrary, when average σ_{ci} values from uniaxial compression tests on weathered-altered rock specimens were used, the estimations of the rock mass deformation modulus were in very good agreement with the pressure meter's measurements. The response of the structures to the excavation supports the later finding; hence the assumption on

Fig. 7. General view of the excavation of the *Peristeri* Station.

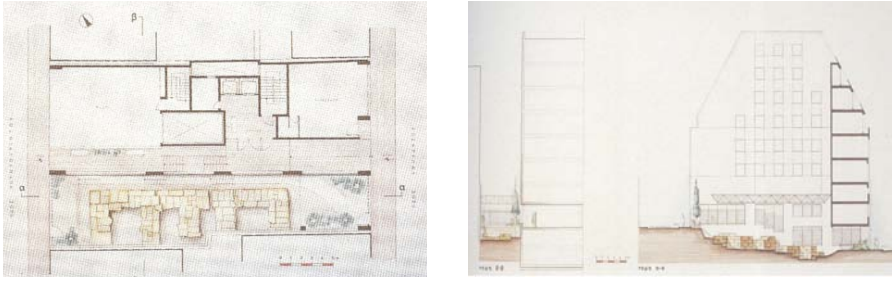
the intact rock strength needs a modification.
The excavation for the construction of the *Peristeri* Station (see Figs. 4 and 7) has a depth of 25.35 m, length of 112.25 m of which 67.67 m are constructed with the cut & cover method and 44.58 m would be tunnelled and width ranging from 21 m to 32 m.
To design the temporary support system an extensive series of parametric elastoplastic analyses was conducted using the computer code PLAXIS. The support system consists of the following:
• Bored piles of Ø 1000 mm diameter every 1.50 m, with 30.00 m length (4.65 m embedment), constructed with C 25 / 30 reinforced concrete.
• Pile cup beam from C 25 / 30 reinforced concrete. The dimensions of the pile cup beam vary depending on the applied loads from place to place, the main load being that from the truss, where applied.
So, the width and the height of the pile cup beam is 1.20 m x 1.00 m where only ground anchors are used for the support and 1.50 m x 1.20 m where a truss is based on the pile cup beam.

4.2. Harmonic Coexistence: The Filon Warehouse (340 BC) and a Contemporary Office Building

During the preliminary investigations for the construction of an office building at Piraeus, the port of Athens, in 1989, the foundations as well as important architectural parts of the north end section of the Filon Warehouse were found. The warehouse was designed by the famous architect from Elefsis Filon and was constructed during the period between 340 BC and 330 BC. It was a long two storey building, with a length of 132.5 m and width of 18 m and it was storing the gear of 1,000 ships, according to Pliny. The warehouse was destroyed in 86 BC by the Roman general Syllas.
Since the expropriation of the land was very expensive but the antiquities were considered of great importance, the decision was made leave the obligatory free space (30% of the total area of the land) to the side of the antiquities and to erect the building at a distance of 1.30 m from the warehouse foundations, using this corridor as access to the archaeological site (see Figs 9 and 10). Furthermore, the section of the building's ground floor neighbouring the antiquities was left open (pilotis), thus permitting the optical contact to the antiquities to everybody walking along the building (Boubiotis & Floros, 1994).
From the geological point of view the area of the building is covered by the Neocene geological formation named "Piraeus Marl", consisting of lime marl, marly limestone, lime or / and marly sandstone and conglomerate, however the marl or marly limestone phases prevail. The strength of the marl phase of the formation (q_u = 150 ÷ 500 kPa) permits the excavation of vertical slopes of considerable height without any support, providing

Fig. 8. The excavation support system of the *Peristeri* Station next to the Evaggelistria Church.

that it retains much of its original water content, otherwise it desiccates to soil.
For the construction of the building the excavations reached a level of three to six meters below the antiquities with vertical stable slopes. To maintain the stability of the slopes the simplest measure was to protect them from loosening their original humidity by covering them with polythene sheets.



Figs. 9 and 10. Ground-plan and sections of the office building and the Filon's warehouse antiquities.

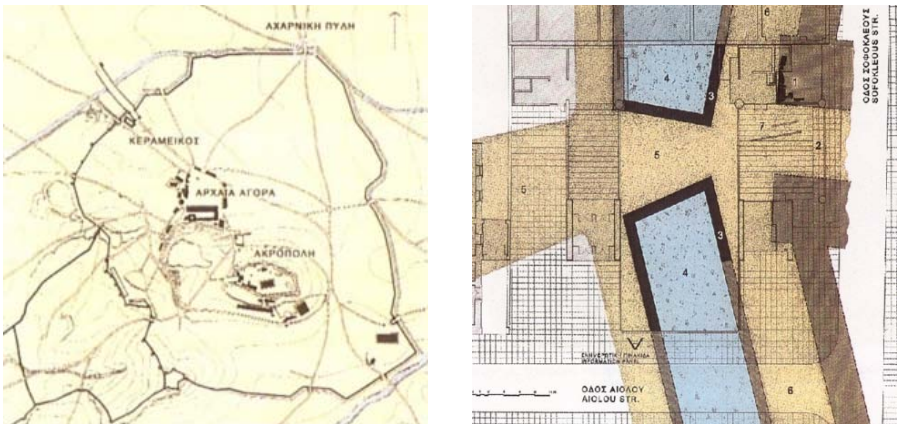


Fig. 11. Location of the Acharnian Gate and the antiquities found at the site of the National Bank of Greece Administration Building.

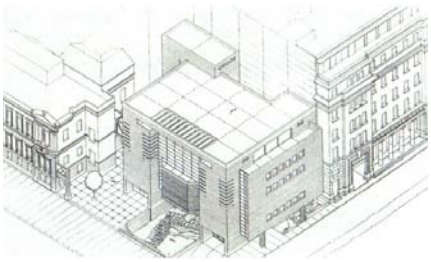
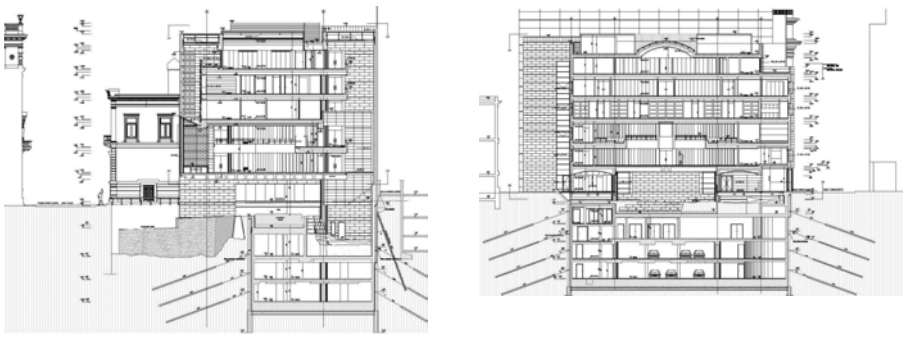


Fig. 12. Drawing of the National Bank of Greece Administration Building with the antiquities preserved in the ground floor – basement.

Fig. 13. Ground – basement plan of of the National Bank of Greece Administration Building.



Figs. 14 & 15. Cross sections T1 and T4 of the National Bank of Greece Administration Building with the antiquities preserved in the ground floor – basement. The underground floors below the antiquities are also shown.

4.3. The National Bank of Greece Administration Building and the Acharnian Gate

The archaeological excavation prior to the construction of the new administration building of the National Bank of Greece (Karatzas Building) at the centre of modern Athens brought to light important antiquities concerning the approach to the most important Acharnian Gate of the ancient Athens circuit wall (location 2 at Fig. 11).
Scanty remains of the city wall (most likely foundations of a tower – location 1) as well as extended parts of the front rampart (proteichisma – location 3) and the moat (tafros – location 4) were discovered. An ancient road (location 5) was also found preserving on its surface the grooves of cartwheels (location 7). The road crosses the peripheral road (location 6) of the circuit wall and intersects the front-rampart and the moat. It is identified with the ancient road from Athens to Acharnai. The archaeological excavation started in 1974, while the design of the building started in 1997.
The preservation and the exhibition of the antiquities were prerequisites for constructing the building at this site. This, combined with the other operational prerequisite that the building should have underground floors formulated a serious geotechnical problem, requiring innovative solution to be overcome.
The building was designed taking into account these requirements. Fig. 12 shows a drawing of the building with the antiquities preserved in the ground floor – basement, Fig. 13 the ground – basement plan and Figs. 14 & 15 the cross sections T1 and T4 with the antiquities preserved in the ground floor – basement.
The construction of the building started with the construction of the temporary support of the excavation slopes and of the antiquities.
The final depth of the excavation would be at -14.50, with the top of the antiquities at -0.50 to -1.40 and the bottom at -2.60, while the anticipated foundation level of the ancient city wall was at -6.00.
In order to create a working platform for the construction of the temporary support, the whole site was filled with earth materials up to

Fig. 16. Protection of the antiquities before earth filling.

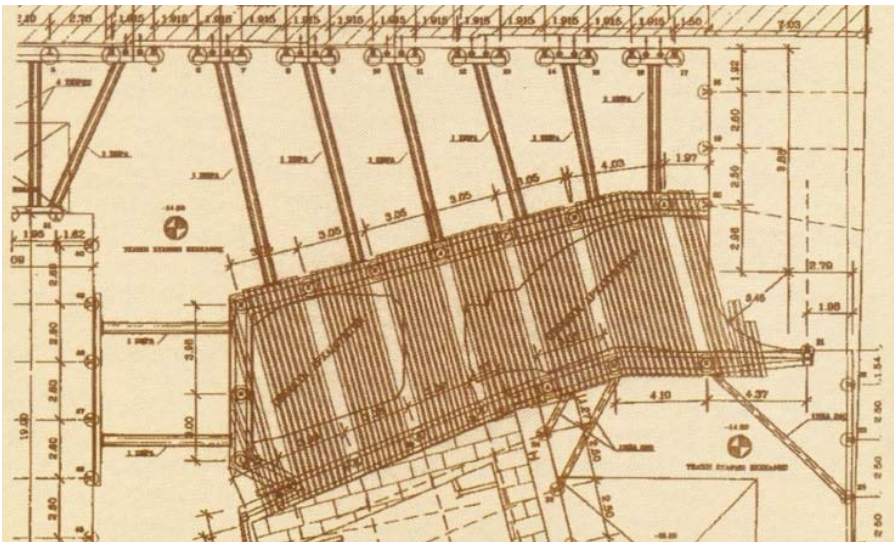


Fig. 17. Plan of the temporary support system for the construction of the National Bank of Greece Administration Building.

the level ± 0.00. Before this, the antiquities were wrapped with wooden plaques (2.5 cm thick) and polythene sheets (Fig. 16) to avoid destruction, while layers of geotextile were put in the fill for more safety.

According to the geotechnical investigations, the subsoil consists of a surface fill layer of about 2.50 m thickness, for which the geotechnical parameters are:

$$\gamma = 19\ kN/m^3,\ \varphi = 38°,\ c = 5\ kPa,\ E_s = 50\ MPa$$

while the main geological formation of the site is bold schist with the following geotechnical parameters:

$$\gamma = 21\ kN/m^3,\ \varphi = 25°,\ c = 20 \div 80\ kPa,\ E_s = 60 \div 80\ MPa$$

Fig. 17 shows the plan of the whole temporary support system, i.e. that for the excavation walls and that for the antiquities.

The "Berlin" type wall was used for the temporary support of the vertical slopes of the excavation. This is a rather flexible support system consisting of vertical steel beams (2 U 260) (sometimes of bored reinforced concrete piles), earth anchors and shotcrete (Fig. 18).

The method of the forepoles (horizontal micro piles) was used for the support of the antiquities. First, steel tube piles were places round the antiquities.

In the next stage the forepoles were constructed using Ø 250 mm rotary hammer drill and reinforcement consisting of two concentric steel tubes, the external having external diameter Ø 193.7 mm and thickness 7.1 mm and the internal having external diameter Ø 139.7 mm and thickness 7.1 mm.

Fig. 18. The "Berlin" type of wall used for the temporary support of the excavation slopes.

Fig. 19. Construction of the fore poles under the antiquities.

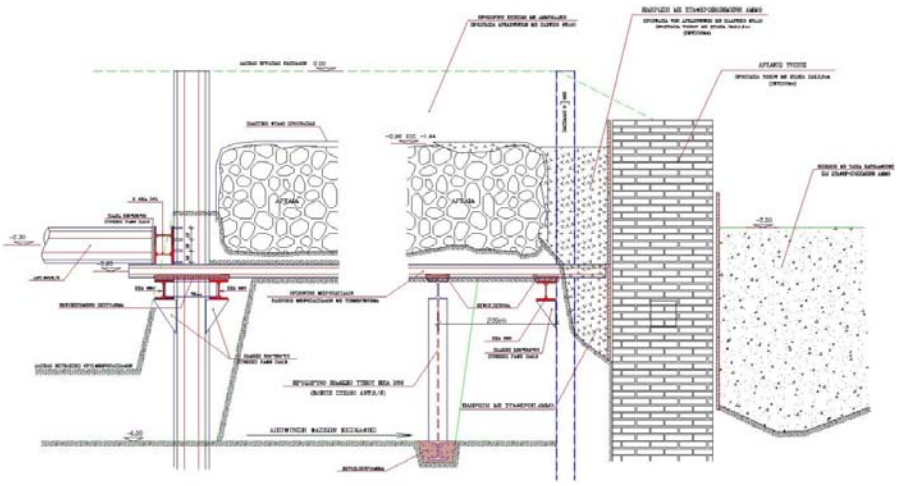


Fig. 20. shows details of the support of the antiquities.

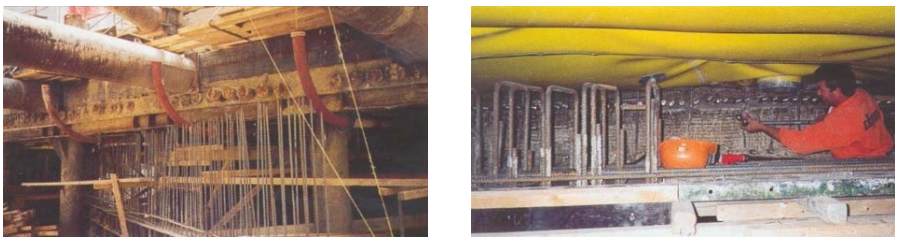
Fig. 21. Excavation under the antiquities. Temporary support with steel frames.

The micro piles were filed with cement mortar with a 2 : 1 cement to water ratio.
After the construction of the forepoles horizontal steel beams HEA 260 were welded to the steel piles under the fore poles, in order to act as their support after the excavation of the ground under the forepoles (Fig. 19). To ensure the good contact of the forepoles and the steel beams, shotcrete was applied.
Finally, steel tube trusses Ø 508 mm / 8 mm thick were used for the lateral support of the system.
In the next stage the ground under the fore poles was excavated (Fig. 21) and a layer of shotcrete, reinforced with steel wire mesh was applied. Temporary supports of steel frames were used in some places (Fig. 21).
The final difficult step was the concreting of the roof slab of the 2nd basement, just under the fore poles supporting the Acharnian Gate.
Due to the presence of the members of the temporary support system (steel tubes and beams), the concreting of the slab was made in sections, providing special attachments for the continuity of the steel reinforcement bars (see Figs. 23 & 24).
It is worth to notice that, because of the significance of the antiquities, the support systems of the excavation slopes and of the antiquities, though temporary, have been designed to sustain seismic loads.
On September 7, 1999, when the excavation had reached the level of -10.00, a shallow earthquake of magnitude M 5.9 occurred in the north-western suburbs of Athens, at a distance of about 18 km from the construction site.
Accelerations as much as a = 0.229 g and a = 0.511 g have been measured in the centre of Athens (at a distance of about 0.5 km from the site), however he support responded extremely well, without any failures and damages.

4.4. Temporary or Permanent Burial of Antiquities

Many antiquities have being found during the excavations for the reconstruction of an old 3 storey and a basement building at the Plaka area of Athens, consisting of parts of marble roman baths, which develop mainly in the neighbouring property and "siroi" (large storage earthen jars in the ground) of the Byzantine era (Figs. 25-28).
Because of these findings and the consequent necessary detailed ar-

Fig. 22. Partial excavation (a) and excavation to the final level (b, c).



Figs. 23 and 24. Details of the preparations for concreting the slabs under the antiquities.

chaeological investigation to a depth well below the foundation level of the neighbouring structures, which would result in considerable delays of the construction programme, the temporary support of the neighbouring structure was necessary. 18 mini piles were drilled, with Ø 250 mm diameter and 7.00 m length (about 4 m embedment), reinforced with IPE 140 steel beams.

Similar beams were used as pile cap beams (Figs. 25, 26 and 29).

After the investigations, the archaeological service decided that the antiquities could be buried and the new structure be built over them.However, since the burial of any ancient monument is considered as intervention to the monument, some rules should be followed, particularly the Articles 9, 10, 11, 12, 13, 14 and 15 of the Venice Charter, in order to achieve the following:

• Reversibility of the burial: The burying materials must easily be removed leaving the monument at the same condition as before the burial.

• Preservation of the structural condition of the monument: The burial should not change the performance of the structural members of the monument during the whole period of the burial.

• Minimization of the change in the appearance of the brick masonries: The burial should not change the technological and construction characteristics of the brick masonries, as they are considered witnesses of the ancient technology.

• Ability of load bearing: The burial should be able to bear safely the loads of any structure at its top (the loads of the new building.

• Minimization of the loads transferred to the structural members of the monument.

• The burial method should secure the maximum life time for the monument.

In this particular case the new building will have a raft foundation and the burial would be performed using well graded sand with less than 5% fines. This method offers the following advantages:

• The minimal load transfer to the antiquities.

• Easy excavation and removal of the burying material.

• Infinite project life.

• Short construction time.

• Ease construction.

• Low cost.

The construction sequence is the follow:

i. Cleaning of the bottom of the excavation.

ii. Gradual filling of the excavation with sand, starting from the "siroi" and continuing to the rest parts of the excavation.

iii. Placement of separation geotextile on top of the fill and then concreting of the raft foundation slab.

Another case of burying the antiquities, temporary this time is that of the extension of the Iraklion Museum. The Museum has been constructed over antiquities, which should remain visit able at the basement of the new building. In order to meet this requirement, the building was founded on piles drilled in the prevailing geological formation in Iraklion named "Iraklion Marl", consisting of Neocene white

Fig. 25 and 26. The antiquities at the 1 Cherofontos Str., Plaka property.

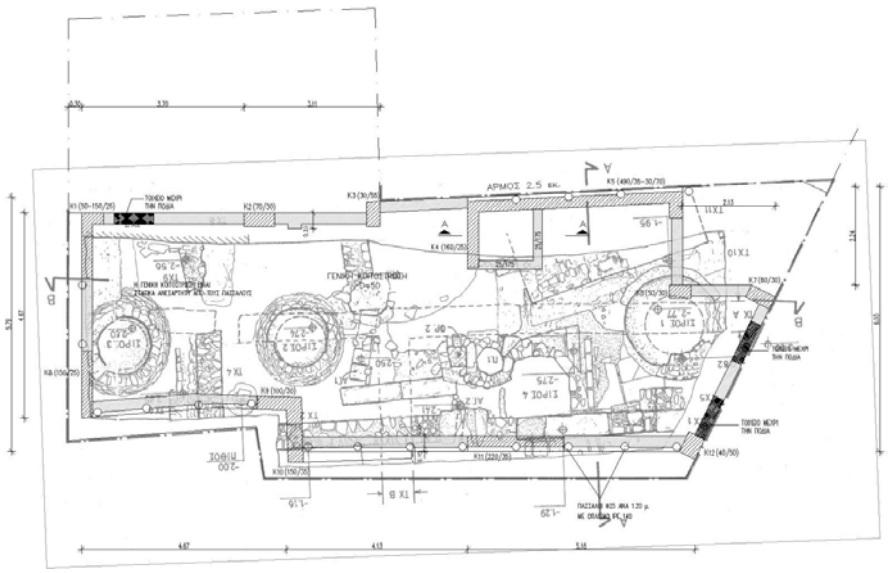


Fig. 27. Plan of the foundation of the building at Cherefontos with the antiquities found.

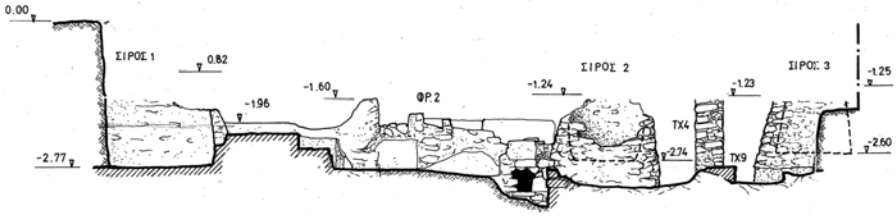


Fig. 28. Section along the Cherefontos site with the antiquities found.

Fig. 29. Detail of the temporary support of a neighbouring structure at the Cherefontos cite.

marls and marly limestones. The piling pattern was dictated by the location of the antiquities in order to avoid their destruction. Since there was not enough space for the piling machine to move between the antiquities, the antiquities were buried, temporarily, in order to create free space on top of them.

The height and the material for the construction of the embankment depend on the characteristics of the piling machine (weight, dimensions of the tracks etc.) as well as on the antiquities themselves (sort of ancient masonry, dimensions, simple walls or walls with arches, condition of the arches etc.).

The selection of piles of Ø 800 mm diameter was based on the account of their diameter as well as on the relative low weight of the piling machine, thus minimizing the load that would be applied to the antiquities. The calculations of the vertical pressures induced by the loads of the piling rig as well as of the horizontal forces induced by the fill compaction showed that for a height of the embankment of 1 m the vertical deformation of the arch is of the order of 0.5 mm, which is acceptable.

The construction sequence was the following:

i. Filling the arches with masonries of low strength, permitting their easy removal after the construction of the basement of the building. The partly destroyed arches were completed to avoid the nonuniform loading (see Fig. 30).

ii. Protection – wrapping of the antiquities with geotextile. Also, application of geotextile at the bottom of the excavation between the antiquities. A non-woven geotextile has been selected.

iii. Placement of a first layer (0.30 m) of fill material (coarse sand with fine gravels, Ø 2-12 mm) at the bottom of the excavation (see Fig 31).

iv. Construction of the embankment using gravels (Ø < 70 mm) up to 0.30 m over the arches. This material requires minimum com-

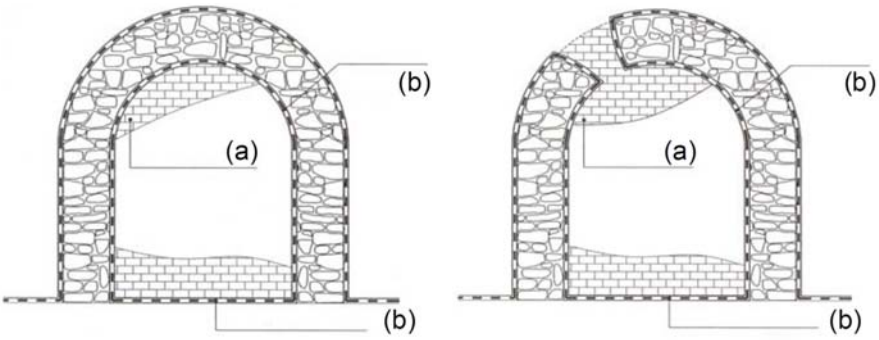


Fig. 30. Protection of ancient masonry: (a) low strength masonry, (b) non-woven polypropylene geotextile.

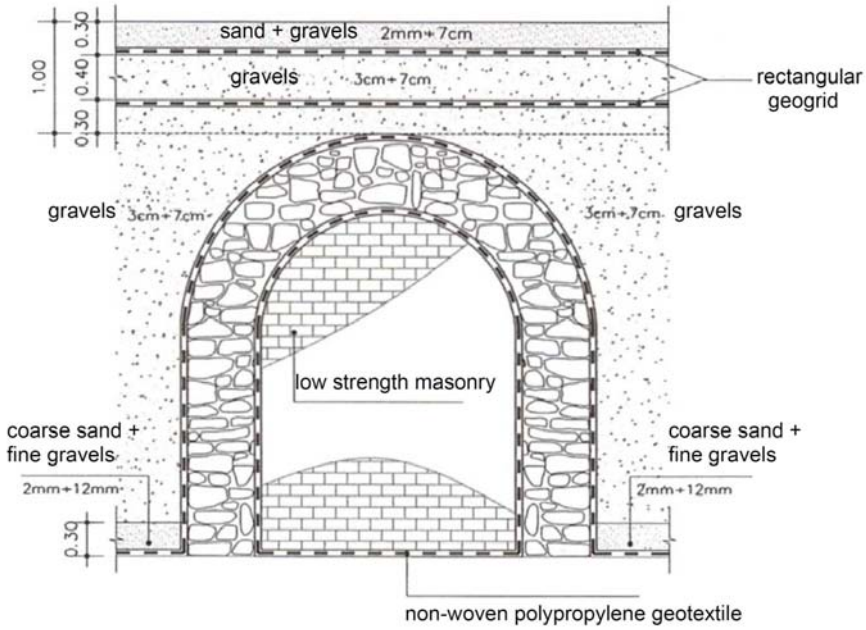


Fig. 31. Construction of the embankment over the ancient masonries.

Fig. 32. Buttressing of the facades of the twostorey building of the Islamic Art Museum.

paction and results in the minimum compaction pressures applied to the ancient masonries and arches. The calculations have shown that the placement of the fill on each side of the masonry should not differ more than 0.50 m in order to avoid the one side horizontal loading of the masonry.

v. Placement of a first layer of a rectangular geogrid, assuring the smooth transfer of the stresses produced by the movements of the piling machine.

vi. Placement of the next layer of fill (0.40 m).

vii. Placement of the second layer of a rectangular geogrid.

viii. Placement of the last layer of fill (0.30 m) consisting of sand and gravels (Ø 2-70 mm).

4.5. The Benaki Museum of Islamic Art in Athens

The new Museum of Islamic Art, an annex of the Benaki Museum, situated in the historical centre of Athens, is housed in a two-building complex built between 1915 and 1935. Both buildings are of the neoclassical architectural form and were declared as listed buildings, as to the preservation of their facades, in 1989.

For converting the buildings into a museum, the architects designed wide-scale interventions in both buildings, i.e. abolishing all the inside walls and partitions, however without any interference in the facades.

During the excavations for the foundation of the building complex, ancient stone blocks were encountered at a depth of approximately 3 m in the three storey building, which had also a basement. The Archaeological Service was called and they start the detailed investigation of the site. In order for the archaeologists to carry out their excavations, the buildings, after the demolition of the inside walls and partitions, had to be appropriately buttressed to ensure the safety of the work teams.

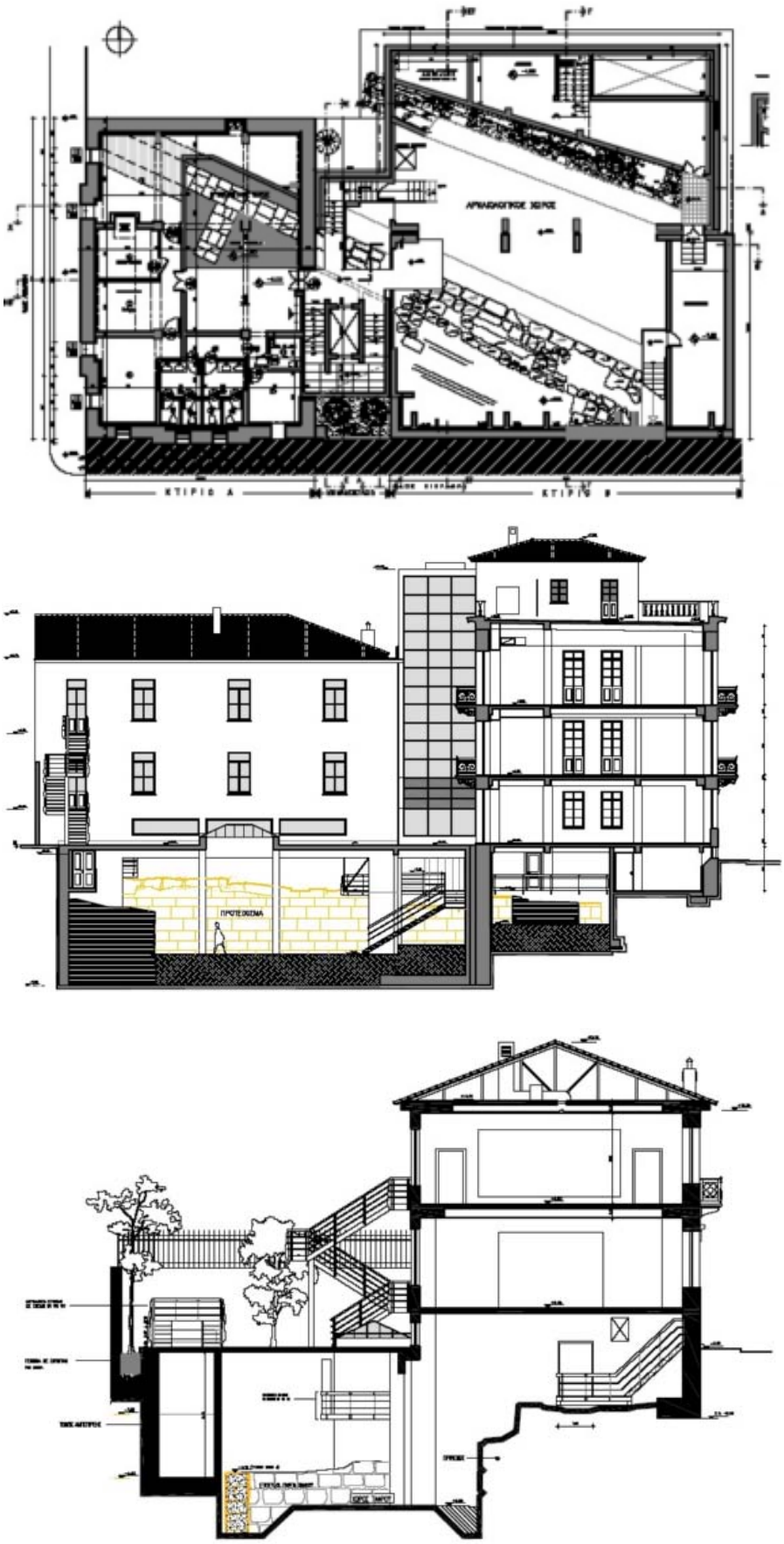
The metal buttressing partitions were placed so that they might later be used in the construction (support) of the new floors (Fig. 32).

After the construction of the buttressing system the archaeological excavation continued and proved that the antiquities were a part of the rampart of ancient Athens. The rampart is preserved to a height of 13 courses of masonry, measuring 5.60 m and running along an eastwest

Fig. 35. Construction of micro piles at the Benaki Islamic Art Museum.

Fig. 34. Initial and final stage of the archaeological excavations at the Islamic Art Museum.

line (Figs. 33 & 34). It was a new defensive enceinte erected in the 4th century B.C. in front of the Themistoclean Wall, built in 478 B.C., to reinforce the Athenian defences.
Outside the rampart a trench was found, measuring approximately 9 m in width, as well as its retaining wall, expertly built of large stone blocks and smaller irregular stones. When the city's fortifications were destroyed by the Romans, the trench was covered by the debris of the rampart.
Later, in the 1st century A.D., it disappeared completely under the large quantity of rubble produced by the clearing of the city's ruins.
Within the perimeter of the rampart the Peripheral Road, preserved to a limited width, was found. It was a road constructed in the 4th century B.C. between the Themistoclean Wall and the rampart, encircling the city and linking the suburbs. On the surface of the road the grooves caused by the carriage wheels can be seen.
Finally, a small section of the Valerian's Wall (3rd century A.D.) was uncovered. For the construction of this wall marble architectural members from the ruined monuments were used, among which a Memorial Stele of the last quarter of the 5th century B.C. Demosion Sima. Demosion Sima was the cemetery extending on either side of the road leading to the Academy, immediately outside the city walls in the area of the Kerameikos.
The final excavation reached the depth of approximately 8.00 m below the ground surface.
The importance of the antiquities found, the need for their preservation and display in the basement of the buildings were considered in the final design of the new buildings.
The geotechnical investigations performed (Malandraki and Tsatsanifos, 1997) showed that the soil profile consists of a surface fill layer (0.30 ÷ 0.70 m thick), followed by layers of screes and weathering mantle of the bedrock in the form of clayey sand with gravels or sandy clay, sometimes with gravels (down to 7.60 ÷ 8.00 m). The strength of these layers is low, N_{SPT} = 5 ÷ 13 (N_{mean} = 8). The bedrock consists of the geological formation known as "Athenian Schist", which, in this part of Athens, appears in the form of weathered and altered peridotite and clayey schist (N_{SPT} = refusal). The ground water table was found at a depth of 5.30 m below the ground surface.
The reinforced concrete columns of Building A were founded on spread footings on the bedrock, except one, somewhere in the middle of the antiquities, where, due to the



Figs. 36-37a, 37b. Plan of the basement floor of the Islamic Art Museum with the antiquities. The Benaki Islamic Art Museum was inaugurated in August 2004, just before the Athens Olympic Games.
Cross sections of the Islamic Art Museum with the antiquities preserved in its basement.

Figs. 38a, 38b. The display of the antiquities at the basement of the Benaki Islamic Art Museum.

lack of space, a micro pile foundation was implemented. On the other hand, in Building B, where the antiquities to be preserved were of different time era and found at different levels, in order to ensure uniform foundation of the structural members of the building micro piles were used for all (Fig. 35). In both buildings the pattern – locations of the columns of their skeletons was again dictated by the presence of the antiquities.
Fig. 36 show the plan of the basement of the museum, with the antiquities as they have preserved and exhibited, Figs. 37 cross sections of the buildings, again with the preserved antiquities and Figs. 38 the final display of the antiquities at the basement of the museum.

4.6. The New Acropolis Museum in Athens

The new Acropolis Museum has been constructed at the skirts of the Acropolis hill. A whole block of buildings has been expropriated and extensive archaeological investigations preceded the construction of the Museum. A view of the archaeological excavation is shown in Fig. 39.

Fig. 39. View of the archaeological excavation at the site of the New Acropolis Museum.

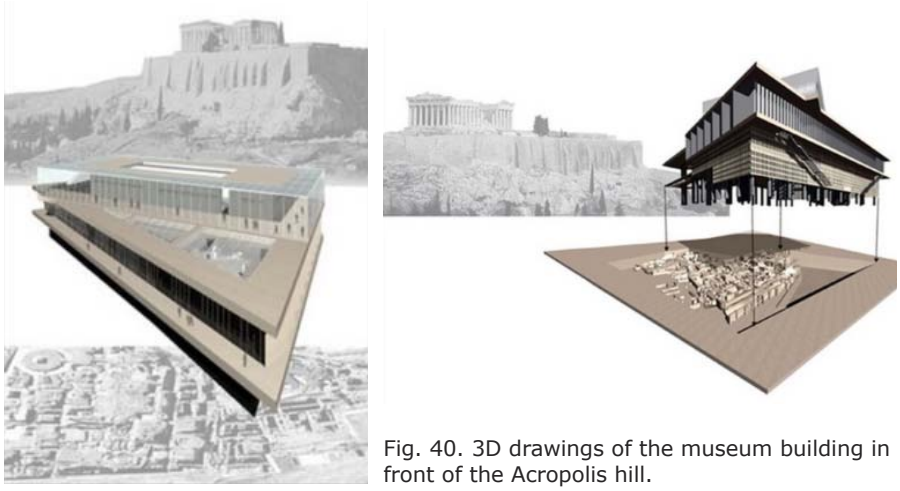


Fig. 40. 3D drawings of the museum building in front of the Acropolis hill.

Fig. 41. Ground plan of New Acropolis Museum with the antiquities found.

The museum has been designed by the Bernard Tschumi Architects Office having in mind that the antiquities should remain visitable under the museum.
Fig. 40 show 3D drawings of the museum building in front of the Acropolis hill.
The museum consists of two sections, one at the south – south-eastern side of the site, which has 3 underground floors and the other at the western – north-western side of the site, without basement. Fig. 41 shows the ground plan of the museum over the antiquities. The beige colour corresponds to the section of the building without basement, permitting the viewing of the antiquities through the glass first flour of the building. The central entrance is located at the northwest side of the building.
The main geotechnical problems, due to the existence of the antiquities, were the following:
i. Due to the density of the antiquities (of the Roman era) at the main section of the museum, the only feasible mode of foundation was that of the concrete bored piles (Ø 1200 mm, 16 m long) at locations dictated by the existence of the antiquities. The cylindrical columns of the building are direct extensions of the piles. For the construction of the piles the antiquities were temporarily buried.
ii. The section of the museum with the 3 underground floors was founded on a raft at a depth of 10 m to 15 m below the ground surface. The main problem in this section was the support of the vertical slopes, for which the existence of the antiquities immediately to the east side and the proximity to the Athens METRO ACROPOLIS Station, shaft and tunnels should be considered.
iii. Finally, the seismic isolation of the building and the small depth of the underground water table were taken into account for the solution of the geotechnical problems.
The geotechnical investigations comprised 11 boreholes, with sampling and *in situ* testing (Standard Penetration Tests), 4 series of cross-hole tests, 3 pressure meter boreholes and laboratory testing (Fig. 42).
The geological setting of the area consists of a thin surface layer of fill, followed by the bed-rock of the area in the form of the Athenian Schist, which, in turn, consists of three main layers:

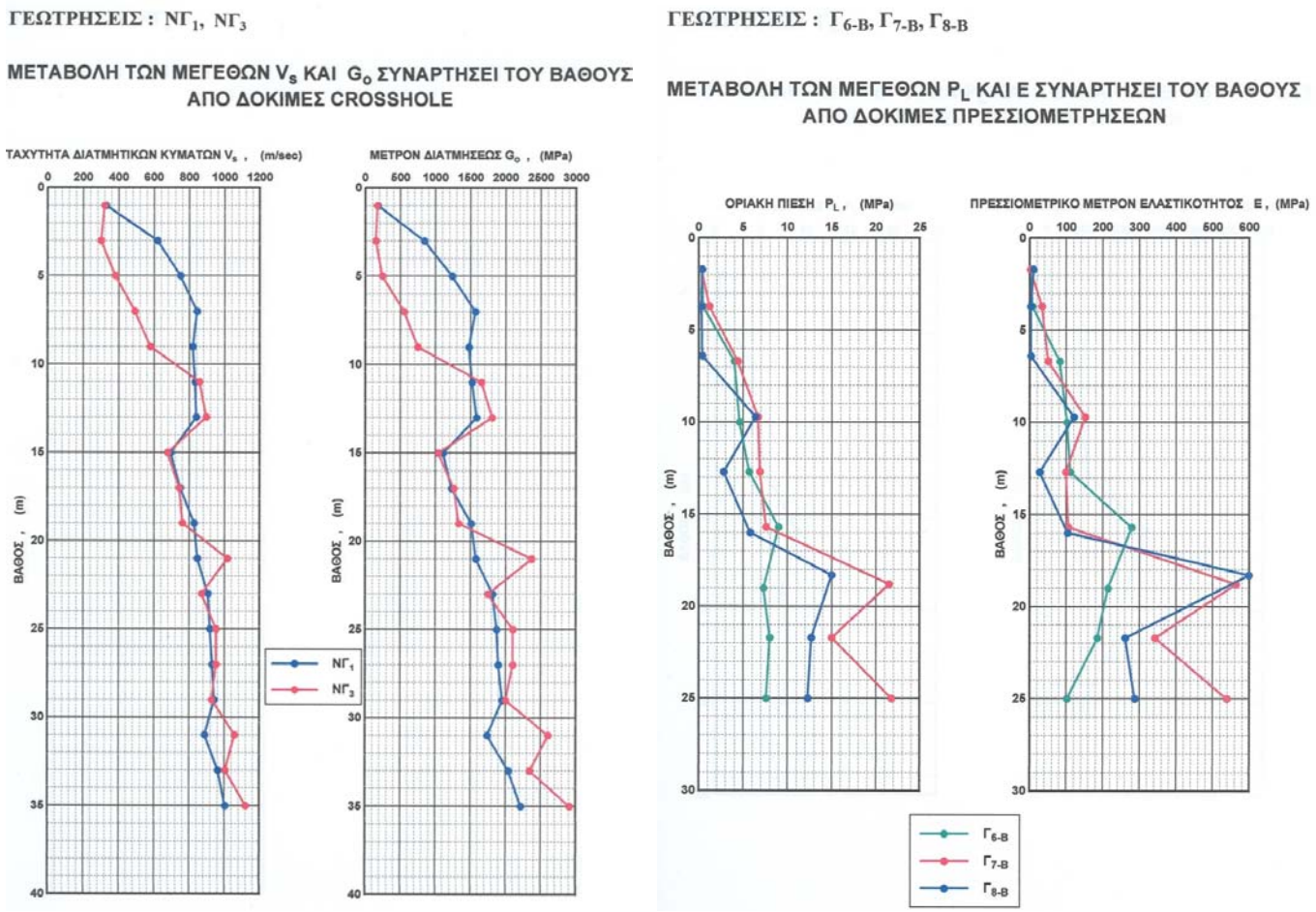
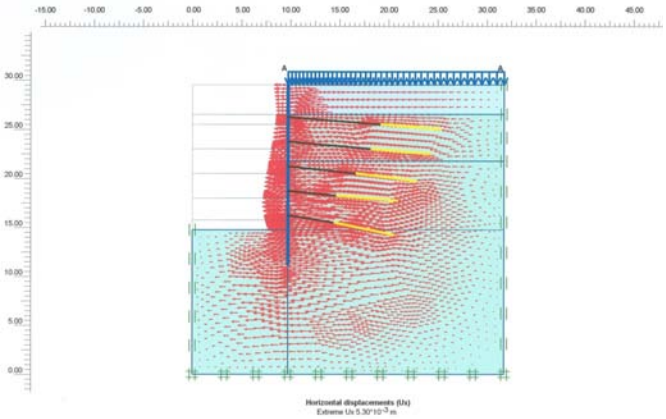


Fig. 42. Typical results of cross-hole and pressure meter tests.



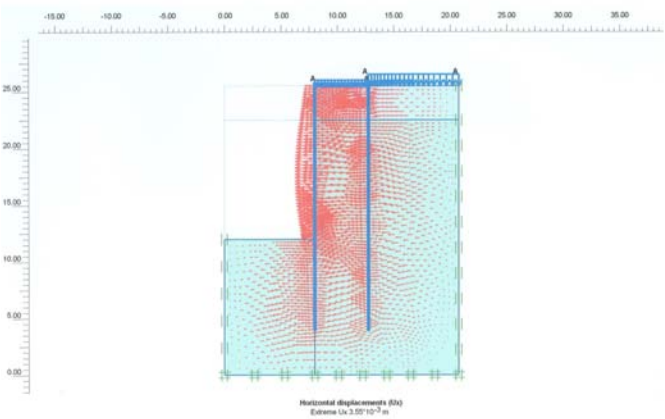


Fig. 43. Results of PLAXIS FEM analysis of the 1st support system; Fig. 44. Results of PLAXIS FEM analysis of the 2nd support system.

Layer I: Weathering – alteration mantle of varying thickness (2.50 m to 8.00 m) from place to place within the limits of the site. In the section with the underground floors the thickness of the mantle varies from 2.50 m to 6.10 m.

Layer II: Brown-green to grey-green clayey schist with layers of weak sandstone from place to place, of different degree of weathering and alteration from place to place. The layer extends to depths ranging from 17.50 m to 20.50 m from the ground surface.

Layer III: Very weathered – soily dark grey to black-grey clayey schist or fragmented from place to place.

The ground water table was found at depths ranging from 3.00 m to 5.50 m from the ground surface.

In order to construct the piles, the antiquities were temporarily buried. Initially, successive hollow concrete drums were placed at the locations where the piles would be bored.

A non-woven geotextile was used afterwards, for covering the antiquities, and then successive layers of well graded coarse materials (fine gravels, mixtures of sand and gravels, coarse gravels) were applied, with 40 kN/m axial strength geogrid in-between. Finally, a geotextile was placed between the final two layers. The fill reached the top of the hollow concrete drums.

The design of the required thickness of fill was based on the requirement that the combination of the vertical and horizontal pressures on the antiquities – brick

walls, produced by the loads of the pile rigs (490 kN), do not result in stresses that can not be sustained by the antiquities.
The horizontal pressures were estimated, initially, using simplified elasticity formulas. The detailed FEM analyses showed that the initial estimations were conservative and that the use of the geogrid could considerably decrease the horizontal pressures.
Regarding the vertical slopes of the excavation, the main design criterion was the minimum horizontal – mainly – deformations due to the immediate presence of the antiquities. Two types of support systems were used:
i. System of Ø 600 mm concrete bored piles, with 2 to 5 rows of temporary pre-stressed anchors Ø 120 mm with Ad = 540 kN design load (Fig. 43).
ii. The proximity of the Athens Metro *Acropolis* Station, to the east side of the excavation, did not allow for the construction of the pre-stressed anchors. So, a system of successive frames consisting of two concrete bored piles (with a distance of 4 – 5 m among them) bridged with steel beams was used (Fig. 44).
The design of the support systems was based on analysis using the *Plaxis* computer code. The geotechnical parameters used (φ', c') were estimated through the Hoek-Brown procedure.

4.7. The Divani Acropolis Building at 18 Erechtheiou Str. in Athens

During the preparatory works for constructing a multi-storey building at the 18 Erechtheiou Str. property, the owner, Divani Acropolis S.A., asked the archaeological service to conduct investigations at the site. The investigation revealed an impressive part of the Athens fortification walls: a 19 m long part of the front rampart (proteichisma) of the 4th century B.C., consisting of 16 courses of masonry, measuring 7.52 m, which was changed at the end of the Hellenistic era to a wall of 4 m width, the moat (tafros) and its retaining wall, of the same period as the front rampart. The retaining wall has a length of 7 m and consists of 14 courses of masonry, measuring 6.60 m. A rectangular tower was added at the east side of the front rampart in the Hellenistic era, with internal dimensions 4.00 m x 4.00 m and 1.0 m thick walls.
It was decided to construct the building with the antiquities visit able at the basement – ground floor of the building. Since the ancient wall, to which the front rampart was changed, is running parallel to the north side of the property (see Fig. 45), the initial proposal, by the engineers, for the superstructure was to have columns along the two sides of the property, founded on piles bored into the Athenian Schist bedrock, and 12.50 m long beams bridging the span between the columns. This proposal was based on the assumption that there were no antiquities along the south side of the property and that the piles along the north side would be drilled through the filling material of the wall down to the bedrock.
However, there was a strong opposition to this proposal by the archaeologists because of the following reason. The fortification wall of the ancient Greek cities consisted of two parallel stone masonry walls at a distance of 3 ÷ 4 m, while the gap between the two walls was filled with any kind of soily and rocky material found near the construction site, including ruins from previous ages dwellings. It has been found that sometimes the filling material of the fortification walls is much more precious than the walls themselves (including pots, clay shells, even frag-

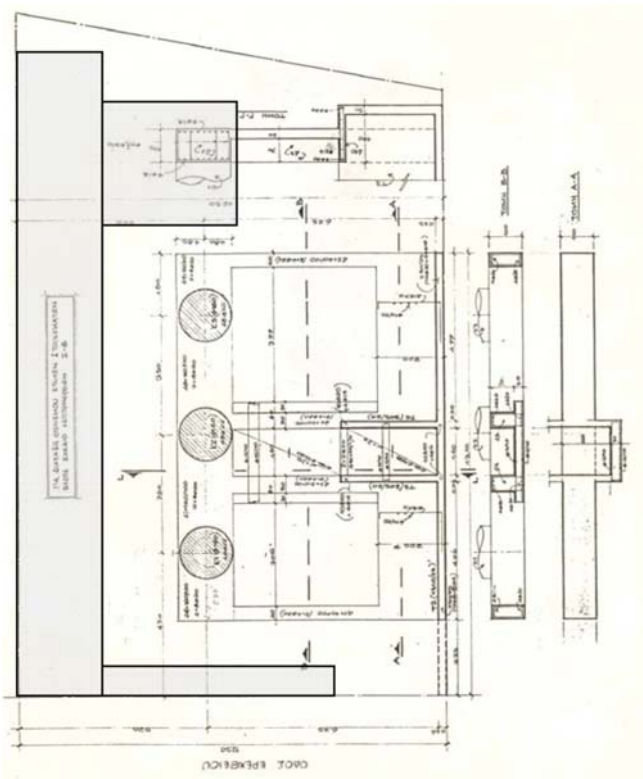


Fig. 45. Foundation of the 18 Erechtheiou Str. building; Figs. 46a, 46b. The foundation and the columns of the basement of the 18 Erechtheiou Str. building.

ments of sculpture and of architectural members).
So, the one row of columns was moved from the side of the property and the beams were designed as cantilever beams over the antiquities (see Fig. 46). The foundation was of the semi-raft type.

5. Case studies – Preservation, Restoration and Rehabilitation of Monuments and Historic Buildings

The most famous example of the contribution of geotechnical engineering in the restoration of a monument is that of the Leaning Tower of Pisa, where the soil extraction method has been applied.
The tower is founded on weak, highly compressible soils and its inclination has been increasing inexorably over the years to the point at which it was about to reach leaning instability (about 5.5 degrees to the vertical: see Fig. 47 from Burland et al., 2003).
Any disturbance to the ground beneath the south side of the foundation was very dangerous; therefore the use of conventional geotechnical approaches at the south side, such as underpinning, grouting etc., involved unacceptable risk. Since the internationally accepted conventions for the conservation and preservation of monuments and historic sites provided that any intrusive intervention on the Tower had to be kept to an absolute minimum, permanent stabilisation schemes involving propping or visible support were unacceptable and in any case could have triggered the collapse of the fragile masonry. After a careful consideration of a number of possible approaches, the International Committee for the Safeguard and Stabilisation of the Tower of Pisa, appointed by the Italian Government, adopted a controlled removal of small volumes of soil from beneath the north side of the tower foundation (underexcavation – see Figs 48 and 49).
This technique provided an ultra soft method of increasing the stability of the tower, which is completely consistent with the requirement of architectural conservation.
Different physical and numerical models have been employed to predict the effects of soil removal on the stability. The preliminary underexcavation intervention, only undertaken once the Commission was satisfied by comprehensive numerical and physical modelling together with a large scale trial, has demonstrated that the tower responds very positively to soil extraction. The final underexcavation has attained the target of reducing the tilt of the tower by half a degree, i.e. to bring the tower "back to future" to the time just before the excavation of the catino in 1838.

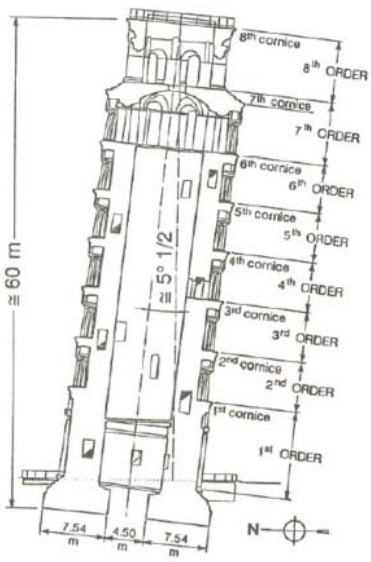


Fig. 47. Cross section of the Leaning Tower of Pisa.

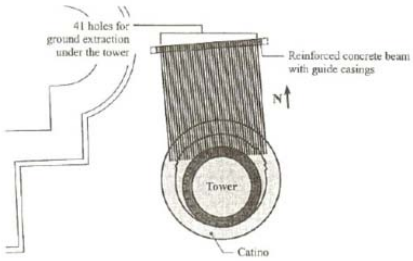


Fig. 48. Pisa Tower. Holes for full ground extraction (Burland et al. 2003).

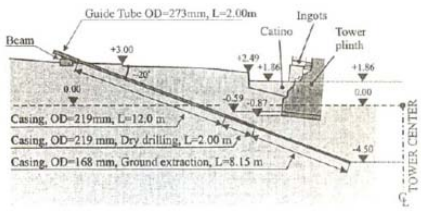


Fig. 49. Pisa Tower. A hole for full ground extraction (Burland et al. 2003).

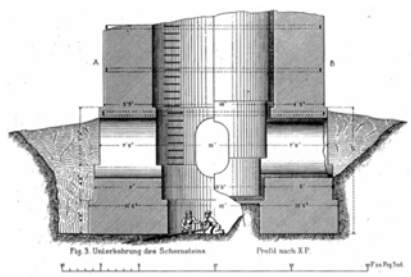


Fig. 50. Vertical section at base of Bochum chimney showing the process of soil extraction (Johnston & Burland, 2004).

The technique of soil extraction has been used for rehabilitation of buildings longer before proposed by Terracina (1962) for Pisa. Johnston & Burland (2004) reported the application of the method as early as 1832 by James Trubshaw for the stabilization of the 15th century tower of St Chad's church in Wybunbury, South Cheshire. Barends (2002) gives a full contemporary account of the stabilization of a leaning church tower at Nijland by means of soil extraction in 1866. The method of soil extraction was also used to straighten a 100 m high chimney at the Bochum Cast Steel Works in Germany. The report on the work was discovered in the journal the 'Zeitschif Bauwesen' published in 1867 and written by Haarman – the engineer who executed the work (see Fig. 50, Johnston & Burland, 2004). Brandl (1989) has described the use of soil extraction to correct uneven settlement of piles supporting bridge piers, while the use of soil extraction has been widely used in Mexico City to reduce the differential settlement of a number of buildings due to regional subsidence and earthquake effects, before its application to the Pisa Tower (Tamez et al., 1997).
A similar to the soil extraction approach was proposed by Poulos et al. (2003) for the rehabilitation of buildings on piles which have undergone uneven settlements due to uneven ground conditions, or/and interaction among closely-spaced buildings, or/and faults in the foundation piling. The approach, which has been termed the "RSS" (Removal of Soil Support) method, involves the drilling of a number of boreholes on the "high side" of the building, so that restoring vertical movements will be developed within the area of the building foundation (see Fig. 51). A major advantage of the method is that it is not intrusive (i.e. it can be performed outside the building footprint) and can be controlled and adjusted via an observational approach.
A very interesting example of underpinning for strengthening the foundation of a historic building was presented by Sata (2003). The AEB Bank chose a two-storied historic building for its headquarters in Budapest (see Fig. 52). The re-

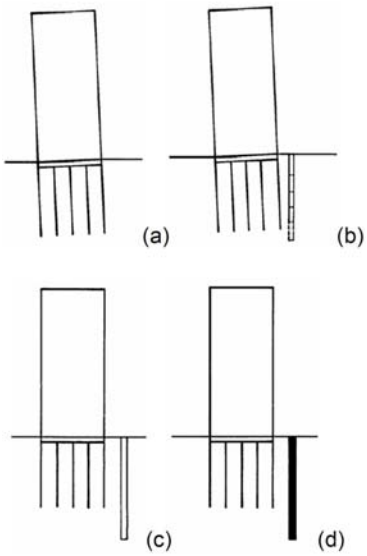


Fig. 51. Principle of the RSS method: (a) Tilting of pile – supported structure (b) Progressive drilling of boreholes on the "high" side of the foundation (c) Restoration of structure tilt (d) Grouting of boreholes.

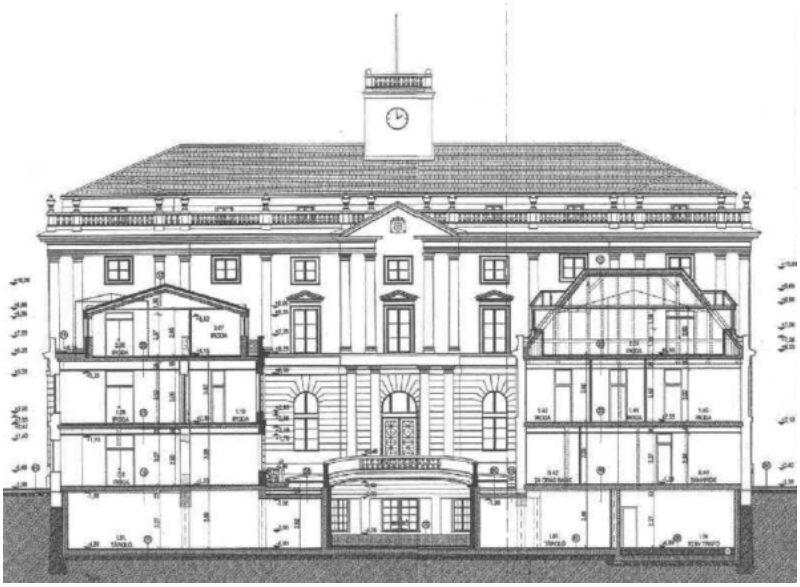


Fig. 52. Architectural section of the renewed AEB Bank in Budapest.

Fig. 53. The AEB Bank building "in the air".

newal, reutilisation and enlargement of the building should follow the original architecture. An underground garage had also to be constructed, requiring the deepening of the foundation level. Jet-grouting was used, and the whole intervention was executed as follows:

i. Reinforcement of the external walls, creating a deeper definitive foundation level – by using the jet-grouting technology and CFA piling.

ii. Creation of temporary supports for the main brick walls, by using the already mentioned jet grouting technology.

iii. Construction of the foundation of the final supports of the brick walls.

iv. Excavation and construction of the basement slab, construction of the final structure and removal of the temporary supports.

In order to avoid any horizontal movements or / and vertical displacements of the very fragile brick-walls, jet piles were made on the two sides of the wall, and into them common steel tubes were placed. The loads of the internal walls were between 100 and 300 kN per meter and were transferred to the ground, temporarily, through these steel tubes-micro piles (Fig. 53).

The connection between these so-called micro-pile heads and the wall is shown in Fig. 54. After this treatment, the reinforced wall behaved as a disk. These simple steel structures made possible the transfer of the linear loads to the micro-piles and hence to the geotechnical substratum.

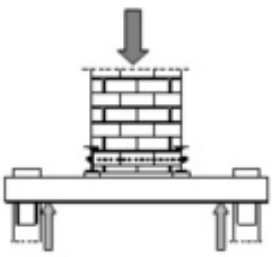


Fig. 54. The connection between the micro-pile heads and the wall for the AEB Bank building.

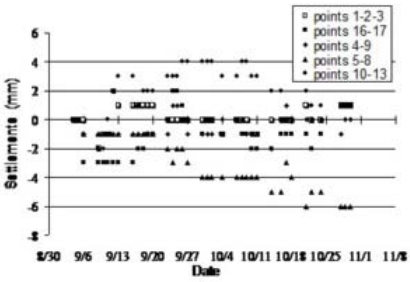


Fig. 55. Measured settlements (September-October 2002) at the AEB Bank Building.

The main concerns of the designer were firstly how to consider and solve the foundation of the walls over the jet-grouting piles, i.e. as real piles or as "deepened" shallow foundations and secondly how to minimize the settlements to acceptable for the historic structure levels.

The initial settlement estimations, using both considerations, predicted values ranging from 1.6 mm to 16.66 mm, which were greater than the admissible. To solve this problem a pre-stressing force between the wall and the piles was induced (see Fig. 54), which acted against the gravitational force of the wall.
Due to the pre-stressing the resulted-measured displacements did not exceed 6 mm and in some cases the result was even an uplift of the structure (see Fig. 55).

6. Concluding remarks

The Major of the City of Sparta confessed that he is not in a position to say if it is a "privilege" of having the new Sparta built over the ruins of the old city. However, the author believes that it is a privilege having the new Athens built over the ruins of the old city, since it is good for the geotechnical profession! Building in ancient cities like Athens demands geotechnical engineering expertise, thus our services by the geotechnical engineers!
However, we should not forget that it is difficult and very expensive to build in ancient cities. Also, the time for the implementation of the project some times is quite long.
The solution of the many problems that arise poses great challenges to the geotechnical engineer. The main problems are those associated with the deformations of the existing monuments and historic buildings during the construction of the new structures. In the case of the restoration of monuments, the authenticity principle should be applied also for the foundations of the monuments, where it is deemed necessary and could be applied with the required safety factor. Also in the case of the restoration of monuments the differentiation of the mode of the foundation of different parts of the building should be avoided. Finally, the cooperation of the geotechnical engineers with the archaeologists and architects is always necessary when dealing with monuments and historic buildings.

Acknowledgements

The author thanks Mr. Spyros Gounaropoulos and Mr. Christos Valanides for providing the photographs from the construction period of the National Bank of Greece Administration Building.

References

Almatzi, A., Anagnostou, I., Giagoulis, T. and Hourmouziadi, A. (1997) "First information for the technology of the lake settlements of prehistory", Proc. 1st International Conference on Ancient Greek Technology, 4-7 September, Thessaloniki, Greece, pp. 425-429 (in Greek).
Andrikopoulou, K. (2004) Protection Works for the Ancient Ruins at the New Iraklion Museum Construction Site (in Greek).
Barends, F. B. J. (2002) "A Dutch leaning tower saved in 1866 by the same method used for the Pisa tower", Geotechnique, Vol. 52, No 2, pp. 141-142.
Brandl, H. (1989) "Underpinning", Special Lecture D, Proceedings 12th International Conference on Soil Mechanics & Foundation Engineering, Vol. 4, pp. 2227-2258.
Burland, J.B, Jamiolkowsky, M. & Viggiani, C. (2003) "The Stabilisation of the Leaning Tower of Pisa", Soils and Foundations, Vol. 43, No. 5, pp. 63-80.
Boubiotis, S. & Floros, C. (1994) "The Filon's Warehouse and an eleven storey office building. Coinhabitants with two and a half millenniums age difference at the Zea, Piraeus", Proceedings of the Scientific Conference "New Cities over Old Ones – The Example of Sparta", Sparta, 18 – 20 February, p. 13 (in Greek). Also as "Harmonic coexistence: The Filon Warehouse (340 BC) and a contemporary office building", The World of Buildings, No. 6, December.
Calligas, P. (2004) Restoration and Adaptation of the Benaki Museum's Neoclassical Building Complex, to a Museum of Islamic Art in Kerameikos, Athens, Report submitted to the Europa Nostra Awards 2004 Competition.
Cavvadias, E., Pascualin, C. and Loucas, P. (2002) "The application of the method of forepoles", KTIRIO, Vol. 147, pp. 109 – 111 (in Greek).
D' Agostino, S. (2005) TC-19 Preservation of Historic Sites / Guidelines – Part I. General Principles of the Interventions (draft).
Dimacopoulos, J. (1985) "Anastylosis and anasteloseis", ICOMOS Information, January / March, no. 1, pp. 16–25.
European Foundations (2004) Piling-Jack Plug. Vol. 37, No. 23, Summer, p. 17.
Hoek, E and Diederichs, M.S. (2006) "Empirical estimation of rock mass modulus", International Journal of Rock Mechanics and Mining Sciences, Vol. 43, No. 2, pp. 203–215.
International Scientific Committee for Analysis and Restoration of Structures of Architectural Heritage (ISCARSAH) / International Council on Monuments and Sites (ICOMOS) (2001) Recommendations for the Analysis, Conservation and Structural Restoration of Architectural Heritage.
Iwasaki, Y. (2005) "Technical Session 4c: Preservation of Historic Sites. General Report", Proc. XVI ICSMGE, 12 – 16 September, Osaka, Japan.
Johnston, G. & Burland, J.B. (2004) "Some Historic Examples of Underexcavation", Advances in geotechnical engineering, The Skempton Conference. London, Vol. 2, pp. 1068-1079.
Loucas, P., Pascualin, C. and Cavvadias, E. (2000) "The support of the section of the ancient Acharnian Road", ERGOTAXIAKA THEMATA, Vol. 56, pp.34–39.
Malandraki, V. and Tsatsanifos, C. (1997) Geotechnical Investigation for the Restoration and Reform of the Building on Dipylou Str. and 22 Asomaton Str. of the Benaki Museum (in Greek).
Matalas, D. (1994) "Preface of Demosthenes A. Matalas, Mayor of Sparta", Proceedings of the Scientific Conference "New Cities over Old Ones – The Example of Sparta", Sparta, 18 – 20 February, p. 13 (in Greek).
Ovando – Shelley, E. (2005) TC-19 Preservation of Historic Sites / Guidelines – Part II. Specific Problems: Foundations (draft).
Papadopoulos, V. (2008) Geotechnical Problems Related with the New Acropolis Museum, Personal Communication.
Poulos, H.G. (2005) "Pile Behavior – Consequences of Geological and Construction Imperfections", Journal Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 131, No. 5, pp. 538-563 (Terzaghi Lecture).
Poulos, H.G., Badelow, F. & Powell, G.E. (2003) "A Theoretical Study of Constructive Application of Excavation for Foundation Correction", Proceedings International Conference on Response of Buildings to Excavation – Induced Ground Movements, London, CIRIA Spec. Pub. 199, F.M. Jardine, ed., pp. 469-484.
Sata, L. (2003) "Foundation strengthening of a historic building", Proceedings 2nd International Young Geotechnical Engineers Conference, Mamaia, Romania.
Tamez, E., Ovando-Shelley, E. & Santoyo, E. (1997) "Underexcavation of Mexico City's Metropolitan Cathedral and Sagrario Church", Proceedings 14th International Conference on Soil Mechanics & Foundation Engineering, Vol. 4, pp. 2105–2126.
Terracina, F. (1962) "Foundation of the leaning tower of Pisa", Géotechnique, Vol. 12, No. 4, pp. 336-339.
Tsatsanifos, C. (2003) "Geotechnical engineering in urban areas – Unexpected situations (old bombs, tombs, underground spaces, wells, drainage, etc.)". Proc. XIIIth European Conference on Soil Mechanics and Geotechnical Engineering, Prague, Czech Republic, 25 – 28 August 2003, pp. 523-531.
Tsatsanifos, C. (2005) "The General Principle of the Authenticity and the Foundations of Monuments", Panellist Paper, Technical Session 4c: Preservation of Historic Sites, Proc. 16th International Conference on Soil Mechanics and Geotechnical Engineering, Osaka, Japan, 12 – 16 September, Vol. 5.
Tsatsanifos, C. (2007) "Contribution of geotechnical engineering in the rehabilitation of buildings and infrastructures", General Report, Main Session 4: Rehabilitation of Buildings and Infrastructures, Proc. XIVth International Conference on Soil Mechanics and Geotechnical Engineering, Madrid, Spain, 24 – 27 September.
Tsatsanifos, C. and Tsatsanifou, F. (2007) Reconstruction of building according to NG 626 / D / 05 at 1 Cherefontos Str., Plaka – Proposal for Antiquities Burial (in Greek).
Ulitsky, V. M. (2005) TC-19 Preservation of Historic Sites / Guidelines – Part II. Specific Problems: Urban Areas (draft).

Romanian Contribution to COST TD 1406 "Intelligent Management of Heritage Buildings"

Maria Bostenaru Dan, Marina Mihăilă, Alex Dill

COST European cooperation in science and technology are thematic networks founded by COST association (based in Bruxelles) out of European Union funds (Horizon 2020). A COST action has a usual duration of 4 years, and funds exchange of experience, which means participation to usually two meetings a year (management committee and working groups) as well as so-called short term scientific missions of 5 days to 5 weeks, or training schools.

Usually a country is represented by two management committee members from different institutions and eventually several substitutes, and to the working groups also a maximum of two members for each country are invited. COST actions are highly competitive (5-6% success rate).

After an action was successful in the competition, a part of the proposing group, each country member of the COST association can sign the memorandum of understanding.

For Romania the procedure is managed by ANCSI (present Romanian Ministry of Research) which makes the nominations including the recommendation letters for the management committee members from their institutions, which have to include a member taking part in a nationally funded project, where actually research is being funded, as well as a national network of interested scientists. Each country contributes with funds to the COST association and thus the more participation from one country, the more desirable.

The COST action "Intelligent management of heritage buildings" is part of the group on trans_domain proposals after the old partition of COST actions. It features 5 working groups:

- Framework
- Interoperability
- Integration of buildings in surroundings
- Social engagement
- Dissemination

The authors of this paper worked in frame of WG3 and WG4, while there are two further members representing Romania. Within WG3, led by Christian Degrigny, in frame of three short term scientific missions in Karlsruhe and Bruchsal, Germany (including the cities of Darmstadt and Heidelberg), as well as in Romania (mainly in Bucharest), work was done towards several topics.

There are 4 A topics regarding heritage, 3B topics regarding surroundings and 3 C correlation topics.

The not dealt with topics by the authors are 3.A1: Optimised protection of HBs& sites and 3.B1: Legal protection of the surroundings, as well as the C topics which regard:

3.C1: Correlation between visual and technological characteristics;

3.C2: Documentation and monitoring of HBs & sites / surroundings;

3.C3: Training of agents to the preservation of HBs and surroundings.

The topics towards which it was worked are:

Topic 3.A2 Conservation work on damaged parts of HBs (HBs - Heritage Buildings)

Objective: Use of appropriate conservation materials that match well aesthetically and technologically with preserved parts of HBs and its surroundings and that ensure adequate reversibility of the intervention performed.

Case study:

- State Theatre Darmstadt

Conservation in 20th century buildings as in the Mendrisio archive, which we detail in this news.

Topic 3.A3 Replacement / reconstruction of missing parts on HBs

Objective: It includes modern and invasive materials (artistic or/and political gesture, etc.) that might make the restored part a "piece of art"

Case studies:

- Facade of the ECC Mall in Karlsruhe (replacement as consequence of demolishing the chamber theatre to make place for the mall which occupies a whole block, the monument protected façade was kept);
- St. Stephan church, Karlsruhe (replacement of the cupola with reinforced concrete after destruction in WWII);
- Architecture building on Karlsruhe Institute of Technology campus (replacement of the aula with 1960s construction after destruction in WWII);
- Mathematics building on Karlsruhe Institute of Technology campus (replacement of asbestos containing structural elements in 21st century rehabilitation);
- Castle in Bruchsal (replacement of destroyed elements after WWII);
- Former Gabroveni Inn, Bucharest (replacement of elements disappeared through deterioration following abandonment);
- Headquarters of the Union of Architects, Bucharest (replacement of elements destroyed in the 1989 revolution and fire at the central square through steel and glass addition from the interior);
- Wilson block of flats, Bucharest (replacement of the corner which col-

lapsed in the 1977 Vrancea earthquake).
As we see the replacement follows some destruction which, with exception of the asbestos elements and of the construction of the mall are consequence of natural or man-made hazards. The elements were irremediably lost and the building was completed. In many cases the completion is done in a different style, making the time of addition and the history of the building visible. In other cases (Bruchsal Castle) the reconstruction is done as it was.

Topic 3.A4 Re-use / retrofitting of HBs & sites

Objective: Retrofitting principles - extension of interventions; advanced engineering materials issue
Case studies:
- Headquarters of the Union of Architects, Bucharest (from residential to architecture office);
- Former Gabroveni inn, Bucharest (from inn becoming ruin to cultural centre);
- The Ark industrial building, Bucharest (to cultural centre);
- Dealu Frumos Church, Romania (from church to cultural centre);
- Mathildenhöhe Darmstadt (from artist colony to museum);
- Student dormitory, Karlsruhe (from hospital housing of the nurses to student dormitory);
- Heidelberg old bath (from bath to catering facilities);
- Stephanien bath, Karlsruhe (from bath to church);
- Dammerstock washing salon, Karlsruhe (to architecture office);
- ZKM (Centre for Art and Media), Karlsruhe (from factory to museum);
- Facade of the ECC Mall in Karlsruhe (from theatre to mall);
- Industrial areal in Darmstadt (to architecture office).

As we see, some of the conversions were accompanied by replacement of elements. Most conversions were towards a cultural function, such as architecture office, cultural centre or museum.
The interventions in the case studies considered are considering advanced materials of the 20th century such as reinforced concrete in the reconstruction (for St. Stephan church or the Bruchsal castle, or the architecture faculty) or even advanced materials of the time in construction (Dammerstock, ZKM). In case of the mathematics faculty hazardous once modern materials have been replaced.
Regarding illumination of HB in case of the EC centre it is a permanent one, while the castle in Bruchsal is illuminated on occasions (for example Christmas).
Regarding the other related surroundings topic of change of the function of surroundings, in case of the ZKM the whole areal changed from industrial to high tech, and in Bruchsal from private residence to museum. In case of the former hospital the whole areal changed to be included in the neighboring campus. The Dammerstock and the Mathildenhöhe and the Schlachthof Darmstadt are part of housing neighborhoods now and in the first cases also then, but the user needs upgraded. The campus is to be seen as an urban area as well.
Some of the Mendrisio cases are urban neighbourhoods as well, such as the Speicherstadt Hamburg or the Olympia Park Munich and Güell Park in Barcelona.
Comparisons were made differently for replacement of elements and for conversion respectively.
Comparisons could be made for:
- Industrial buildings conversion
- Churches conversion
- Thermal bath conversion
- 20th century housing
- University buildings
- Unitary quarters

Topic 3.B2: Modification / reshaping / functional change of surroundings

Objective: as far as possible previous case studies were considered from the point of view of natural and architectural highlighting, access to visiors, information panels, illumination, communication, GIS
Case studies were:
- ZKM, Karlsruhe Germany;
- the Faculty of Architecture in Karlsruhe, Germany;
- the Palace in Bruchsal, Germany;
- the church Dealu Frumos, Romania;
- The Ark, Bucharest, Romania;
- the headquarters of the Union of Architects, Bucharest, Romania;
- Cultural Centre Hanul Gabroveni, Bucharest, Romania;
- Wilson block of flats, Bucharest, Romania.

Topic 3.B3: Highlighting of HBs (on site / from the distance)

Objective: A further step was to look at digital heritage as connected to these sites.
Case studies were:
- Villa Tugendhat in Brno, for which a film and a 360 digital view exists
- The ECE media façade presented in film
- An architectural tour of Schlachthof Darmstadt
- Relocated churches in Bucharest in the area of The Ark, included in a film by Trinitas TV for which we developed GIS application on where these were moved to avoid demolition. This is interesting in the dialogue on relocation which ISCARSAH developed. It was put in dialogue with other films on construction of churches ex. those after the novels of Ken Follett. Some of the previous case studies relate to the fate of churches regarding conversion or replacement of elements.
- Castle of Heidelberg in Germany, an example of reconstruction (Julian Hanschke) of the different phases in CAD. This was related to a case study in Bucharest, the castle Stirbey in the city centre (reconstruction by Idei Urbane), which also displays more phases.
- The topic of reconstruction of sites

becoming ruins can be seen in analyzed cases of "Rome was!" by fellow ISCARSAH member Randolf Langenbach, the reconstruction of Lisbon destroyed in the 1755 earthquake by the team around Helena Murteira which again connect to the ruin of the Heidelberg castle. A narrative can be connected between the digital reconstruction and the real replacement of elements we've seen in the case studies mentioned before. The digital reconstructions in case of CAD were done using archive drawings, what we've seen also for the EUR site in Rome in our doctorate.

- Another type of digital reconstruction in Romania was done using photography for the church in Pietrari Angheleşti (project SalvART) for relocating the church at another site. This can be put in dialogue with the study of relocated churches mentioned above.
- Finally digital transposition of heritage which still exists can be done through laser scanning, as it was done in Romania for the castle in Potlogi (still to be visited) and for the monuments of Câmpulung Muscel such as the monastery Negru Vodă and the Bărăţia church.

The analysis of digital reconstruction is still to be performed.

At the architecture school of Mendrisio several years ago a project on a database of restoration of 20th century heritage was run. The database was also presented in Karlsruhe at the conservation of 20th century conferences of Alex Dill, with the case studies of which we found cross cutting themes as follows, following the cited methodology:

1. Authenticity

- Loos, Building in Michaelerplatz, Vienna, 1910
- Gaudì, Güell Park, Barcelona, 1900-14

The two sites are antagonist affirmations of 20th century. While Loos considered that less is more and avoided ornament, the approach of Gaudi is

Fig. 1. Loos building, Viena; Gaudì, Güell Park, Barcelona. Photo: M. Bostenaru Dan.

of making visible the structure through the shape of the load bearing elements. In the Loos building these load bearing elements serve a logic of public-private space with a transparent lower part although this one is bearing the upper floors, as it is public, and a hole façade in the private upper floors.

2. Monument restoration and museification

Later on we visited the villa Tugendhat in Brno, Czech Republic, 1930, architect Mies van der Rohe.

Fig. 2. Villa Tugendhat, Brno. Photo: M. Bostenaru Dan.

This building has to be seen in dialogue with the later approached pavilion of the same architect, Mies van der Rohe, in the dialogue between authentic and copy. The villa Tugendhat is maintained as original after a restoration process in which Alex Dill was in the commission. We studied also the integration in the surroundings as the garden was seen on 3 levels, up to the perspective over the city. To the topic restoration and museification especially the film on the process was relevant, as this displayed the opinions of former inhabitants.

3. Time stratification

- Rietveld, Schroeder House, Utrecht, 1923-24, the Netherlands
- Gropius, Bauhaus Building, Dessau, 1925-26, Germany

Fig. 3. G Rietveld, Schroeder House, Utrecht. Gropius, Bauhaus Building, Dessau. Photo: M. Bostenaru Dan.

Both buildings involve a parcour in the building according to aesthetic principles derived from the 2D thinking of plan and elevation which dictates colour and material.

4. Industrial heritage

- Zollverein, Essen

The conversion to cultural use of this 20th century heritage stays in connection with the other examples of industrial heritage in Germany and Romania we investigated. In particular in Ruhr zone in Germany where it is situated a 10 years project of conversion took place, the IBA (international building exhibition) Emscher Park, involving participative processes.

Fig. 4. Zollverein, Essen, Germany. Photo: pontchen, photocase.

5. Unwanted monuments. Political significance

- Reichstag Building – present German Bundestag (Norman Foster), Berlin

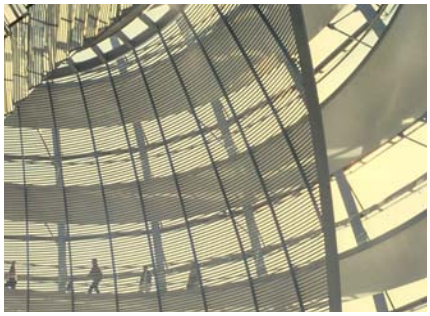


Fig. 5. Reichstag building, Berlin. Photo: M. Bostenaru Dan.

Instead of the suggested examples, this building was visited.

6. Reconstruction

- Mies van der Rohe, German Pavilion, Barcelona, 1929

Fig. 6. German Pavilion , Barcelona. Photo: M. Bostenaru Dan.

The Barcelona Pavilion of Mies van der Rohe is a one-story exhibition building. It uses steel structure although at this height any other structure would have been possible, in order to be able to apply the free plan, an essential feature of the 20th century when walls became not anymore load bearing like in loaded bearing masonry. Free plan walls do not enclose doorways, not only band windows. Mies laid large sheets of glass to close the building to the exterior, unbroken by frames. The walls are plans of different materials without intersections and without doorways. This approach will be theoretised by Le Corbusier. This means that the wall partitions between the rooms are not load bearing, but rather weaving, enclosure, like in Semper's theory. They are also out of different materials and the materiality of the precious materials is important for Mies. Mies played with steel structure in low rise building and this kind of materiality also in the Tugendhat house in Brno, but that has a real function, is not an exhibition pavilion. In fact, the question was posed if a function is adequate for the Tugendhat house or if it is just to be photographed, and Fritz Tugendhat's photos show how life could be in it.

There is another difference between the two, namely that the Tugendhat Villa is an original, while Mies' pavilion in Barcelona, being temporary architecture, had to be reconstructed. The decorative enclosure walls are of different essences of wood and stone, and the texture is important, as for the weaving. The exterior works together with the interior through what we see in the courtyard with the statue or the communication with the surface of water. Important are also the furniture objects, some of them developed specially for the pavilion, masterpieces in design. The steel profiles in the structure communicate with those in the furniture.

Afterwards the Tugendhat villa in Brno was visited and an interview made to complete knowledge between authentic and reconstruction of Mies.

7. Representative typologies

Nothing visited

8. Updating of original functions

Also here we visited nothing from Modernism but we have a number of case studies.

9. Regulations and extemptions

Nothing visited

10. Theoretical entries

We have consulted:

- Preservation institutions – discussed with DOCOMOMO, State Castles and Gardens Baden Württemberg
- Inventories – exchange was done on comparing the SAAI with the inventories in Rome
- Specific topics (see above)

Section I. Historical-critical tools and preservation design

Van Doesburg, Tauber, Arp, Café Aubette, Strasbourg, 1926 is a reconstructed example.

Section II. Material history of buildings and preservation design

Construction materials, techniques and conservation issues

- Edificio per Uffici della Montecatini, Gio Ponti, Milano, 1935-1939

Building services and engineering

- Finlandia Hall, Alvar Aalto, 1967/1971

Fig. 7. Finlandia Hall, Helsinki. Photo: M. Bostenaru Dan.

- Ca' Brütta, Giovanni Muzio, Milano, 1919-1922

This is an example of Novecento architecture typical for Milan in the in-

Fig. 8. Ca' Brutta, Milan. Photo: M. Bostenaru Dan.

terwar time. The buildings were at high technical standards for the time and different from Modernism as seen by the Gruppo 7 architecture in Northern Italy.

- Olympia Stadion, Frei Otto, Munich, 1972

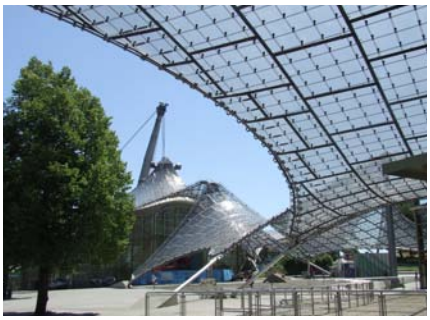


Fig. 9. Olympia Stadion Photo: M. Bostenaru Dan.

An exhibition with the models of Frei Otto was in place in Karlsruhe during the short mission as the archive of the architect is kept in Karlsruhe.

- Grattacielo Pirelli, Gio Ponti, Pier Luigi Nervi, Milano, 1956-1961

The examples from this section mainly include postwar buildings when reinforced concrete reached its ful maturity. Interesting is to see how the only visited interwar building relates to the postwar building which is in Milan as well. Both speak of a well preserved technology since it was

Fig. 10. Grattacielo Pirelli Photo: M.Bostenaru Dan.

high profile already at the time employed.

The post war buildings considered are special structures (auditorium, skyscraper, large sport facility) which required for structural solutions. In the interwar time the new flexibility in housing, which was the main programme of Modernism, required structural solutions.

Fig. 11. Hamburger Speicherstadt Photo: M. Bostenaru Dan.

Section III. Historical-critical tools for urban preservation

The application of classical methods of heritage preservation to the urban structure –"Ensemble"

Nothing visited

Preservation and Design. The "Stadtbild" between urban preservation and city development – "Neighborhood"

- Hamburger Speicherstadt

This is an example of a city turning to water and converting industrial heritage as in some of the case studies. Now with the Elb Philarmonie (Herzog&de Meuron) it gained international attention.

The City as a whole. Building preservation in "Stadtumbau" and "Stadtruckbau" –"City"

Nothing visited

Section IV. Tools and methods for preservation practice

20th century materials including asbestos – health and safety

One of our case studies, although not included in Mendrisio, is relevant for this, namely the Mathematics building in Karlsruhe.

Concrete

We discussed the case studies from the doctorate of the first author (on reinforced concrete in Romania and Italy), and it can be well exemplified of the Muzio examples considered above.

Pigments

Discussed examples from the conference on conservation of 20th century heritage which Alex Dill is organizing since 2004.

Survey and documentation techniques (sources).

As for the preservation institutions considered.

References

COST TD 1406 "Intelligent management of heritage buildings" http://www.cost.eu/COST_Actions/tdp/TD1406

Bostenaru Dan M., Dill A., Mihăilă M. (2017). Integration of Reused and Retrofitted Buildings in Architectural–Cultural Surroundings in South–West Germany. in JULP Review (Journal of Urban and Landscape Planning) 2/2017. pp. 1-11. http://www.julpreview.ro/files/Bostenaru-Hill-Mihaila.pdf

Critical Encyclopaedia for Restoration and Reuse of XXth Century Architecture http://search.usi.ch/en/projects/298/Critical-encyclopaedia-of-restoration-and-reuse-of-XXth-century-architecture

Las Escuelas nacionales de Arte y su importancia en la vida de la República de Cuba

Orestes Modesto del Castillo del Prado

Artículo publicado en el libro M. Paradiso (ed.), *Las Escuelas nacionales de Arte de La Habana. Pasado, presente y futuro*", Dipartimento di Architettura Università degli Studi di Firenze, Firenze 2016.

Las Escuelas Nacionales de Arte, hoy Universidad de las Artes, constituyen en el presente el centro de enseñanza artística de más alto nivel académico del país. El conjunto, conocido internacionalmente, es un vasto complejo de edificaciones construidas desde la década de los años '60 que han marcado una fuerte impronta cultural, tanto desde el punto de vista arquitectónico, que incluye la aplicación de una técnica constructiva dirigida a cumplir condiciones muy específicas para la satisfacción de soluciones de proyecto destinadas a emplear métodos y materiales tradicionales, como desde el punto de vista de la formación en las artes plásticas, la danza contemporánea, el ballet, la música y las artes escénicas para estudiantes nacionales y extranjeros. Consideradas como un hito en la arquitectura contemporánea de Cuba, han atravesado etapas de serias dificultades que van desde la obra concluida y puesta en uso hasta el abandono, la desidia y acciones vandálicas en dos de sus exponentes, Ballet y Música y la no conclusión de Artes Escénicas, en un período en que el Movimiento Moderno, que tuvo un alza extraordinaria en la década de los años '50 y principios de los '60, sufrió un proceso de masificación con obras que, con la justificación de satisfacer las agudas necesidades de vivienda de una población de un fuerte crecimiento demográfico, constituyeron lo que el eminente urbanista cubano Mario Coyula, profesor de gran prestigio internacional, dio en llamar el Trinquenio Amargo.

Reconocidos los valores del conjunto, ante la insistencia de muchas voces que se alzaron en rescate del mismo, incluida su nominación entre los monumentos en riesgo de pérdida total por el World Monuments Watch, se inició un proceso que alcanzó la restauración de las Escuelas de Artes Plásticas y de Danza Contemporánea, quedando aparte Ballet y Música, ambas en penoso estado de deterioro, muy próximo a la ruina total, y Artes Escénicas que debe ser completada adoptando un nuevo carácter en satisfacción de avanzados criterios de enseñanza de esa especialidad al alcanzar el nivel universitario.

Las Escuelas Nacionales de Arte de Cubanacán, también conocidas como Instituto Superior de Arte, denominación que define su carácter de enseñanza superior, tienen indudablemente una importancia considerable en el ámbito cultural de la nación cubana, por la alta calidad de sus espacios construidos, esencialmente las cinco grandes obras de Ricardo Porro, Vittorio Garatti y Roberto Gottardi, el tratamiento paisajístico respetuoso e integrado al entorno existente y la revalorización de una técnica constructiva, que aparte de haber sido elegida como solución alternativa ante carencias de otros materiales de construcción, ha posibilitado alcanzar una riqueza expresiva que otorga un sello inconfundible al conjunto.

La técnica constructiva que se decidió emplear, de uso muy extendido desde tiempos que pueden considerarse como remotos, extendidos por diversas regiones del Globo mucho antes del empleo de materiales que ya, a la altura de

este siglo XXI van, si no cediendo el espacio a nuevas aplicaciones producto del progreso en el estudio del comportamiento de materiales que ofrecen muy altas prestaciones, van compartiendo ese espacio en relación con sus posibilidades de empleo en función de, experiencia de uso, disponibilidad y conocimiento de las técnicas y procedimiento de empleo.

Esa decisión constituyó el empleo de la bóveda tabicada, un tipo estructural que, pese a su trascendencia histórica, no era de total dominio ni de uso extendido en Cuba en el momento de búsqueda de una solución que pudiera ser aplicable y permitiera obtener una respuesta que diera satisfacción a los requerimientos funcionales, que estuviera al alcance de la obtención de materiales para ejecutar una obra de gran magnitud en carácter y volumen. En el momento de iniciar la obra en Cuba existía escasez de acero para emplearlo como refuerzo del hormigón en esas grandes cantidades y se optó por la tipología estructural de la bóveda tabicada ejecutada con piezas cerámicas y muros portantes de ladrillo. Hubo necesidad de preparar al personal que ejecutaría la obra de las bóvedas en procedimientos que no eran de empleo generalizado, en el Ministerio de la Construcción trabajaba un maestro de obras catalán, Gumersindo, a su vez enseñado por su padre que trabajó con Antoni Gaudí.

Ese trabajo de preparación y adiestramiento permitió que los distintos tipos de bóveda tabicada empleados en el conjunto, conocidos como “bóveda catalana” en forma muy satisfactoria en cuanto a dimensiones y requerimientos estructurales, que varían de una Escuela a otra. El trabajo de construcción comenzó en 1962 y continuó hasta 1965. Se completaron las Escuelas de Artes Plásticas, Danza Moderna y Ballet. Esta última se transformó en Escuela de Circo, destino que no tuvo una larga permanencia, fue abandonada y a esto siguió un lamentable proceso de vandalización, estado que aún persiste. Las Escuelas de Música y Artes Escénicas quedaron inconclusas hasta el presente. En la década del ´90 se trazó un plan de restauración general que no ha tenido continuidad, en el año 2008 se intervinieron las Escuelas de Artes Plásticas y Danza Moderna, actualmente en uso.

El proyecto de los edificios de este complejo arquitectónico, que se desarrolló con el propósito de cumplir las aspiraciones de tener para el país las mejores y más hermosas escuelas para la formación artística de jóvenes cubanos y de otras latitudes, fue objeto

de agudas críticas, algunas de ellas sin objetividad en sus planteamientos. Como ejemplo me permito citar las opiniones de dos arquitectos de gran prestigio tanto en Cuba como en el ámbito internacional y que fueron publicadas en 1965 y 1969, respectivamente.

En su artículo *Las Escuelas de Arte de La Habana*, el arquitecto Hugo Consuegra manifiesta que los autores del proyecto «han devenido símbolos ferozmente atacados o endiosados» y expresa que de la definición de esa polémica dependería en gran medida el rumbo y el futuro de la arquitectura cubana y afirma que esa es la importancia histórica de las Escuelas para Cuba. Considera el Arq. Consuegra que la Escuela de Ballet de Vittorio Garatti es una de las obras más refinadas de Cuba y cito: «Las Escuelas Nacionales de Arte, por su emplazamiento paradisíaco y su relación con los clubes marítimos (hoy círculos sociales, Nota del Autor) serán sin duda, como apunta Vittorio Garatti, el núcleo del gran pulmón recreativo de La Habana y su función como centro intelectual irá mucho más lejos de la mera labor docente». Coincido plenamente con la consideración del Arq. Consuegra y extiendo ese concepto de obra refinada a todo el conjunto. El tiempo ha sido el encargado en demostrar que lo expresado por Vittorio Garatti no admite, hoy día, discusión alguna.

Con respecto a la dificilísima situación que tuvo el proyecto, la ejecución y puesta en funcionamiento de las Escuelas (hay que tener en cuenta que la Escuela de Ballet nunca fue utilizada a los fines para los cuales fue creada) vale la pena transcribir aquí algunas de las ideas expuestas fundamentalmente por Mario Coyula en su conferencia *El Trinquenio Amargo y la ciudad distópica: autopsia de una utopía* y también en otras intervenciones. Cito: «La obra estuvo marginada oficialmente. Prácticamente no se quería que se hablara de las Escuelas de Arte. Era una obra maldita. Los arquitectos, y esto es una paradoja, cumplieron el encargo de hacer las Escuelas más hermosas del mundo. Irónicamente, después fueron criticados por eso. A finales de los ‘60 y principios de los ‘70 hubo unos tres años, por lo menos, en que existió un período que no era gris, sino amargo. Todos fuimos dispersados para ‘tomar contacto’ con la realidad. Gente que estaba soñando con bellezas que no eran importantes, para que aprendieran como era la vida en realidad. Los que estaban más interesados en la cultura eran vistos como gente peligrosa porque no se entendían bien. Podían

hacer una cosa y había un significado oculto». «Era política del Ministerio de la Construcción (MiCons), el empleo de sistemas de construcción prefabricada porque consideraban que preocuparse por la belleza estaba en contra del interés por producir. Tenías que hacer edificios que no eran prefabricados y que pareciesen prefabricados». «Surgió alrededor de las Escuelas Nacionales de Arte una polémica que dividió a los arquitectos cubanos. A los que estaban a favor de ese tipo de arquitectura se les ponía una etiqueta de elitistas, intelectuales, artistas… que sólo querían su propia satisfacción. Había envidia».
Es necesario tener en cuenta que en las soluciones de proyecto los tres arquitectos crearon espacios y formas inéditas en obras con un verdadero carácter experimental, otorgado por la revitalización de la técnica constructiva empleada, combinando tradición y modernidad por el uso de formas y materiales.
Ha quedado demostrada la vigencia de esas obras, por encima de dificultades objetivas en las requeridas intervenciones posteriores a su inicio y puesta en marcha, tras medio siglo de haber sido concebidas y ejecutadas.
Es muy importante valorar los siguientes aspectos:
• Las Escuelas constituyen un espacio público al servicio de la población con un programa docente innovador.
• En ellas se ha alcanzado la formación de artistas de primera línea, reconocidos internacionalmente, en cada una de las especialidades objeto de enseñanza.
• Son un lugar de encuentro social con espacios adecuados para la creación artística y el debate interdisciplinar.
El tiempo ha dado la razón a un conjunto de obras arquitectónicas que continúan despertando curiosidad.
No puedo concluir este artículo sin hacer una referencia especial a tres valiosos elementos que describen y analizan todo el transcurso de las Escuelas Nacionales de Arte de La Habana, desde su concepción para dar cabal satisfacción al sueño, los criterios y argumentos que les dieron origen, pasando por un largo período de abandono y desidia hasta la necesaria rectificación de 1999 en que se alcanza la posibilidad de intervenir en la Escuelas de Artes Plásticas y Danza Contemporánea y la llegada al momento presente en que una crítica situación económica ha puesto freno al trabajo iniciado. Tengo la secreta esperanza que algún día se alcance la recuperación que permita el imprescindible rescate total de ese espléndido conjunto de obras que dan a Cuba una clara posición en los campos de la arquitectura y de la formación académica en las bellas artes.
Los elementos a que hago referencia son el libro *Revolution of Forms. Cuba's forgotten Art Schools*, de John Loomis, arquitecto, profesor y crítico de arquitectura de reconocido prestigio, que desde la primera edición funcionó como detonante para el conocimiento internacional de esta obra. Loomis vino a Cuba en una primera visita y quiso conocer las Escuelas, que le despertaron el interés que lo ha llevado a continuar tratando el tema.
En orden cronológico le sigue *El Trinquenio Amargo*, la ya citada conferencia dictada por Mario Coyula, en la que hizo un análisis de la arquitectura cubana en el plazo de tiempo en que la masificación de las construcciones tuvo preponderancia sobre los conceptos de diseño que primaron en nuestro país desde los orígenes de la arquitectura tradicional, la que tuvo una acertada evolución que la fue ajustando expresiva y funcionalmente al tiempo en que se desarrollaba y que culminó en brillantes ejemplos del Movimiento Moderno que hicieron una interpretación contemporánea de esas raíces, sin hacer copia de sus antecedentes.
Puede afirmarse que, entre otros destacados arquitectos cubanos, los autores de los proyectos de las Escuelas Nacionales de Arte son cultores de esos principios, alcanzando un importante reconocimiento internacional a su trabajo al recibir en Roma, de manos del Presidente de la República Italiana el premio Vittorio De Sica para la Arquitectura, del año 2012.
Finalmente, el más reciente de esos tres elementos, la tesis doctoral de la arquitecta María José Pizarro Juanas, profesora de la Escuela Técnica Superior de Arquitectura de la Universidad Politécnica de Madrid, expuesta en el año 2013, posiblemente el más extenso trabajo investigativo sobre las Escuelas Nacionales de Arte de La Habana hasta el presente. La importancia mayor de las Escuelas de Arte de Cubanacán está tanto en su uso como centro docente de enseñanza superior en diversas vertientes artísticas, algunas no contempladas ni existentes en el momento de su concepción, y en la continuidad de su existencia como conjunto arquitectónico y paisajístico que, pese a su edad, mantiene una indudable vigencia y que como entidad orgánica deberá someterse a procesos de crecimiento y desarrollo.

Los arquitectos Vittorio Garatti, Ricardo Porro y Roberto Gottardi.

En este punto quiero hacer un símil con lo que he planteado siempre a mis alumnos y ante cualquier auditorio que se disponga a escucharme. Para el arquitecto insertar arquitectura contemporánea en un centro histórico no es una posibilidad, es un deber insoslayable que tiene unas reglas que se resumen en lo siguiente: lo que se haga tiene que respetar en todas sus características el entorno en que se inserta, sin copiarlo haciendo cosas que inevitablemente conducen a un falso histórico.
En las Escuelas Nacionales de Arte, por su indudable posición dentro del patrimonio moderno, debe hacerse cumplir este concepto, teniendo en cuenta, sobre todo, el más absoluto respeto por los autores originales y los criterios que los condujeron a la creación de esa obra, cuya monumentalidad, al principio criticada acremente, es uno de sus aspectos más preciados.
Respeto que admitiría bajo ese precepto, otras intervenciones aun por otros autores, deberá ser mantenido, no como una imposición arbitraria, sino como un reconocimiento a la altísima calidad de la obra, y no solamente se cuente con la valiosa presencia física y vigencia de sus creadores, sino más allá, por el alto significado de lo que ellos han sido capaces de materializar, convirtiendo sueños en obra edificada.

Todas las fotos, a excepción del retrato de los arquitectos, son de M. M. Segarra Lagunes, 2010.

Assessment of mechanical properties of the historical bricks of Burgos gate in Alcalá de Henares in Madrid*

*Reprinted from: SAHC2014 – 9th International Conference on Structural Analysis of Historical Constructions, F. Peña & M. Chávez (eds.), Mexico City, Mexico, 14–17 October 2014.

Marek Skłodowski[1], Mónica Alvarez de Buergo[2], Gonzalo Barluenga[3], Rafael Fort[2]

[1] Institute of Fundamental Technological Research, Warsaw (Poland). e-mail: msklod@ippt.pan.pl
[2] Instituto de Geociencias IGEO (CSIC,UCM), Madrid (Spain). e-mail: monica.alvarez@csic.es, rafael.fort@csic.es
[3] Escuela Técnica Superior de Arquitectura y Geodesia. Universidad de Alcalá, Madrid (Spain) e-mail: gonzalo.barluenga@uah.es

Keywords
micro-core, CoDiT, minor-destructive testing, brick, Alcalá de Henares

Abstract
The subject of the research is a comparative study of minor-destructive strength measurement method using micro-core specimens and standard testing of large size specimens from the Medieval structure of Puerta de Burgos (Burgos Gate), being a remain of the former town fortress now leading to the Monastery of St. Bernard and the Archbishop´s Palace in the city Alcala de Henares near Madrid. Standard size specimens were tested within the framework of the project of the Regional Government of Madrid "Durability and conservation of built heritage geomaterials" by Instituto de GeocienciasIGEO (CSIC-UCM), Spain. Micro-cores testing of sub-size specimens were done at Smart Technology Centre of Institute of Fundamental Technological Research Polish Academy of Sciences. Standard tests included measurement of longitudinal ultrasonic wave velocity, flexural strength and uniaxial compressive strength measurements. They form a set of the reference results for the other group of tests using minor-destructive Compact Diagnostic Test (CoDiT) procedure based on measurements and analysis of the mechanical properties of small samples of the materials drilled out in a form of micro-cores having the diameter of several millimeters. Minor-destructive CoDiT procedure allowed measuring of ultrasonic surface wave and longitudinal wave velocities, uniaxial compressive, flexural and indirect tensile strengths of original construction bricks. The results of standard tests and CoDiT tests of micro-cores having less than 8 mm diameter confirm that mechanical properties of historic materials can be assessed on the basis of micro-core testing if the tested material is homogeneous enough within the size of the micro-core being used.

Figure 1: The Gate of Burgos, from left to right: South façade: in 2003; after the 2005´s collapse; in 2012, after its restoration.

1. Introduction

The first stretch of the fortified wall in which the Burgos wall is enclosed dates back from the 13th century, as the main entry to the Archbishop´s Palace. At this stage a first cubic structure was built, a little bit higher than the wall in which it was embedded. The Gate was successively enlarged, both in surface and height, in the 14th and 15th centuries with superimposed bodies [1]. Some collapses of part of the structure occurred along the history of the Gate, the latest in 2005. This collapse probably happened because during a long period the structure was in a semi-ruined state caused by a complete lack of maintenance. The last restoration was carried out in 2011, mainly focused on its structural consolidation (Figs. 1, 2).

Besides bricks, which are the main building materials, due to the fact that Alcala de Henares surroundings have important clays deposits

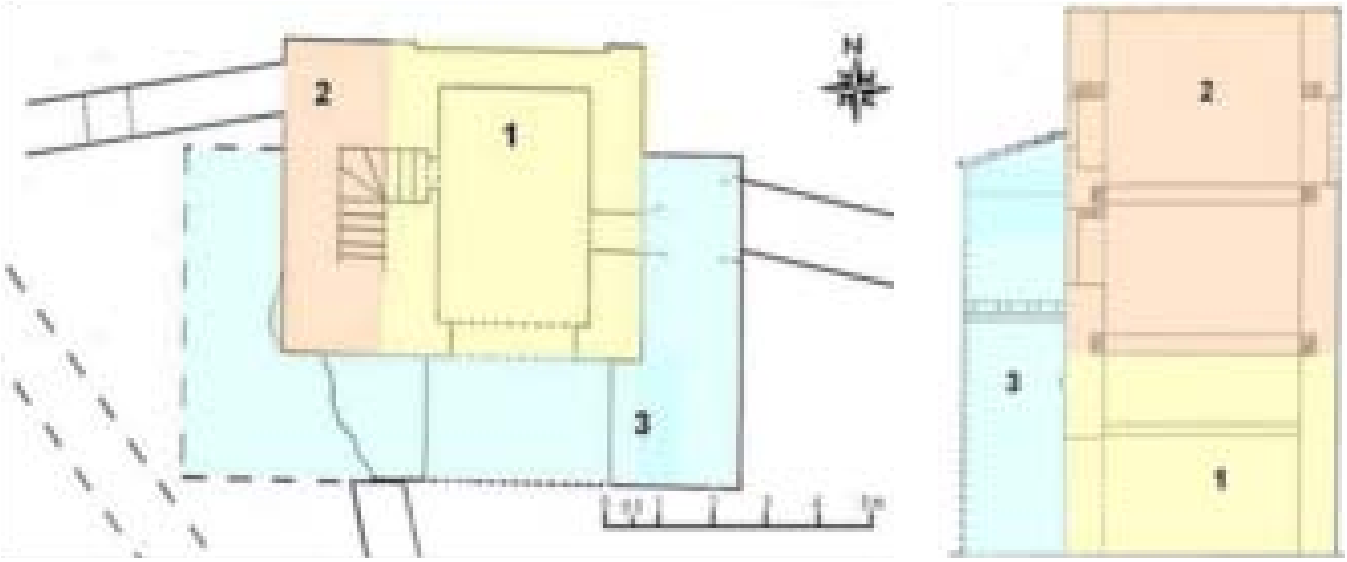


Figure 2: The 3 main construction stages of the structure, in ground plan, left, and elevation, right. 1: 13th century; 2: 14th century; 3: 15th century.

Figure 3: Stockpile of bricks from the 2005´s collapse of the structure, left, and bricks sampled (right).

which have derived in a significant ceramic industry [2], the structure was also constructed with rammed-earth and stone (limestone).

The fortified wall complex was listed Cultural Interest Good in 1968, and the University and Walled Complex of Alcala de Henares is UNESCO's World Heritage since 1998. The Burgos Gate is the oldest mediaeval structure of the city. It was the exit of the historical city towards the North.

The bricks analyzed in this study were sampled from waste material available after the last structural collapse of 2005. The bricks were tested by standard and nonstandard methods to assess mechanical properties of Burgos Gate construction material.

2. Standard Testing Methods

The average size of the bricks employed in the Gate is 273 mm long, 168 wide and 39 mm thick. Bricks from corresponding to the 3rd construction stage (15th century) available after the last collapse were sampled (Figure 3). From previous studies [3], these bricks show a real density of 2460 Kg·m-3, a bulk density of 1670 Kg·m-3, a porosity accessible to water or open porosity (n0) of 32%, a capillarity coefficient of 6.2 Kg·m-2·h0.5, and a coefficient of water absorption after 48 hours of 18%.

Ultrasound velocity measurements were performed with 3 different equipments:

- Pundit Plus CNS Farnell with 54 KHz transducers (at Alcala University);
- Ultrasonic Testing 309 ultras 55 with 54 KHz transducers (at Alcala University;
- Pundit CNS Electronics with 1 MHz transducers (at Petrophysics Laboratorio of Geosciences Institute).

The dimensions of the prismatic specimens, obtained from representative bricks, were 160 mm long and 40 mm side, in average.

Mechanical tests were performed at the University of Alcala de Henares - uniaxial compression strength (UCS) and flexural strength - by means of a RMU testing equipment, Multitester, with a capacity of 20 Ton, with a breaking load rate of 1kN/s (UCS and FS) and a distance between supports of 100 mm (FS).

The specimens dimension was the

same as referred for ultrasound velocity measurements. Results of the ultrasonic and strength measurements are presented in Section 4.

3. CoDiT Measurements

Compact Diagnostic Test method (CoDiT) was developed for testing properties of heritage construction materials with minimal possible destruction to the monument [4]. It uses small samples of the material called micro-cores and whenever it is possible micro-cores should be over-cored as a by-product during drilling holes for technical purposes. In this case one gets specimens for testing instead of pulverizing historic material. The common example is fixing of scaffolding to a monument when possibly drilled micro-cores would have a diameter of 10—12 mm and no additional destruction to the monument would be introduced.

In experiments performed at Institute of Fundamental Technological Research Polish Academy of Sciences smaller specimens with diameter around 8 mm were used to show that in some cases even such a small material samples can provide valuable material characteristics.

CoDiT procedure is a sequence of experimental steps, which allows us to measure many physical and mechanical properties of historic materials [5, 6, 7]. Testing a single micro-core in accordance with CoDiT procedure enables to measure material flexural strength (FS), indirect tensile strength (ITS) uniaxial compressive strength (UCS), Young modulus of elasticity (E) and ultrasonic longitudinal (VP) and surface Rayleigh waves (VR) velocities.

Brick sample from Burgos Gate is shown in Fig. 4. The sample and assigned local coordinate system is shown on the left. The right image shows drilled sample surface and micro-cores. On the brick surface several lines parallel to Z-direction were drawn prior to drilling to allow further orientation of micro-core specimens with respect to the coordinate system. The orientation is necessary during FS and ITS measurements to ensure identical loading direction of each specimen.

At first Rayleigh surface wave VR velocity was measured on the flat surface of the brick sample parallel and perpendicular to the lines drawn on that surface. The measurements were done with edge probes [8, 9, 10, 11] at five surface points for each of both directions before micro-cores drilling.

Figure 5 shows edge probes placed on the brick surface and one of the registered surface wave profiles. Upper wave profile is a measured signal and lower one is the reference wave. Propagation time was measured using signal correlation method.

The next step was over-coring of the specimens and selecting the ones suitable for three point bending tests. The selection was done on the basis of specimens' length and morphology (visible pores, voids, cracks and inclusions). Figure 6 presents specimen L11 under three CoDiT strength tests.

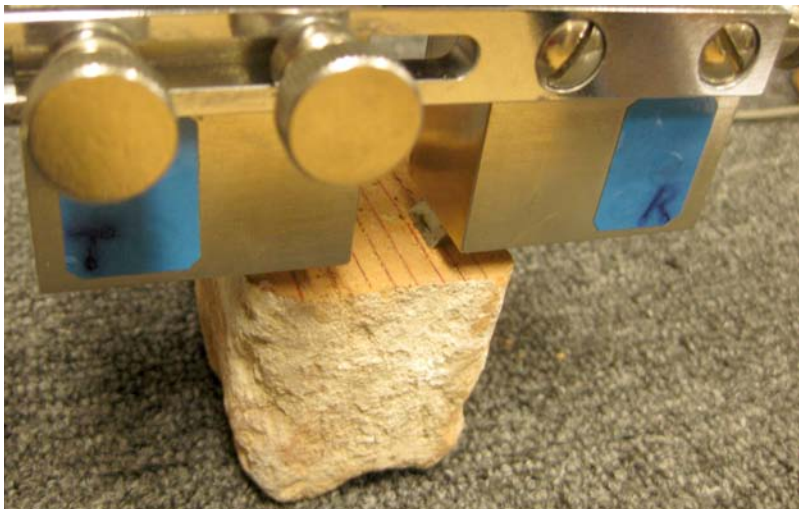
Three-point bending (left picture) provides FS strength and two shorter "half-specimens" of different length. Both 'half-specimens' had their ends cut to produce cylinders with flat parallel bases. The longer cylinder of slenderness approx. 2:1 was used for UCS testing (central picture). The shorter one with slenderness approx. 1:1 was used for ITS measurement (right picture)

Longitudinal VP wave velocity was measured on cylinders resulting from bending test.

The cylinders and 1 MHz ultrasonic probes were placed in vertical position as shown in Fig. 7 and measurements in transmission mode were done.

To assure proper contact of the specimen and the probes additional dead load was used. In this test wave propagation time was measured on the basis of wave

Figure 4: Sample of the brick from Puerta de Burgos with sample coordinate system (left) and drilled micro-core specimens (right).



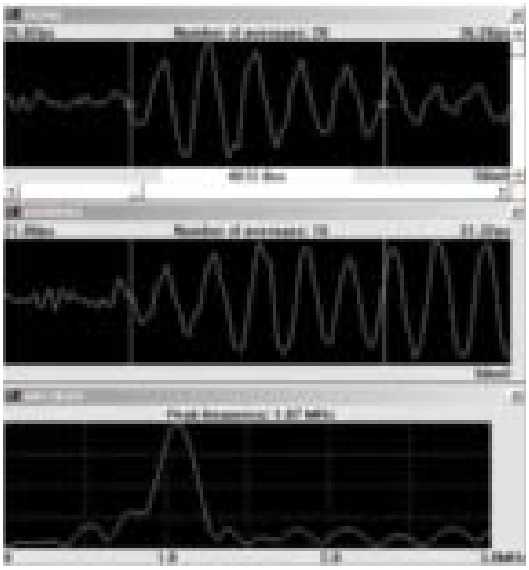


Figure 5: Surface Rayleigh wave VR propagating in X-direction measured with edge probes (left) by signal correlation method.

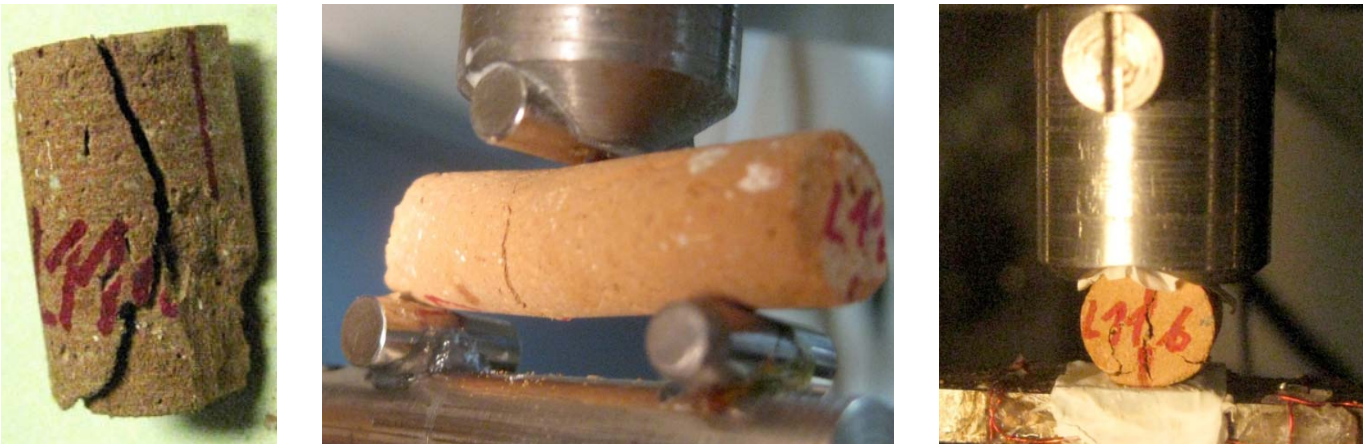


Figure 6: Micro-core L11 after testing using CoDiT method: three-point bending (left), uniaxial compression (center) and diametral compression (right).

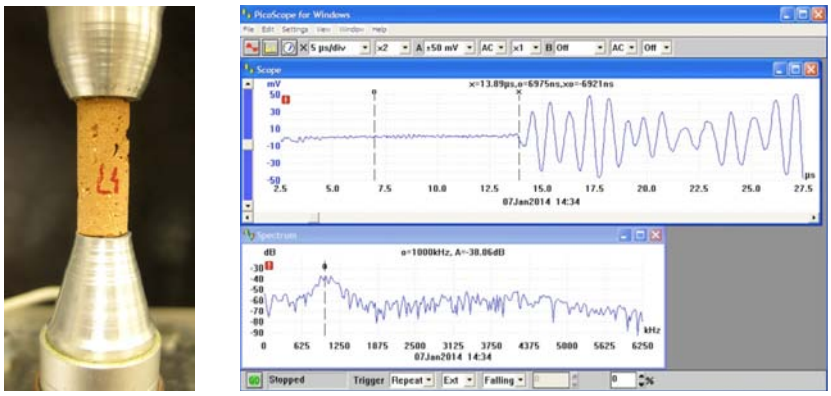


Figure 7: Recording of longitudinal VP wave in a brick specimen from Puerta de Burgos.

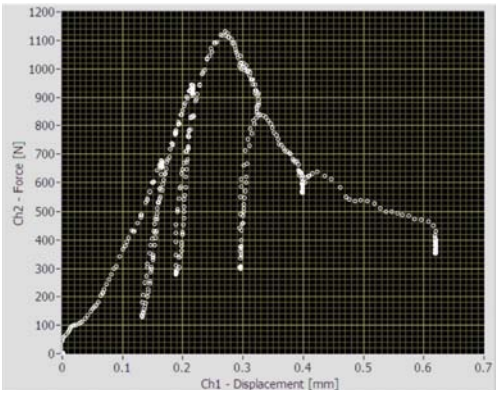


Figure 8: Micro-core uniaxial compression curve with unloading used for E-modulus calculation.

falling edge zero-crossing point as it is shown in the right picture.
Uniaxial compressive strength measurements were done with loading-unloading-reloading sequence.
Unloading part of the load-displacement characteristic was used to calculate the brick elasticity E modulus.
One of the recorded characteristics is shown in Fig. 8.

4. Results and brick properties assessment

Standard tests allowed measurement of longitudinal wave velocity, FS and UCS characteristics. CoDiT experiments provided VR and VP velocities and FS, UCS and ITS data. The results are grouped in two tables below.
Both groups of tests allowed assessment of mechanical properties of medieval bricks from Puerta de Burgos of Alcala de Henares in Madrid.
Table 1 includes sound wave velocity data measured with various methods at three laboratories.
In CoDiT method the same 1 MHz nominal frequency was used during surface wave and longitudinal wave measurements.
Longitudinal wave velocities are all in a very good agreement within a fraction of the standard deviation

Table 1: Sound wave velocities.

Equipment	Nominal freq. [kHz]	VP mean [m/s]	VP StDev.	VR z-direction [m/s]	VR_z StDev.	VR x-direction [m/s]	VR_x StDev.
CoDiT	1000	2500	114	886	295	939	117
Pundit	1000	2495	43	-	-	-	-
Pundit Plus	54	2509	232	-	-	-	-
Ultras 55	54	2360	250	-	-	-	-

Table 2: Brick elasticity and strength.

Method	E [GPa]	E StDev.	UCS [MPa]	UCS StDev.	FS [MPa]	FS StDev.	ITS [MPa]	ITS StDev
CoDiT	5.9	3.9	24.6	3.8	6.3	0.6	2.4	0.7
Standard			12.33	5.5	4.8	single specimen	-	-

independent of the measurement method.
Strength data are collected in **Table 2**.
Standard compressive strength measurements were done on three different bricks. CoDiT measurements used a piece of one brick only and all the micro-cores were drilled out from that single material sample.
This surely was a non-optimal sampling procedure. Normally in CoDiT method micro-cores should be drilled out from several various places of a historic structure element to provide more representative non-local values.
It can be observed that CoDiT results overestimate the strength values of UCS and FS measurements. This can be attributed to above mentioned different specimen sets used in both tests, which could make the data statistically incomparable.
Calculated standard deviation of standard and CoDiT strength data confirm that hand made medieval bricks have very inhomogeneous mechanical properties.
Thus whenever possible a greater number of specimens should be used to get more statistically representative results.

5. Conclusions

• Standard tests allowed measurement of VP wave velocity, FS and UCS characteristics of several bricks. CoDiT experiments provided VR and VP velocities and FS, UCS, ITS data measured on specimens over-cored from a small sample of one brick only.
• Brick strength properties assessed by standard and CoDiT method could not be this time statistically compared due to above mentioned various and limited sets of original materials used in the tests.
• Longitudinal wave velocities measured by standard methods and on micro-cores are in the very good agreement.
• Both methods show that historic hand made brick materials have a great variation of their strength properties confirmed by the large standard deviations of the measurement results.

6. Acknowledgement

Our acknowledgements to GEOMATERIALES programme (S2009-MAT1629) within Instituto de Geociencias IGEO (CSIC, UCM), to the Research Group financed by the Complutense University of Madrid "Alteration and Conservation of heritage stone materials" (ref. 921349), and to RedLabPat, the network on Science and Technology in Heritage Conservation (International Campus of Excellence CEI Moncloa).
We thank the architect of the Archibishop of Alcalá de Henares his helpful contribution in the allowance of the bricks sampling for research purposes.

References

[1] M. C. López de Azcona, R. Fort., M. Alvarez de Buergo, F, Mingarro, M. J. Varas, E. M. Pérez-Monserrat, *Un ejemplo de arquitectura hispana: Puerta de Burgos en la muralla de Alcalá de Henares, Madrid. Restauración y Rehabilitación*, 87, 50-57, 2004.
[2] M. Alvarez de Buergo, *Caracterización, alteración medioambiental y restauración en paramentos del patrimonio arquitectónico*. Monografía CEDEX M-58, Ed. CEDEX, Ministerio de Fomento, Secretaría General Técnica, 303 p., 1997.
[3] M. Alvarez de Buergo, M. C. López de Azcona, R. Fort, F. Mingarro, M. J. Varas, *Estudio para la restauración de la Puerta de Burgos en Alcalá de Henares*, Madrid. Libro de resúmenes del II Congreso Iberoamericano del Patrimonio Cultural "Conservar las Raíces", CD-ROM, 2003.
[4] M. Skłodowski, *Compact Diagnostic Test: Outline of Historical Monuments Testing Procedure*. IFTR Reports, 3, 2006.
[5] M. Skłodowski, *Micro-Cores Technology for Testing of Historical Materials*. J. Radić, V. Rajčić, R. Žarnić eds. Proc. Int. Conf. Heritage Protection, constructional aspects, Cavtat, Croatia, October 14-17, 2006.
[6] M. Skłodowski, *Quasi-non-destructive testing of historical structural materials using micro-cores*. P. B. Lourenço, P. Roca, C. Modena, S. Agrawal eds. Proc. 5th Int. Conf. Structural Analysis of Historical Constructions, New Delhi, India, November 6-8, 2006. 859-865, Advanced Research Series, MacMillan 2007.
[7] M. Skłodowski, *Minor Destructive Testing of XVIII Century Brick Wall Using Compact Diagnostic Test CoDiT. Advanced Materials Research*, Vols. 133-134, 223-228, Trans Tech Publications, Switzerland, 2010.
[8] Z. Pęski, Z. *Nowa metoda generowania fali powierzchniowej*, 13 Krajowa Konferencja Badań Nieniszczących, Kozubnik, Poland, October 25-27, 1984.
[9] J. Pinińska, *Surface wave velocity as a laboratory nondestructive control of the rock properties*, Proc. 5th Int. IAEG Congress, Buenos Aires, October 20-25, 1986. Rotterdam, Boston: Balkema 1986.
[10] M. Skłodowski, *Application of ultrasonic Rayleigh wave to testing of maonry materials*, Modena, Lourenço & Roca eds. Structural Analysis of Historical Constructions. Padova, Italy, November 10-13, 2004. Vol. 1, 395-400, A. A. Balkema Publishers, Taylor & Francis Group, London, 2005.
[11] M. Skłodowski, *Application of Ultrasonic Edge Probes to On-Site Testing of Mechanical Properties of Historical Materials*. P. Tiano & C. Pardini eds. Proc. Int. Workshop – SMW08 In Situ Monitoring of Monumental Surfaces, Florence, Italy, October 27-29, 2008, 177-186, Edifir 2008.

ISCARSAH Workshop Korea 2017 Report

In-Souk Cho (VP ISCARSAH / ICOMOS Korea)

ICOMOS-ISCARSAH Meeting, 6. June 2017
ICOMOS-ISCARSAH Scientific symposium and International Workshop on the scope of the materials and techniques: Stone, Wood and Earth, 7-9 June 2017

Host: ICOMOS-ISCARSAH
Organizer: National Research Institute of Cultural Heritage Korea and ICOMOS-KOREA.
Topics: on the scope of the material and techniques-Stone, Wood and Earth.
Subjects: Architectural heritages of Korea.
Venue: Seoul, AnDong, GyeongJu.
Meeting and Symposium: National Palace Museum of Korea (NPM), Seoul.
Workshops (Indoor and field): Seoul, Andong, Gyeongju.
Architectural Heritage: eight (8) cases.
Seoul: Sungnyemun Gate; Heunginjimun Gate; Juhamnu Pavilion of ChangDeokGung Palace.
Andong: Seven-story Brick Pagoda at BeopHeungsa Temple Site, Andong; Imcheonggak House, Andong.
Gyeongju: Gyeongju National Research Institute of Cultural Heritage; CheomSeongdae Observatory; Dabotap Pagoda and three-story Stone Pagoda at Bulguksa Buddhist Temple.
Archaeological Excavation sites: two (2) cases.
Gyeongju: Wolseong Palace Site.
Gyeongju: Jjoksaem Archaeological Site.
Official language: English.
Participated ISCs: ISCARSAH with four (4) ISCs among Twenty-eight (28) ICOMOS-ISCs.
IIWC (International committee on Wood).
ISCS (International committee on Stone).
ISCEAH (International committee on Earthen Architectural Heritage).
ICORP (International committee on Risk Preparedness).
Sponsored by: Jongno-gu and Jongno Foundation for Arts & Culture (JFAC); Han Yang University Far East Architectural History Lab (FAHL); Crown Haitai Confectionery Group; Sungik Construction Co. LTD; National Intangible Cultural Heritage and Intangible Cultural Heritage of Humanity by UNESCO (2010), Major Carpentry (Traditional Wooden Architecture), Daemokjang, Shin Eung-soo; Buddhist Venerable BeopHyun and Bongwon-sa Buddhist Temple (Taego Order), Seoul; Bulguksa Buddhist Temple (Jogye Order), GyeongJu; President of Korea Institute of Registered Architects (KIRA).
Events and performances: Pre-event at the BongWonSa Buddhist Temple: Yeongsanjae (Celebration of Buddha's Sermon on Vulture Peak Mountain) - National Intangible Cultural Heritage No. 50 and Intangible Cultural Heritage of Humanity by UNESCO (2009), 6 June.
Welcome Dinner at the President Hotel (Mozart Room) in Seoul: Performance of Young Jeongjae Gukak Hui, 7 June.
Friendship Dinner at the Sweet Hotel in GyeongJu, 8 June.
Farewell Dinner at Mugyewon (Hanok), Jongno-gu, Seoul: Korean traditional music performance of Rageum Orchestra, 9 June.
International Participants: Approximately 20 foreign experts from 15 countries including nine (9) invited chairperson or president of ISCs and Bureau members of ISCARSAH and approximately 30 Korean experts:
Görün Arun (Turkey / President of ISCARSAH); Marcela Hurtado (Chile / S.G. of ISCARSAH); Maria Margarita Segarra-Lagunes (Mexico / VP of ISCARSAH); Stephen Kelley (USA / VP of ISCARSAH); Khalid El Harrouni (Morocco / VP of ISCARSAH); Bernd Mittnacht (Germany / ISCARSAH); Ian McGillivray (Canada / President of IIWC); Stephen Simon (USA President of ISCS); Julio Vargas-Neumann (Brazil); Marek Sklodowski (Poland / ISCARSAH); Mehrdad Hejazi (Iran / ISCASAH); Toshikazu Hanazato (Japan / ISCARSAH); Yoshinori Iwasaki (Japan / ISCARSAH / ISCS); Yin Nyein Aye (Myanmar / National Museum of Myanmar); Farideh KHALAGHI (Iran / spouse of Hejazi); Ewa SKLODOVSKA (Poland / spouse of Sklodowski); Maria DURBECK (Germany / Mittnacht Beratende Ingenieure); Mary Glendinning (Canada / McGillivray Architects); Khajija OUKASSI (Morocco / spouse of El Harrouni).
Korea Participants: In-Souk Cho (Korea / VP ISCARSAH), Sansun Jo (Korea, ISCARSAH) and others.

Major Workshop Sites

1) Remains of Seoul Fortress Wall (Hanyangdoseong, the Seoul City Wall) and the main Gate to Seoul: Sungnyemun Gate, Seoul (National Treasure No. 1 /1962)

In the old days, Seoul was a typically medieval walled city, surrounded by an imposing stone wall controlled by a system of massive gates such as Sungnyemun. The walls were an impressive site, snaking along the ridge lines of surrounding mountains such as Mt. Mokmyeoksan (Namsan) and Mt. Baekgaksan (Bukaksan). Although segments still exist, mostly high in the surrounding mountains, little is left of the old walls.
In the area around Sungnyemun, the walls were dealt a decisive blow with the start of tram service in 1899. To make way for the tram tracks, the walls were pulled down, not just in Sungnyemun, but around Seoul's other main gates as well. The opening of tram service may have proved a major boon to Seoul's urban development,

Sungnyemun Gate, Seoul.

Heunginjimun Gate, Seoul.

but they came at the price of an integral part of Seoul's history.
Recently, the Cultural Heritage Administration rebuilt sections of the old city walls as part of its push to turn the old downtown area into a UNESCO recognized historic site.
Arguably Korea's most famous national landmark, Sungnyemun Gate served for centuries as the southern gateway to the royal capital of Seoul. Sungnyemun is the principal gate of the city fortress surrounding Seoul. It is also known as 'Namdaemun' (Southern Gate) in reference to its location. Before the 2008 fire, the imposing gate with its magnificent Korean-style roof was the oldest remaining wooden structure in Seoul, dating from the construction of Seoul's old city walls in 1398.
Urban development over the last century has led to the city spilling out beyond the old city walls, but Sungnyemun still marks the beginning of the "old" city center. Due to its historical and architectural value, it has been designated Korea's National Treasure No. 1.
Sungnyemun once stood isolated on a traffic island amidst one of Seoul's busiest roads. One British newspaper once referred to the gate as "Asia's most dangerous tourist attraction." Several years ago, however, a grassy plaza was constructed around the gate, making it much more accessible and safer to the public. The stately ancient gate, surrounded by imposing modern skyscrapers, is one of the most iconic images of the city. The gate was lit up at night, make for wonderful photos. Regular changing of the guard ceremonies took place at the gate. The wooden structure atop the gate was severely damaged by arson on 10 February 2008. Restoration work finished in 2013.

2) Heunginjimun Gate, Seoul (Treasure No. 1 / 1963)

HanyangdoSeong, the Seoul City Wall surrounding Seoul was built to protect the Joseon's capital, Hanseong – present Seoul, where numbers of important national institutions were situated. Among the eight gates of the fortress walls, the one located on the east of Seoul is called "Dongdaemun (The Great Gate in the East)".
When the capital walls were settled, the construction of Dongdaemun started in 1398 and repaired in 1453, and acquired its current appearance as a result of restoration work carried out in 1869 (the 6th year of the reign of King Gojong).
The gate is a two-story building exhibiting the characteristic construction style of the late Joseon period. It measures 5 kan (a unit of measurement referring to the distance between two columns) at the front and 2 kan at the sides, has a hipped-and-gabled roof, and resembles a trapezoid when viewed from the front.
The eaves of the roof are supported by a bracket system consisting of thin weak brackets with excessive decoration, placed on and between the pillars. Heunginjimun Gate is the only gate of the wall to have a semi-circular barbican built both for defensive and offensive purposes. It has the hip roof that seems like a trapezoid seen from the side.And on the outside of the gate, a crescent wall is established to make it stronger. Among the eight gates, it is the only gate that has its own wall to defend it. It's considered an important cultural asset for studying of the construction history.

**** The Five Constant Virtues of Confucianism***

Confucius also formed an ideal based on five virtues a gentleman should practice in his everyday life besides the

fact he must be well educated. Ren (仁) is the virtue of benevolence and humanity, yi (義)of honesty and uprightness, li (禮)of correct behavior, zhi (智) of knowledge and wisdom, and xin (信)of faithfulness and integrity.
Each disciple had to try to act in their life according to those five virtues since it was the way to live a healthy life in harmony.

3) A World Heritage Site: ChangDeokGung Palace Complex (Historic site No. 122 / 1963). A Stroll through 600 Years of Korea's History and Architecture.

The Changdeokgung complex was constructed in the early 15th century. The principles of Neo-Confucianism, the ruling order of the Joseon Dynasty, are well realized in its architecture, in harmony with the natural topography and features of the site. As the keeper of six hundred years of Korean history, Changdeokgung remains one of the most beloved heritage sites of the Korean people today. The Changdeokgung complex has been designated a World Heritage Site as "an outstanding example of Far Eastern palace architecture and garden design, exceptional for the way in which the buildings are integrated into and harmonized with natural setting, adopting to the topography and retaining indigenous tree cover."
(http://whc.unesco.org/en/list/816 [Aug.7, 2011.Translator.]). The following is an overview of the key aspects of the spatial organization and some of its symbolic significance.

ChangDeokGung Palace Complex, Seoul.

ChangDeokGung Palace Complex, Seoul.

ChangDeokGung Palace Complex, Seoul.

The Palace Buildings: Nature as the Architectural Background

Major buildings in the palace building complex can be categorized into residential quarters, which include Huijeongdang (the king's sleeping quarters), Daejojeon (the queen's residence) and Donggung (the crown prince's residence); Gweollaegaksa, the office complex for various court officials for supporting the king in governing the country; Seonjeongjeon (king's main office for daily business); and Injeongjeon (the "throne hall") where major ceremonial events took place.
In addition, Yeongyeongdang in Huwon (the rear garden area) and Nakseonjae nearby Donggung, both of which were added at later times in history, serve as meaningful links be-

ChangDeokGung Palace Complex, Seoul.

ChangDeokGung Palace Complex, Seoul.

tween the past and the present.
The salient aspect of architecture in the Changdeokgung complex is that nature was an integral component. In other words, nature plays an active role as a background for the buildings constructed.

The Symbolic (Sequencing), the Practical (Connecting), and the Physical (Breathing) Layout of the Spaces

A certain symbolic sequence is involved in entering the palace compound and its major quarters. The area one finds oneself upon entering through Donhwamun, the main gate to the palace compound, is an "outer court". From here, one proceeds from west to east and crosses geumcheon, the "forbidden stream," symbolically entering an area that is specially "protected" for the king. Immediately after crossing the stream, one passes through Jinseonmun, a major gate, to reach an "inner court."
The inner court here is a quadrilateral yard that tapers off toward the far side. From here one can enter jojeong, the royal court, and reach Injeongjeon, or the "throne hall," the first and symbolically the most important building of the palace complex. The royal court, a stone-floored outdoor yard in front of the throne hall where important royal ceremonies take place, is an integral part of any throne hall in Korean palaces. One can enter the royal court by passing through Injeongmun, or the Injeongjeon Gate. The throne hall and the court sit on the skirts of a mountain; they face south and are surrounded on their three sides by hoerang, or open corridors.
As for Yeongyeongdang, built in the rear garden, one crosses a small stream over a wide stone bridge to reach Jangnakmun, the main gate for Yeongyeongdang. Passing through the gate one finds oneself in a narrow rectangular outer yard. From there one finds two gates, Suinmun and Jangyangmun to the west and east, respectively. The former leads to anchae, or the inner quarters, or the women's domain, and the latter leads to sarangchae, or the men's and guest's quarters. Anchae and sarangchae each has its own yard, and each is surrounded by its own haengak, or utilities corridors. Inside the buildings, the inner quarters and the men's quarters are connected; however, in the yard area, they are separated by a low wall with a gate.
The sequence of entering Yeongyeongdang is often described as crossing "the bridge of ravens and magpies" over the Milky Way and entering the Moon Palace." The expression is a reference to the stone sculpture of a cassia tree and four toads on a stone base placed at the head of the bridge that leads to the modest residential sub-complex.
The sequence of crossing a bridge, passing through a gate, and entering the main space through a yard is similar for both Injeongjeon and Yeongyeongdang. But, there is a difference in size, role, usage, and status of the spaces. Here, one can see that a unit space of Korean architecture includes a yard encircling the main building and the yard being surrounded by corridors – either open, as in the more formal Injeongjeon and the royal court, or closed, as in the more modest Yeongyeongdang – or walls, regardless of the actual size of the building. In addition, the palace residential and office buildings have three spatial/functional components: chamber (房), hall (廳), and "balcony (樓)". In a properly oriented building, daecheong (廳), with its wood floor, is the area in which the cool air from the terraced flower beds in the back yard and the heat from the front yard intersect to provide an agreeable space to the inhabitants in the heat of the summer.

The Rear Garden: Minimal Architectural Intervention

The Changdeokgung huwon, or the Rear Garden, features both landscaped plants and man-made ponds and pavilions that are geometrically designed, on the one hand, and the original features of the natural setting of the site, on the other. The Rear Garden complex was designed in such way as to minimize man-made intervention and to maximize the pleasure of enjoying nature as is through the changing seasons. The smaller the man-made structures, such as pavilions, the greater the appreciation of nature would be. The Changdeokgung rear garden complex includes the Buyongji area with the Buyongjeong, Juhamnu, and Yeonghwadang pavilions; the Aeryeonji area with the Aeryeonjeong and Gioheon pavilions; the Bandoji area with Gwallamjeong and Jondeokjeong; and the Oknyucheon stream area with Soyoam Rock and the Soyojeong, Taegeukjeong and Cheonguijeong pavilions. Water plays a lead role in the rear garden complex. Along the Oknyucheon stream area, for example, pavilions were built at various locations each with a different orientation, while the man-made ponds such as Buyongjeong and Aeryeonjeong were designed in such a way as to reflect their own images in the water. In addition, water played a role of enhancing an open area and creating a tranquil atmosphere. Pavilions were built in various shapes to complement the natural surroundings.

Buyongjeong resembles a lotus blossom, Aeryeongjeong is square-shaped, Jondeokjeong is hexagonal, and Gwallamjeong is in the form of a folding fan. They all have two of their "legs" immersed in water. This can be understood as a means to personify an image of the ancient sages who would seek to cool off during the summer by dipping their feet into a mountain stream's cool waters. Ponds were created based on the notion of Cheon-won-ji-bang, under which it is thought that "the sky is round and the earth is square," and the relationship of water and fish that is often compared to that of the king and his subjects. These design considerations were related to scientific principles that allowed the water to circulate and not stagnate.

Cheonguijeong is a noteworthy pavilion found at the innermost area of Oknyucheon. It is built with four cylindrical pillars at each corner of a square-shaped wooden floor that is covered with a rounded thatched roof supported by eight purlins and sixty-four rafters. The pavilion is designed in such a way that the structural load is supported by the four cylindrical pillars grounded in the king's test rice paddy. The pavilion's design is meant to symbolize the relationship between the heaven, mankind, and earth, and an awareness of the changing seasons, in regard to the rice-growing cycle.

Unlike the building spaces that are intended to accommodate people's coming and going in an efficient manner, the garden areas are meant to encourage people to stroll leisurely about and appreciate the ever-changing nature. Small and simple pavilions in the rear garden area are complemented by overhead hanging plaques and juryeon, or pillar tablets, with elaborate writings that endowed the small spaces great significance.

(from KF newsletter August 2011 by Cho In-Souk
http://newsletter.kf.or.kr/news/news_201108/eng/sub_07.html).

Juhamnu Pavilion (Treasure No. 1769 / 2012)

Juhamnu Pavilion is a two-story wooden structure built in the palace's rear garden as a storage facility for the writings produced by the king. The lower story is perfectly designed to serve its function as a royal library, the upper story for observation of the natural beauty surrounding it.

The pavilion is generally regarded as the main stage of King Jeongjo (1752~1800 / r. 1776~1800)'s political reforms and the cultural renaissance of Joseon, and as the place where his distinguished scholar-statesmen, including Jeong Yak-yong (1762~1836), Park Je-ga (1750~1805), Yu Deuk-gong (1748~1807), and Yi Deok-mu (1741~1793), worked together to develop state policies and where the king's own writings, paintings, calligraphic works and seals were stored.

The building, which maintains its original condition, is located on the upper part of a slope in harmony with the surroundings, and has a verandah, four-panel folding doors, and a traditional floor-heating system. The architecture features a two-story structure measuring five kan (a unit of measurement referring to the distance between two columns) at the front and four kan at the sides, single-block columns, and narrow verandas on all four sides. The base is a four-tier structure made by piling up rectangular stones in regular courses and covering them with stones. The building is also marked by the use of double-winged brackets combined with other elements that designed to ornament the space between the column heads and the eaves while supporting the roof structures, double-layer eaves, and hipped-and-gabled roof. The ridge and rakes are finished with lime plaster, and there are ornamental "eagle heads" on the ridge, "dragon heads" on the rakes, and "miscellaneous figurines" on the hip ridges (based on the CHA explanation).

Seven-story Brick Pagoda at Beopheungsa Temple Site, Andong.

4) Seven-story Brick Pagoda at Beopheungsa Temple Site, Andong (National Treasure No. 16 / 1962)

Standing 17m tall, the Seven-story Brick Pagoda at the Beopheungsa Buddhist Temple Site is the largest and oldest brick pagoda remaining in Korea.

Though the pagoda is a high seven-story pagoda, it looks very stable.

Given that the name of the site where the pagoda stands is Beopheung-ri. Presumably, the pagoda used to belong to Beopheungsa, a Buddhist temple built during the Unified Silla Period (676~935).
The pagoda's body stands on a single-story platform, and is made of firmly masonry bricks. The body is made of dark gray bricks without patterns, and there is a niche at the center of the first floor in which a Buddha image would have been enshrined.
Eight Guardian Deities and Four Guardian Kings are carved out of granite on each side of the pedestal, while on the southern side there is stairway leading to the niche in the body of the first floor. Unfortunately, the upper side of the platform is now cemented. The roof stone has a mark that shows there were roof tiles on its upper side, which is very different from common brick pagodas whose upper and lower roof stones are staircase-shaped. Considering that there is the mark of roofing tiles on the roof, it is estimated as a material that proves that the brick pagoda was built by imitating the appearance of wooden pagodas. (based on the CHA explanation)

Imcheonggak House, Andong.

5) Imcheonggak House, Andong (Treasure No. 182 / 1963)

Imcheonggak House was built by Yi Myeong, a high-ranking official of the Ministry of Justice, in 1515 (the 10th year of the reign of King Jungjong (1488-1544 r. 1506-1544) of the Joseon Dynasty), and was also inhabited by Lee Sang-ryong (1858~1932), the third president of the Provisional Government of the Republic of Korea in Shanghai.
This house is located on the eastern slope of Yeongnamsan Mountain and faces the Nakdonggang River, in what is, according to Pung-su (ch. Fengshui) theory "sitting north and facing south", or "carrying Yin at the back and encompassing Yang in the front" or "having hills behind and river in front. During the construction of the Central Railway Line (1936 onward), some fifty buildings of the servant's quarters and various attached houses were torn down, thus reducing the scale of the house to its current size; however, with the remaining houses around the main gate, Imcheonggak House has retained a spectacular appearance nonetheless.
Designated as a treasure in recognition of its well-preserved state, Gunjajeong Pavilion was the detached quarters of Imcheonggak House. It is a '丁'-shaped architecture measuring three kan (a unit of measurement referring to the distance between two columns) at the front and two at the sides, and has a hip-and-gable roof resembling the character 八 when viewed from the side. It has four rooms, including a south-facing vestibule at the center of the building, and a '丁'-shaped room with a Korean under-the-floor heating system in the western part. A narrow wooden porch and a handrail run around the exterior of the building, and there are two sets of stone stairs serving as entrances to the building (based on the CHA explanation).

Cheomseongdae Observatory, Gyeongju.

6) Cheomseongdae Observatory, Gyeongju (National Treasure No. 31 / 1962)

Cheomseongdae Observatory is thought to have been built during the reign of Queen Seondeok (? ~ 647 / r. 632-647) of the Silla Dynasty for observation of the movements of heavenly bodies.It is the oldest astronomical observatory in Asia and is widely regarded as a precious cultural heritage that gives us a clear idea of the level of technological development of that time.
During the ancient period, astronomy was deeply related to agriculture as farming times were often determined according to the movements of the stars. It was also deeply related to politics in that the horoscope was considered to be important, since the good or bad fortune of a nation could be predicted according to the results of their observation of the stars.
Standing approximately 9 m in height, this observatory consists of a cylindrical body, a platform, and a square top.
The cylindrical body includes 27 layers of fan-shaped stones, and the

outer face is trimmed smooth whereas the interior wall face is not even.
At the upper part, long ends of stone material that is geared into inside part of hash shape are extended to the outside. This arrangement can be seen in layers 19-20 and 25-26, and so it is assumed that a ladder was easily placed easy on those steps in the inside.
Around the southeast opening, the lower part is filled with rubble, while the upper part to the top is open and hollow. The eastern half of the uppermost step is blocked with a stone slab. It is presumed that there might have been some devices for observation inside the observatory.
The record of an ancient book states, "People can climb up through its middle". It seems that one simply placed a ladder on its outside and climbed inside through a window, and then climbed up to the top via another ladder to observe the stars (based on the CHA explanation).

Dabotap Pagoda of Bulguksa Temple, Gyeongju.

7) Dabotap Pagoda of Bulguksa Temple, Gyeongju (National Treasure No. 20) and Three-story Stone Pagoda of Bulguksa Temple, Gyeongju (National Treasure No. 21)

Bulguksa is the most famous Buddhist temple in Korea and the home to a number of important relics from the Silla period (BCE 57-CE 935) including most obviously the two stone pagodas Tabot'ap and Sokkat'ap.
Although it was neither the largest Silla temples nor the chief temples of the Koryo or Joseon periods, Bulguksa has also become an important regional center of the Jogye Order of Korean Buddhism.
While it has been rebuilt on a number of occasions, much of the present form of the temple can be traced to a major archaeological investigation and reconstruction effort carried out by presidential order between 1969 and 1973.
More recently, in December 1995, Bulguksa and Sokkuram were one of Korean sites (14 sites as of 2020) to be added to the UNESCO World Heritage list. Bulguksa was known to be built in 8th Century at the time of King Gyeongdeok of the Silla Dynasty in addition to Seokguram, and was completed during the reign of King Hyegong of Silla.

Dabotap Pagoda of Bulguksa Temple, Gyeongju (National Treasure No. 20)

It stands to the right as one faces the Main Hall. "Tabo" means "many treasures," and the Dabotap is dedicated to the Dabo Yorae-the Buddha of Many Treasures. Dabo was a disciple of Sakyamuni who eventually achieved enlightenment. During his life he dreamed of rising from the ground as a pagoda, and he requested that such a pagoda be built after his death to house his remains. Historically, there are records of a Dabot'ap being built in China in 732; the pagoda at Bulguksa was built less than twenty years later. However, while there are other Dabotaps, there is no pagoda in the world whose appearance can really be called similar to the Dabotap at Bulguksa
In comparison to the ornate and unique Dabotap, the 8.2m ***Sokkatap, Three-story Stone Pagoda*** of Bulguksa Temple, Gyeongju (National Treasure No. 21) represents the typical style of Korean stone pagodas: an alternation of unadorned square body sections and their grooves, laid upon a square base, with a thin finial at the very top.
Indeed, along with the twin pagodas at Kamunsa, Sokkatap is said to represent the "golden ratio" of Silla pagoda architecture; it is considered Korea's most "typical" stone pagoda and is even pictured on the ten-won coin. The reason for this has to do with the ratio between the heights of the body sections. This ratio varies in different pagodas constructed at different times.
In Sokkat'ap (and in the Kamunsa pagodas) it is 4:2:2 (first:second:third), which is analogized to the ratio of the human body and held to represent a sort of classical perfection against the more "mannerist" appearance of late Silla and early Koryo pagodas, for example. During restoration work in 1966, a wood-block printing plate containing a section of the Dharani Sutra was found in Sokkatap. This is considered to be the world's oldest surviving wood-block printing plate (from the lecture by In-Souk Cho).

**** The Emergence of the Treasure Tower***

At that time a loud voice issued from the treasure tower, speaking words of praise: "Excellent, excellent! Shakyamuni, World-Honored One, that you can take the great wisdom of equality, a Law to instruct the bodhisattvas, guarded and kept in mind by the Buddhas, the Lotus Sutra of the Wonderful Law, and preach it for the sake of the great assembly! It is as you say, as you say. Shakyamuni, World-Honored One, all that you have expounded is the truth!".
At that time the four kinds of believers saw the great treasure tower suspended in the air, and they heard the voice that issued from the tower. All experienced the joy of the Law, marveling at this thing they had never known before. They rose from their seats, pressed their palms together in reverence, and then retired to one side.
At that time, there was a bodhisattva and mahasattva named Great Joy of Preaching, who understood the doubts that were in the minds of the heavenly and human beings, asuras and other beings of all the world. He said to the Buddha:"World-Honored One, for what reason has this treasure tower risen up out of the earth? And why does this voice issue from its midst?".

At that time the Buddha said: "Bodhisattva Great Joy of Preaching in the treasure tower is the complete body of a Thus Come One. Long ago, an immeasurable thousand, ten thousand, million asamkhyas of world sto the east, in a land called Treasure Purity there was a Buddha named Many Treasures".
When this Buddha was originally carrying out the bodhisattva way, he made a great vow, saying , 'If after I have become a buddha and entered extinction, in the lands in the ten directions there is any place where the Lotus Sutra is preached, then my funerary tower, in order that I may listen to the sutra, will come forth and appear in that spot to testify to the sutra and praise its excellence'.
When that Buddha had finished carrying out the Buddha way and was on the point of passing into extinction, in the midst of the great assembly of heavenly and human beings he said to the monks, "After I have passed into extinction, if there are those who wish to offer alms to my complete body, then they should erect a great tower". That Buddha, through his transcendental powers and the power of his vow, insures that, throughout the world in the ten directions, no matter in what place, if there are those who preach the Lotus Sutra, this treasure tower will in all cases come forth and appear in their presence and his complete body will be in the tower, speaking words of praise and saying, Excellent, excellent!
"Great Joy of Preaching, now this tower of the Thus Come One Many Treasures, because it heard the preaching of the Lotus Sutra, has come forth out of the ground and speaks words of praise, saying, Excellent, excellent!" (from the Lotus Sutra).

**** Seokguram Grotto and Bulguksa Temple (World Heritage Site / 1995)***
Established in the 8th century under the Silla Dynasty, on the slopes of Mount Tohamsan, Seokguram Grotto and Bulguksa Temple (built in 774) form a religious architectural complex of exceptional significance. Prime Minister Kim Dae-seong initiated and supervised the construction of the temple and the grotto, the former built in memory of his parents in his present life and the latter in memory of his parents from a previous life.
Bulguksa is a Buddhist temple complex that comprises a series of wooden buildings on raised stone terraces. The grounds of Bulguksa are divided into three areas – Birojeon (the Vairocana Buddha Hall), Daeungjeon (the Hall of Great Enlightenment) and Geungnakjeon (the Hall of Supreme Bliss).
These areas and the stone terraces were designed to represent the land of Buddha. The stone terraces, bridges and the two pagodas – Seokgatap (Pagoda of Sakyamuni) and Dabotap (Pagoda of Bountiful Treasures) – facing the Daeungjeon attest to the fine masonry work of the Silla (from WHS https://whc.unesco.org/en/list/736).

8) Wolseong Palace Site, Gyeongju (Historic Site No. 16 / 1963 / UNESCO WHS Gyeongju Historic Areas / 2000) and Jjok Saem Archaeological Site at Gyeongju
Wolseong is the capital fortress where the royal palace of Silla was once located. This was constructed in 101 CE, the 22nd year of the reign of King Pasa (? ~ 112CE), to defend the royal palace, which was moved from Geumseong, the capital of Silla (57 BCE ~ 935 CE).
It is called Banwolseong or Sinwolseong because, as the name implies, it is shaped like a half-moon. It was also called Jaeseong, meaning the fortress where the king resides. Namcheongang River flows along the south wall, providing a natural barrier. There are sites of Imhaejeon Hall and many other buildings. Seokbinggo, the famous Ice Storehouse, was moved here from the western part of Wolseong (based on the CHA explanation).

**** Gyeongju Historic Areas (World Heritage Site / 2000)***
The Gyeongju Historic Areas contain a remarkable concentration of outstanding examples of Korean Buddhist art, in the form of sculptures, reliefs, pagodas, and the remains of temples and palaces from the flowering culture of Silla dynasty, in particular between the 7th and 10th century. The Korean peninsula was ruled for almost 1,000 years (57 BCE – 935 CE) by the Silla dynasty, and the sites and monuments in and around Gyeongju bear outstanding testimony to its cultural achievements. These monuments are of exceptional significance in the development of Buddhist and secular architecture in Korea.
The property comprises five distinct areas situated in the centre of Gyeongju and in its suburbs.
The Mount Namsan Belt lies to the north of the city and covers 2,650 ha. The Buddhist monuments that have been excavated at the time of inscription include the ruins of 122 temples, 53 stone statues, 64 pagodas and 16 stone lanterns. Excavations have also revealed the remains of the pre-Buddhist natural and animistic cults of the region. 36 individual monuments, including rock-cut reliefs or engravings, stone images and heads, pagodas, royal tombs and tomb groups, wells, a group of stone banner poles, the Namsan Mountain Fortress, the Poseokjeong Pavilion site and the Seochulji Pond, exist within this area.
The Wolseong Belt includes the ruined palace site of Wolseong, the Gyerim woodland which legend identifies as the birthplace of the founder of the Gyeongju Kim clan, Anapji Pond, on the site of the ruined Imhaejeon Palace, and the Cheomseongdae Observatory.
The Tumuli Park Belt consists of three groups of Royal Tombs. Most of the mounds are domed, but some take the form of a half-moon or a gourd. They contain double wood coffins covered with gravel, and excavations have revealed rich grave goods of gold, glass, and fine ceramics. One of the earlier tombs yielded a mural painting of a winged horse on birch bark.
Hwangnyongsa Belt consists of two Buddhist temples, Bunhwangsa Temple and the ruins of Hwangnyongsa Temple. Hwangnyongsa, built to the order of King Jinheung (540 – 576 CE) was the largest temple ever built in Korea, covering some 72,500 m2. An 80 m high, nine-storey pagoda was added in 645 CE. The pagoda in Bunhwangsa was built in 634 CE, using dressed block stones.
The Sanseong Fortress Belt consists of defensive facilities along the east coast and at other strategic points and includes the Myeonghwal Mountain Fortress (from WHS https://whc.unesco.org/en/list/976).