International Association for Shell and Spatial Structures
IASS WG12+18 Joint International Colloquium on

Bio-based and Bio-inspired Environmentally Compatible Structures

Final Program and Proceedings

April 10-13, 2015
Tokyo Denki University, Senju Campus
Tokyo, Japan

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General Colloquium Information

The 2015 Colloquium of the International Association for Shell and Spatial Structures Working Group 12 (Timber Spatial Structures) and Working Group 18 (Environmentally Compatible Structures) "Bio-based and Bio-inspired Environmentally Compatible Structures," is conducted under the auspices of:

- The International Association for Shell and Spatial Structure (IASS) – www.iass-structures.org
- Tokyo Denki University – www.web.dendai.ac.jp

Colloquium Venue and Room Information

The Colloquium is held in the 100th Anniversary Hall of Tokyo Denki University Senju Campus, Building 1, Floor 1, Senju Asahi-Cho 5, Adachi-ku, Tokyo 120-8551.
The 100th Anniversary Hall can be accessed from the main entrance of Building 1 located next to "Italian Tomato."
The 100th Anniversary Hall is a large event space that will be separated into three rooms via dividers with the designations A, B, and C.
Room A will used for the opening ceremony, keynote speeches, reading drama, and parallel sessions.
Room B will be used for coffee breaks and lunch.
Room C will be used for parallel sessions.

Computer Access

Wireless network connections are available throughout the campus. Login details will be provided to participants during the Colloquium.

Bus Transportation

Tokyo: One-way bus transportation will be provided from the Colloquium to the cocktail party, traditional theatrical comedy, and closing ceremony/dinner party.
Kyoto: Bus tour will be provided for technical tour participants.

Colloquium Secretariat

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Full Paper List

(Full papers will be provided via the attached CD)

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15T-01	General Formulation Of Restoring Force And Stiffness Characteristics Of Column Rocking Behavior Of Chinese Ancient Timber Structure
15T-03	Optimization Of Elastically Deformed Gridshell With Partially Released Joints
15T-04	Environmental Assessment Of Cardboard As A Building Structure
15T-05	Study On The Wooden Frame For The Exterior Parts Of The Atrium In Consideration Of Dismantling And Displaying
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15T-10	Operation Modeling And Analysis Of The Stress-Strain State Of Different Variants Of Technical Performance Of Timber Grid Roof Joints
15T-11	To The Problem Of Numeric Research Of Stressed-Strained State Of A Closed – Type Building
15T-12	Complex Of Dome - Ribbed Buildings
15T-13	Selection Of Thermal Insulation Materials Based On A Multiple Criteria Analysis
15T-15	Practical Utilization Of Life Cycle Design Method For Building Structures
15T-16	“2 Landscapes” – Interaction Of 2 Gridshells Based On A Modified Stewart - Gough - Principle
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15T-18	Nature Inspired Principles Of Environmentally Compatible Structure
15T-19	Fractal Structures Based On The Geometry Of Nature
15T-20	Seismic Performance And Probabilistic-Based Design Of Timber-Steel Hybrid Structures
15T-23	Computational Morphogenesis Of Free Formed Shells With Consideration Of Structural Stability
15T-24	Structural Design Method Of Topo Shell Constructed By New Material
15T-26	Modular, Adaptable Shelters For Environmentally Sensitive Archaeological Sites
15T-27	Optimisation Of Minimum Unit-Tensegrity Structures Considering Its Robustness And Global Displacements
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15T-39	Seismic Reinforcement Was Planned Reinforcement Material To The Right Place - Structural Design Of Shiozaki Building In Japan -
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Modular, adaptable shelters for environmentally sensitive archaeological sites

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Abstract

The Valle dei Templi Park, located in the Italian island of Sicily, extends over a surface of 1,300 hectares and preserves an extraordinary monumental heritage and landscape, dating back to Greek times and a UNESCO World Heritage site since 1997. Though visited by millions of tourists, the archaeological sites are not appropriately equipped for tourist use: this is why the Park Agency is promoting actions to improve facilities that are appropriate for today's visitors and cultural standards.

The "Architecture X Archaeology" workshop, that took place in 2013, explored the design and construction of lightweight, temporary structures to shelter archaeological sites and excavations otherwise exposed to the weather. The workshop was promoted by the Valle dei Templi Park Agency and was supported by the JSB programme, where Toyo Ito is one of the jury members.

The interdisciplinary design of different types of shelters was based on locally available materials, but mixed the construction cultures of Italy and Japan through the participating universities. A Building and Information Modelling (BIM) process was adopted to control parameters related to the temporality of the shelters, their maintenance and their adaptability to the different local landscapes.

The teams of Politecnico di Milano and the University of Tokyo developed two distinct solutions for specific applications. The "AkragaShelter" was designed to protect archaeological remains and, based on a mix of local stones, wood and plastic, is not intended to move, but can be dismantled in the future. The "Molecular Shelter" was instead designed around a single timber section to shelter temporary excavation sites, moving with the archaeologists in time; four persons are enough to displace the structure without dismantling it.

The shelters were then constructed on site and they now represent the first step of a plan to introduce in the Valle dei Templi Park architectural elements that are at the same time contemporary and respectful of the sensitive heritage and landscape. The purpose is to prove that contemporary architecture, structure and archaeology can coexist harmoniously.

Keywords: shelters; lightweight structures; temporary structures; parametric design; educational activities; timber structures; gabion systems; archaeology.

1. Introduction

"Architecture X Archaeology" is a co-joint workshop held in 2013 in the Valle dei Templi Archaeological Park in Agrigento, Sicily (Italy). Tokyo University, Politecnico di Milano and Università di Palermo explored the design and construction of lightweight, temporary structures to shelter archaeological sites and excavation works otherwise exposed to the weather.

This peculiar goal emerged from discussions with the Valle dei Templi Park agency, that highlighted the need of improved tourist infrastructure in the area, at the same time respecting the landscape and the archaeological remains and providing better working conditions for the archaeologists on site.

The introduction of additional elements in the landscape proves challenging, because – even if the shelters themselves are small – they inevitably transform the site, altering the relationship between ancient remains and landscape. The projects have then attempted a dialogue with the context – they listened to and answered it – through the design of a respectful architecture based on an optimised use of structures and materials.

The workshop was divided into two parts: the first preliminary part, 45 days long, took place at each university. The second phase, 7 days long, took place on site. The preliminary part introduced issues related to the complexity of designing within archaeological sites, applications of computational design, structural stability, and practical solutions for quick physical materialization of ideas within limited time and budget. The second part explored the culture and nature of Akragas (the ancient name for Agrigento) which served as a pretext for further exploring alternative designs for archaeological sites.

2. The site and its needs

Located in the Southern Italian island of Sicily, the Valle dei Templi Archaeological Park, covering an area of nearly 1,300 hectares, preserves an extraordinary monumental and natural heritage that includes the ruins of ancient Greek city of Akragas (today's Agrigento) and the surrounding landscape. Listed in 1997 as a Unesco World Heritage Site, the Valley of Temples is home to one of the largest archaeological complex of Mediterranean area, immersed in an outstanding rural landscape punctuated by centuries old olive and almond trees.

Though visited by millions of tourists each year, attracted by this extraordinarily rich archaeological legacy, Agrigento's archaeological sites are not appropriately equipped for tourist use. To improve the beneficial effects of tourism on the local economy it is then necessary to plan and build adequate structures for visitors, and to provide improved protection for both the remains and the archaeologists at work.

The Park Agency promoted the "Architecture X Archaeology" workshop as an occasion of specific reflection about the construction of shelters, with the related technical aspects – anchoring to uneven ground, run-off and/or collection of rain water, etc. – and the cultural issues implied by the inevitable transformation of the original site.

3. The AXA workshop

The workshop was promoted by the Valle dei Templi Park Agency and was supported by the Japan Supporting Board for International Activities of Architecture (JSB) of the AIJ (Architecture Institute of Japan) and JIA (The Japan Institute of Architects). Japanese architects such as Kengo Kuma served as scientific advisors and Toyo Ito served as one of the jury members of this programme.

The aim of the workshop was to develop innovative ideas about shelter structures for archaeological sites, with a modular and flexible structure adaptable to different sites and needs. Teams were required to design and build full-scale prototypes of their shelters, merging theoretical ideas and proposals with hands-on activities and confrontation with the physical reality of materials and construction.

Despite differences in the use of software (Rhinoceros, Grasshopper, BIM, Autocad), main material of choice (wood, stones, micro-perforated polycarbonate), fabrication method (CNC routing, manual sawing), and budget (from 1,000 € to 6,000 €, including all costs) it was possible to analyse and compare the proposals during the design process and the construction phase.

The collaboration between academia and the Valle dei Templi Park Agency consisted of both taught sessions throughout the academic year and collaborative work before and during the workshop. Functionaries of the archaeological park provided students from Japan and Italy with reference books, technical drawings, aerial photos, and cadastral maps of the site. The preliminary research and design activity conducted co-jointly by professors, tutors, and students was used to achieve a mature design during the workshop and build the prototypes in a short time.

Students were asked to focus on a reciprocal and beneficial dialogue between architectural and archaeological issues. In fact, the final results show the great potential value which the interdisciplinary integration between architecture and archaeology offers to both disciplines, both in terms of research and analysis and also in terms of how the planning pertains to the execution of contemporary interventions in sensitive sites.

4. The design of shelters

The shelters designed and assembled in the AXA workshop are the first visible prototypes of a potentially wider catalogue of solutions for the protection of archaeological sites in natural environments.

The participating teams have interpreted their projects as elements in continuity with the landscape, not conflicting but rather merging with it, and respecting the ancient remains they protect. The collaboration between Politecnico di Milano and the University of Tokyo led to a very fertile cross-pollination of Eastern and Western culture, with the development of two peculiar alternative project that, while using local materials, refer to wider cultural backgrounds – and construction traditions – such as the Japanese Zen mysticism and the Mediterranean Greek classicism.

Two distinct solutions were developed for specific applications. The "AkragaShelter" was designed to protect archaeological remains in time and, based on a mix of local stones, wood and plastic, is not intended to move, but can be dismantled in the future; this shelter allows tourists to experience visible remains without exposing the latter to the elements. The "Molecular Shelter" was instead designed around a single timber section to protect temporary excavation sites, moving with the archaeologists in time as they discover more remains around the site; four persons are enough to displace the structure without dismantling it.

Digital techniques for the formation of shapes have been used for the definition of the design. Both teams used digital strategies to design the shelters, in particular with two different levels of interaction between design and digital environment (Fig. 1):

- parametric and associative modelling for the AkragaShelter;
- scripting modelling for the Molecular Shelter.

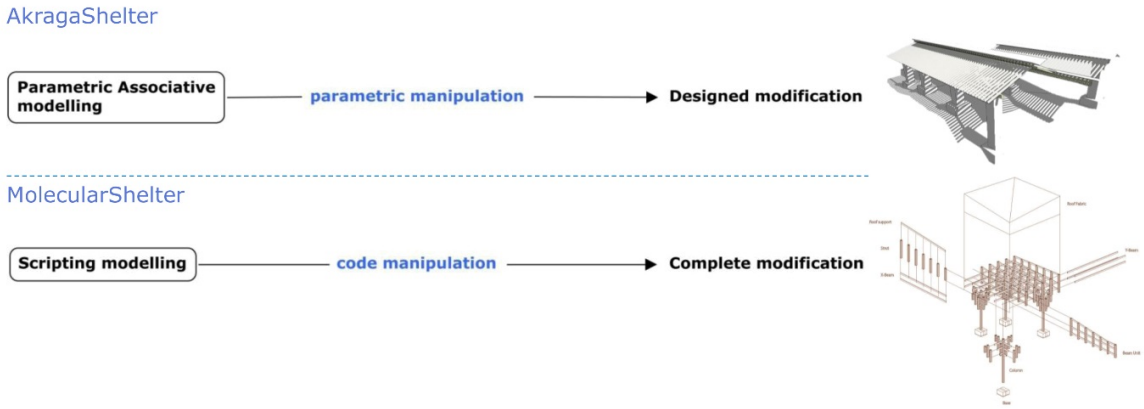

Figure 1: The digital approach used in the shelters' design.

The first approach has led the team to interact with different mechanisms of formation of the model. The team members controlled the models via parametric manipulations, they defined and created parameters and association between them, and therefore they obtained and investigated different design solutions.

In the second approach, the team generated every part of the model through a script. The team members interacted with the models via code manipulation, and then, they used these complex relations between the components of the shelter, to control every aspect, first of the design, and later of construction.

Finally, the teams used the digital models as tools to investigate the best solutions for their concept.

4.1. AkragaShelter

AkragaShelter sits by a temple built to honour a sacred spring dedicated to Demeter, wife of Zeus: a special and holy place, where architecture and nature combine and unite in an empathic way.

The small pavilion, with a plan of about 20 m^2, was built to protect some portions of the temple, now dismantled and aligned on the ground, waiting to be reassembled. However, this system could serve the Park Valley of the Temples also for other purposes. Due to the sacredness of the place and the impressive archaeological site, the team opted for a simple design solution which makes use of materials such as wood, corrugated fiberglass, and rocks collected on site.

As the design work was shared with the Kengo Kuma Lab, the team referred to some aspects of Japanese culture – Zen mysticism – as well as local ones – Greek classicism. The reference to the Greek temples of Agrigento is expressed in the project through the use of massive columns realised in galvanised steel gabions filled with local stones, anchoring the shelter to the ground. This reference is highlighted by the slope of the roof, angled 22.5°, identical to that of the Temple of Concordia (Fig. 2). Moreover, the wooden roof evokes the typical gable roof of the Greek temples. Concerning the reference to Japanese culture, the shelter gets inspiration from the Ise Shrine, the most important Japanese shrine, made of Inoki wood (cypress). In particular, it looks at the temporality and reversibility of Ise – which is disassembled and reassembled every 20 years – and at the shape of the roof summit, surmounted by a V-shaped ventilation device that is also used for water collection. The roof structure is covered by white corrugated fiberglass panels (Fig. 3), providing soft atmosphere when the shelter is lit up at night, with an effect similar to a Japanese lamp made of rice paper.

Fig. 2: White corrugated fiberglass covers AkragaShelter, giving it a soft atmosphere.

Fig. 3: The shelter references the nearby temple dedicated to Demeter, wife of Zeus.

The concept of AkragaShelter follows specific requirements, which can be summarized in the follow main principles:

- integrate the shelter in the natural landscape;
- make the shelter flexible and adaptable to different areas.

Following these two main ideas, the structure of the shelter has been built using natural materials. The column and the foundation are based on a gabion wall system (a dry system derived by the invention of Leonardo Da Vinci, the "Corbeille Leonard") filled with local stones, picked up from the site. The structure, just a metal net filled up in place, is light and easy to transport, making the component transportable and reusable (Fig. 4).

Fig. 4: Gabion walls during the construction stage of the AkragaShelter.

The colour of the stones harmonizes the shelter with the surrounding environment, and other environmental concerns were considered in the design. One of these is the V-shaped component on top of the roof, enhancing the Venturi effect and ventilating the work space under the roof.

Since the goal of the workshop was to design replicable modules for the archaeological park, the use of digital design techniques was fundamental for the adaptability of the result to different areas and ground conditions.

AkragaSheleter was designed as a parametric and associative model. The shelter – which is modular and flexible – was conceived as a module that can be built in different areas of the park. Four variables have been taken into consideration for making the model: 1) the variety of sites with ruins in the park, 2) the different orientations of the sites, 3) the different size of the ruins to be covered by the shelter, 4) the uneven level of the ground.

Each requirement (flexibility, modularity, temporality, land morphology and ruin size) has been considered as a parameter in the digital model. Following this scheme, a digital design model was generated. It can adapt its global geometry and the geometry of its components to the different variables. The height of every column is adjusted to ground conditions. The ground has been modelled as a cloud of points, and can be replaced by a laser scanning survey of other areas in the Valley of Temples. The length and width of the roof came as a result of the dimensions of the ruins. Every component of the shelter is hierarchically associated to the geometry of other components in a tree of associative relationships.

Once the shelter was digitally modelled, it was possible to simulate the real condition of the site and associate its geometry to a database, from which it is consequently possible to extract: amount, dimension and specifications of construction elements, as shown in Fig. 5.

The team built a small architecture, simple and respectful of the surroundings yet functional and elegant, perfectly integrated in the natural environment of the Valley of Temples. This experiment shows the possibility in the use of this modelling strategy in a very simple geometry. Here the advantage is in the adaptability of the parametric shelter to different environmental situations.

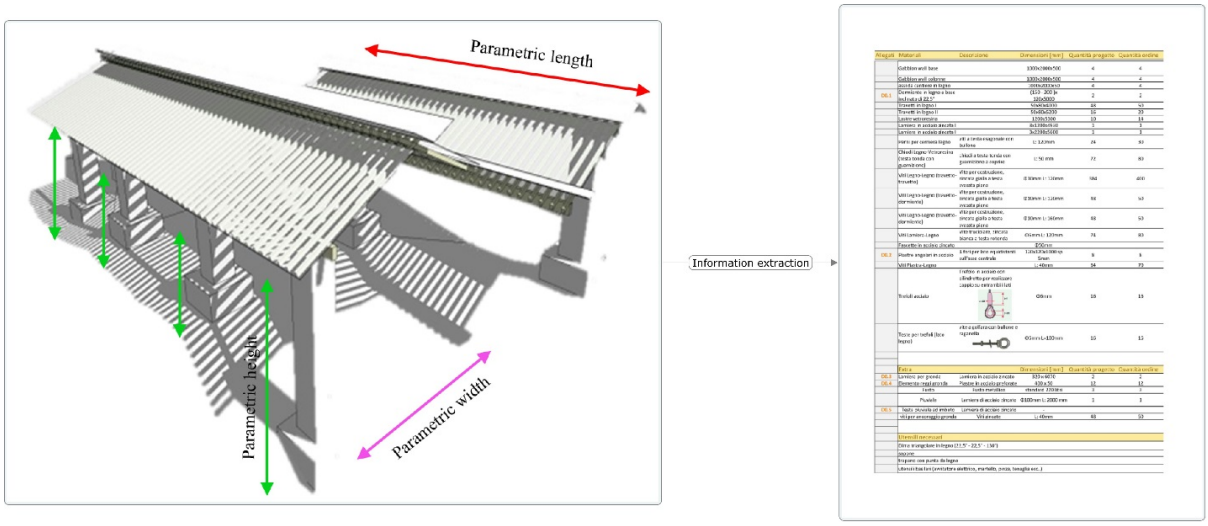

Fig. 5: Parametric model and construction information database.

4.2. The Molecular Shelter

While respecting the local context, the Molecular Shelter design reinterprets a concept borrowed from Japanese traditional culture. In fact, the shelter takes inspiration from the bracket system "To-Kyou: 斗栱" found in traditional Japanese temples, where the roof plays a prominent role. The bracket system "To-Kyou" derived from Chinese architecture and was reinterpreted innovatively as Japanese style in the medieval era (8^{th} – 12^{th} century). It is a kind of stacking structure composed of wood materials and it enabled architects to design flexibly plans, structures and compositions of the temples in that era.

The eaves – which extend far beyond the walls, covering verandas – have a practical function because they protect the building by carrying the rain as far away as possible from its perimeter. The roof's weight is supported by the simple bracket systems. The shelter meets the requests of the Park Agency that asked for a shelter with a roof as large as possible, designed to carry the rain as far away as possible from the excavations, movable from site to site, and with the possibility to set it up again in different locations and with minimum surface area at the column base (Fig. 6). Column sizes were checked by professor engineer Jun Sato through structural analysis software to optimize them to the thinnest possible size.

The traditional bracketing system was reinterpreted in the design, yet, it keeps an extremely essentiality both from the structural and aesthetical points of view, and present an intrinsic elasticity, which lessens the impact of lateral forces by acting as a shock absorber. With the "To-Kyou" bracket system it is not possible to change the position of columns after the construction, but with the system developed for the Molecular Shelter it is possible to change it under the grid ceiling-structure even after the construction. The inclination of the roof is borrowed from Tempio della Concordia, so to have a direct reference to existing forms in the landscape. The shelter – being made of multiple units – is light, easy to fabricate and assemble in a reasonably short time, movable, adaptable to the site, and modular. The structure is designed to allow archaeologists to hang their working tools.

The whole structure of the shelter is composed by a joint system of 4 small struts, with constant section, bound along both x and y direction beams with M6 screws (Fig. 7). The screws add resistance against rotational movements due to horizontal external forces. Being modular, the system allows future extensions. If requested by particular site conditions, columns can be positioned at different points of the grid. The structure weighs around 100 Kg, and can be easily moved by four people. The shelter was anchored to the ground by 4 concrete blocks of 20 x 20 cm. The prototype shelter is made of local pine trees, cut and assembled with 5,000 M6 size screws. It took five days to assemble it, and the final cost of the pavilion amounted to 1,600 euros.

Concerning computational aspects, programming was developed with Rhino, Grasshopper and Python. This made it possible to organize the exchange of information between Tokyo and Agrigento and optimize the calculation which enables parametrical changes. In particular, the use of parametric software proved to be essential for testing different size and arrays of the grid structure, structure thickness and weight, materials length and number of the elements used. As for the fabrication, a hand-made easy fabrication system was

preferred, which demands only simple holes by drilling and screwing instead of sophisticated machinery hard to find on site. Moreover, due to limited vehicular access to the archaeological areas, it has proved strategic to use transportable lightweight tools instead of heavy machinery.

Fig. 6: The Molecular Shelter integrated in the Valle dei Templi, close to the Temple of Concordia.

Fig. 7: The traditional Japanese bracket system and its reinterpretation.

5. Conclusions

Conceived and finished in a very condensed period of less than 45 days, the prototype shelters introduce in the Valle dei Templi Park architectural elements that are at the same time contemporary and respectful of the sensitive heritage and landscape.

The structural choices, together with computational design and digital fabrication, enabled the quick erection of the shelters on site.

The Japanese and Italian students interacted profitably, both with the local authorities and with the Park Agency functionaries and architects. The architectural design meeting took advantage of the scientific supervision of Kengo Kuma and Jun Sato as well as the contributions of experts like Giuseppe Guerrera, former director of a

master course about archaeology at the University of Palermo. The synergy of academia, public bodies and craftsmanship represented a unique moment of exchange and growth which opens new paths to explore for the future of Sicily.

The shelters produced during the "Architecture X Archaeology" workshop, other than having a functional and aesthetic value, were built only for temporary use; however, they now form the first steps in a wider plan, imagined by the Park's Director Giuseppe Parello, to integrate contemporary architecture within the archaeological park.

The final purpose is to prove that contemporary architecture, structure and archaeology can coexist harmoniously.

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Contractor: DIPARC - Vito and Michele D'Anna

Organization: Laps Architecture, Paris; Atelier2, Milan.

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