ARCHITECTURE HERITAGE and DESIGN

Carmine Gambardella

XVI INTERNATIONAL FORUM

Le Vie dei Mercanti

WORLD HERITAGE and KNOWLEDGE

Representation | Restoration | Redesign | Resilience

ARCHITECTURE HERITAGE and DESIGN | 2
Collana fondata e diretta da Carmine Gambardella

ARCHITECTURE HERITAGE and DESIGN | 2
Collana fondata e diretta da Carmine Gambardella

Carmine Gambardella

WORLD HERITAGE and KNOWLEDGE
Representation, Restoration, Redesign, Resilience
Le Vie dei Mercanti
XVI International Forum di Studi

Editing: Giovanni Bello, Alessandro Ciambrone,
Maria Luigia Di Bennardo

Il volume è stato inserito nella collana Architecture, Heritage and Design, fondata e diretta da Carmine Gambardella, in seguito a a peer review anonimo da parte di due membri del Comitato Scientifico.

The volume has been included in the series Architecture, Heritage and Design, founded and directed by Carmine Gambardella, after an anonymous peer-review by two members of the Scientific Committee.

ISBN 978-88-492-3633-0

Carmine Gambardella

WORLD HERITAGE and KNOWLEDGE
Representation, Restoration, Redesign, Resilience

Le Vie dei Mercanti _ XVI International Forum

Conference Topics:

Heritage
Tangible and intangible dimensions
History
Culture
Collective Identity
Memory
Documentation
Management
Communication for Cultural Heritage
Architecture
Surveying
Representation
Modeling
Data Integration
Technology Platforms
Analysis
Diagnosis and Monitoring Techniques
Conservation
Restoration
Protection
Safety
Resilience
Transformation Projects
Technologies
Materials
Cultural landscapes
Territorial Surveying
Landscape Projects
Environmental Monitoring
Government of the Territory
Sustainable Development

WORLD HERITAGE and KNOWLEDGE
Representation, Restoration, Redesign, Resilience

Le Vie dei Mercanti
XVI International Forum

Napoli | Capri
14 - 15 - 16 June 2018

Scientific and Organizing Local Committee

Alessandro Ciambrone, Coordinator of the scientific program and relationships with the International Scientific Committee

Rosaria Parente, Scientific Assistant of the International Committee President

Giovanni Bello, Giuliana Chierchiello, Enrico De Cenzo, Vincenzo Ferraro Graphics and layout

Dario Martimucci, Web master

Peer review

Scholars has been invited to submit researches on theoretical and methodological aspects related to Smart Design, Planning and Technologies, and show realapplications and experiences carried out on this themes.Based on blind peer review, abstracts has been accepted,conditionally accepted, or rejected.Authors of accepted and conditionally accepted papershas been invited to submit full papers. These has beenagain peer-reviewed and selected for the oral session and publication, or only for the publication in the conference proceedings.

Conference report

300 abstracts and 650 authors from 36 countries:

Albania, Australia, Benin, Belgium, Bosnia and Herzegovina, Brasil, Bulgaria, California, Chile, China, Cipro, Cuba, Egypt, France, Germany, Italy, Japan, Jordan, Kosovo, Malta, Massachusetts, Michigan, Montserrat, New Jersey, New York, New Zealand, Poland, Portugal, Russia, Slovakia, Spain, Switzerland, Texas, Tunisia, Turkey, United Kingdom.

160 papers published after double blind review by the International Scientific Committee

Le Vie dei Mercanti
XVI INTERNATIONAL FORUM
WORLD HERITAGE and KNOWLEDGE
Representation | Restoration | Redesign | Resilience
Naples 14 - Capri 15|16 June 2018

Wedge-shaped bricks spires and domes. Construction and decorative aspects

Francesco DI PAOLA, Giovanni FATTA, Calogero VINCI
Department of Architecture, Polytechnic School, Palermo, Italy
francesco.dipaola,giovanni.fatta,calogero.vinci@unipa.it

Abstract
The use of *maiolica* bricks as artefact for surface decoration is widespread both in monumental and ordinary architectures in the Mediterranean regions, harmonizing the local construction traditions with the Islamic influences. This study presents an in-depth analysis of examples of spires and domes in Sicily featuring earthenware *maiolica* cladding serving both as decoration and structural element. Due to the limited knowledge of these artefacts, incautious construction operations led to an alteration of their material and technical features, putting at risk a centuries-old heritage.
The systematic investigation on more than a hundred samples categorises these architectural polychrome elements for typology, construction and decorative systems, formal and geometric aspects, in relation to the multiple forms and dimensions of the spires while detecting both originalities and similarities with other works found in Italy and rest of Europe. These new in-depth studies here presented were possible thanks to surveying methods and digital representation techniques, which allowed the implementation of operative solutions and the elaboration of hypothesis of guided restoration operations, while innovating and enforcing traditional investigation methods.

Keywords: Polychromatic maiolica tiles, wedge-shaped bricks, parametric model, geometric patterns, conservation practice.

1. Introduction

Maiolica floors and finishing surfaces have always been considered works of high craftsmanship. In some cases, they would be commissioned by famous artists, thus subject to various studies. In more recent times, architectural ceramics and decorative earthenware, have been subject to accurate research studies. This allowed to add them to the vast field of ceramic manufacturing, while in the past they would be considered mere construction elements.
In particular, a study on more than a hundred of *maiolica* bricks spires and domes located in Sicily – based on typology, construction, and decorative elements – allowed to identify their value and find similarities with other works in Italy and rest of Europe.
These architectural elements date back to the sixteenth century – though an older dating is not to be excluded – and define the extremity of spires or tall steeples, which outline the landscape and tend to be part of the iconography of urban centres.
The geometric designs with high-contrast colours raise the profile of the corresponding buildings. They can be found both in minor works of small urban centres or in rich sacred architectures in major cities.
The most interesting aspect is the complexity of such structures. The unusual and original shapes of the single earthenware elements and the brickwork are in contrast with geometrically complex surfaces. The *maiolica* brick is both a structural and a finishing element, while also representing a tile of complex geometric motifs with evident references to the Middle East tradition.
The analysis of such complex architectural elements, where the manufactured piece needs to comply both with static stability norms and aesthetic taste, can contribute to expand the knowledge in this field by identifying a link between art, craftsmanship, architecture, and construction techniques.
The multidisciplinary study thus unites history of art and architecture with an in-depth construction and structural analysis, surveying methods, computer-aided representation, and last but not least,

restoration disciplines. The stories of numerous collapses has shown that these architectural structurally daring topping elements have scarce thickness and are intrinsically fragile.
Though commonly located near the most important centres of ceramic manufacturing, the dissemination in Sicily of such spires and domes – often with different formal and structural features, while all ascribable to the same centuries-old tradition – suggests a contextual investigation on much broader geographic areas. This may help identifying a tradition adopted from other civilizations, in particular Middle Eastern, which developed political, commercial, and cultural relationships in the Sicilian area over the centuries (Fig. 1).

Fig. 1: Sicily, examples of spiers with different geometrical type of coating: Acireale (CT), Gagliano Castelferrato (EN), Palagonia (CT), Enna, Barrafranca (EN), Lucca Sicula (AG), San Mauro Castelverde (PA). (Up, Conical and pyramidal conformation; down, hemispherical and bulboid conformation).

Rather than analysing *maiolica* bricks as tile elements for flooring applications, the study focuses on the application of special wedge-shaped bricks both as decorative and, in most cases, structural elements. The study also identifies specific construction/decorative motifs of these elements, in relation to the correspondent manufacturing origin.
An ongoing careful investigation has allowed to examine many of these unusually shaped bricks. Most of them have been collected by private collectors and specialised museums, retrieved from collapsed structures, or left forgotten in bell towers since the construction. Some were dismantled during consolidation and restoration works or used inadequately.
The study offers an original collection of digital models, developed from data acquired through digital non-invasive structured light techniques. The application of this indirect surveying method allowed, through virtual anastylosis, a better observation of the construction techniques and the evaluation of intervention works on collapsed elements.
The benefit of such study is more evident if we consider the scarcity of documentary material and specialised literature. This resulted into a knowledge loss of the construction methods where these particular bricks were used.
The need of a deeper and well-structured knowledge on the subject is shown by a number of uneducated – and thus detrimental – works of consolidation, conservation, and restoration of spires and domes. These works, either old or recent, have been carried out by different operators in the construction sector without an adequate knowledge.

2. The authenticity of constructions featuring wedge-shaped *maiolica* bricks

The use of *maiolica* bricks as decorative element for surfaces, rather than as construction element, is by many ascribable to the Islamic tradition. However, though these elements can carry figurative-colouristic motifs typically found in Moorish architecture, this reference rarefies when comparing mere detail and construction aspects. This may be due to limited documentation as well.

Nevertheless, considering that this is attributable to cultures where attention to colouristic aspects of the daily environment and high architecture is customary, the existence of a broader relationship is indisputable, since spires featuring wedge-shaped elements can be found in other regions of the Italian peninsula. Noteworthy examples are the spire of the Cathedral of Parma, recently "rediscovered" after a fire ignited by a lightning in 2009 brought to light the old *maiolica* cladding, which was hidden beneath the more recent copper coating; the bell tower of Santa Maria dell'Anima church in Rome, featuring *maiolica* bricks; the spire of San Moisé church in Venice; Sant'Andrea Basilica by Leon Battista Alberti in Mantova; the spires of Palazzo Ducale in Urbino, though these last examples feature non-polished bricks, most commonly used in Lombard areas.

The presence of earthenware non-*maiolica* spires in many Romanesque, or later, architectures in the Italian peninsula suggests that the Sicilian counterparts, of more recent realisation, may be reinterpretations of a construction typology already established elsewhere. These elements may look isolated, scattered, modest in size and craftsmanship, if taken individually. Nevertheless, though they are part of a more extensive – and perhaps lost elsewhere – work, they identify an architectural and construction typology which fulfils an iconic, historical, documentary, and identity-making role yet to be defined.

Within the context of Sicilian ceramic art, an in-depth analysis of the formal and technical characteristics of these base elements may allow to detect those references to the major and most ancient centres of production, which are well-known among scholars and enthusiasts.

The relocation of whole families of ceramists determined import exchanges and spread of manufacturing techniques and models already experimented in the origin areas, which would be used in major urban centres and new territories centuries later.

The styles, forms, colours, and decorative elements contaminated and hybridised the local culture. In the same way, this happened for the production of high-value *maioliche*. The same wedge-shaped bricks are moulded and adapted, while preserving the construction principles already present in the original examples, in order to bring together complex and yet inventive spires and domes.

Though in light of a widespread construction culture, the originality of these structures allows only partially to discuss about real reference models. Rather, it is clear to see multiple cases presenting a common archetype matrix, while featuring a singularity of both the elements and the construction techniques.

The encoded and well-described state-of-the-art practices were replaced by oral tradition, as normally happens to local customs, family- or workshop-based. This would leave substantial room for variations, depending on the economic conditions, availability of qualified workers or, simply, taste.

2.1 Spread of *maiolica* spires in Sicily from the sixteenth to the twentieth century

In-depth historical-archival analysis, shed light on existing relationships between different historical areas of ceramic productions, and allowed to relate the appearance of the first *maiolica* spires in main ceramic manufacturing centres (Caltagirone, Burgio, Sciacca, Collesano, Santo Stefano di Camastra, etc.) and neighbouring regions, with stories of families of ceramists, who would move to new areas, and spread not only new manufacturing methods of base elements, but also construction techniques of more complex structures.

Manufacturing of wedge-shaped bossages for Sicilian steeples is documented since the second half of the sixteenth century. However, up to the nineteenth century, and even in more recent times, new samples would be created. At the same time, partial and total restoration works took place with use of newly-manufactured wedge-shaped bricks, similar to the ancient ones in shape and colour, to allow conservation or restoration of the original appearance of the entire artefact.

Production of *maiolica* bricks for the realisation of spires and domes is common among all the ceramic manufacturing centres in Sicily – from Enna to the Nebrodi, and in particular in the Madonie area. Numerous examples of *maiolica* spires, together with a number of archival references, testify the existence of a construction tradition far from being archaic and recurrent over many centuries.

Judging by the examples found in a wide area covering most part of south-east Sicily, it can be confirmed that over the centuries, the variations in shape and size of the base *maiolica* brick are so minimal that it would be safe to assume that they are linked to the craftsmen of Caltagirone in all those cases where their origin is not documented.

Conversely, in other areas of production (Burgio and Sciacca, for example) a variety of original shapes, sizes, and construction techniques can be found. Here is much more complex, in absence of archival references, to identify the place of origins of the elements (Fig. 2).

PRODUZIONE DI BURGIO			
Località	Fabbrica	Data	Note
① Bisacquino (PA)	Ch. del S. Francesco	XVIII	Degradata
② Bisacquino (PA)	Ch. Madonna delle Grazie	XVIII	
③ Burgio (AG)	Ch. S. Giuseppe	XVIII	
④ Cattolica Eraclea (AG)	Duomo	XVIII	
⑤ Giuliana (PA)	Ch. SS Rosario	XVIII	
⑥ Prizzi (PA)	Chiesa SS. Crocifisso	1711	
⑦ Contessa Entellina (PA)	Abbazia. S. Maria	1750	Parz. distrutta

PRODUZIONE DI CALTAGIRONE			
Località	Fabbrica	Data	Note
⑧ Mazzarino (CL)	Ch. S. Giuseppe	XVIII	
⑨ Mascalucia (CT)	Duomo	XVIII	Degradata
⑩ Piano Tre Mestieri (CT)	Ch. Madonna delle Grazie	XVIII	Degradata
⑪ Aidone (EN)	Ch. S. Antonio Abate	XVIII	Degradata
⑫ Cerami (EN)	Ch. S. Ambrogio	XVIII	
⑬ Nicosia (EN)	Ch. S. Nicola	XVIII	Sostituita
⑭ Caltagirone (CT)	Ch. S. Maria del Gesù	XVIII	
⑮ Ragusa (RG)	Ch. S. Vincenzo Ferreri	XVIII	
⑯ Biancavilla (CT)	Duomo	XVIII	
⑰ Palagonia (CT)	Ch. S. Maria di Loreto	1704	
⑱ Aci Castello (CT)	Ch. S. Giuseppe	1740	Distrutta
⑲ Regalbuto (EN)	Collegio S. Maria	1740	
⑳ Enna (EN)	Ch. SS. Addolorata	1744	
㉑ Delia (EN)	Ch. S. Maria del Gesù	1749	Degradata
㉒ Acate (RG)	Ch. Madonna del Carmelo	1794	

PRODUZIONE DI COLLESANO			
Località	Fabbrica	Data	Note
㉓ Montemaggiore (PA)	Ch. SS. Crocifisso	XVIII	
㉔ Geraci Siculo (PA)	Ch. S. Maria la Porta	XVIII	Distrutta
㉕ Ciminna (PA)	Ch. S. Antonio	XVIII	Parz. distrutta
㉖ Petralia Soprana (PA)	Ch. S. Maria di Loreto	1730	
㉗ Castelbuono (PA)	Ch. SS. Crocifisso	1780	Sostituita
㉘ Vicari (PA)	Ch. S. Vito	1782	Sostituita

PRODUZIONE DI GANGI VECCHIO			
Località	Fabbrica	Data	Note
㉙ Gangi (PA)	Ch. SS. Salvatore	XVIII	
㉚ Gangi (PA)	Ch. S. Nicolò	1775	
㉛ Gangi (PA)	Ch. S. Cataldo	1776	

PRODUZIONE DI SANTO STEFANO DI CAMASTRA			
Località	Fabbrica	Data	Note
㉜ Castell'Umberto (ME)	Ch. S. Barbara	XVIII	Parz. ricostruita
㉝ Mistretta (ME)	Ch. SS. Trinità	XVIII	Degradata
㉞ Mistretta (ME)	Ch. S. Caterina	XVIII	Sostituita
㉟ S. Angelo di Brolo (ME)	Monastero S. Michele	XVIII	Ricostruita
㊱ S. Stefano (ME)	Ch. S. Nicola	XVIII	

PRODUZIONE DI NASO (ME)

Divisione amministrativa della Sicilia nel 1798

Fig. 2: Dissemination of wedge-shaped bricks spires in Sicily in the eighteenth century.

2.2 Structure and form

The spires feature a variety in form, similar to their single elements, which is a result of an harmonisation attempt between the surrounding architectures, the belonging geographic area, the local workers capabilities, or the clients' taste. The high formal value of these pieces and their visibility, would affect ultimately their geometries. The cone-shaped spires, particularly elongated and commonly widespread in mountain regions, would be more curvilinear and sinuous in other regions.

The typologies found can be classified based on the horizontal section and the elevation geometries. We can find conic shapes (more or less elongated); pyramidal (square-, hexagonal-, octagonal-based, equal-sided or symmetrical coupled, more or less hollowed); bulboids (with simple plane curve, vertical section curve, or double-curve); hemispheric (with continuous extrados, or with horizontal mixtilinear section), with or without vertical *maiolica* bulges (Figs. 3-4).

The outermost element is usually made of a stone slab which sections horizontally the artefact, and acts as a base for the top part. This features a sphere made of stone, metal, or ceramic, where the shaft carrying the wrought-iron cross and the metallic top, the so-called *ventarola*, is inserted.
The addition of these three elements can be dated back to the Middle Age, when the sphere would often carry the relics of the saint whom the church was consecrated to.
The most frequent ensign-shaped fluttering *ventarola* would sometimes be replaced by animal shapes (a lion for the Church of San Sebastiano in Chiusa Sclafani; a bovine for the Church of Sant'Antonio from Padova in Cattolica Eraclea), which recall the old tradition of carrying a rooster-shaped *ventarola* – the rooster crows the break of dawn, and similarly it was symbol of the preachers (Dizionario di erudizione storico-ecclesiastica, Venice 1841).
From a structural analysis, two main typologies can be identified. The spires, whose structural frame is mainly made of an apparatus of wedge-shaped earthenware bricks; and the endings where the wedge-shaped bricks either act as cladding or are only partially part of the structural frame. Within each of these two typologies, a further distinction can be made whether other structural support elements, either wooden or iron, are present.

Fig. 3: Sicily, examples of wedge-shaped bricks used in the same spire with different tapering angles.

The choice of structural wedge-shaped bricks, featured in many conic spires and domes, seem to be unrelated to the base diameter of the spire itself. In fact, many renown examples can be found where the bricks have a structural function, and the structure's thickness is limited to that of the composing elements (18 centimetres on average).
Conversely, the wedge-shaped bricks known as "bulboids" feature an internal structural frame with shape approximated to that of a dome made of traditional bricks or rough stone blocks, though the latter cannot be considered simply a cladding, but rather an external counter structure. This is due to the size of the bricks used (long up to 20 cm as in diamond-shaped bricks).

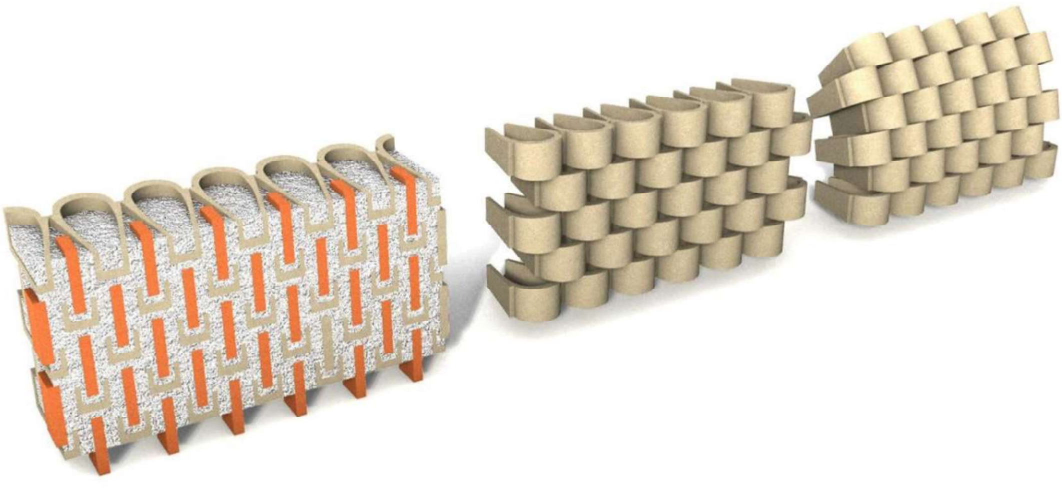

Fig. 4: The accurate staggering of the vertical joints and their geoemtric tapering allow an effective seam between the superimposed rows with the addition of brick flakes.

With regard to the wedge-shaped bricks, which characterize the spire both for its function and technical value, these elements recall at the same time the complex craftsmanship of the construction. They constitute both the structure and the finish — a hybrid between a common brick and an artefact plastically moulded.

This construction-decorative typology is mentioned in the consulted literature only sporadically and incidentally, and never in any in-depth study. The reason for this is also attributable to the objective difficulty of an in-depth observation of the wedge-shaped bricks, since the investigation is often limited to the external and visible part, thus hindering the study of the aggregation system.
Despite the numerous variants, all the bricks produced for the construction of *maiolica* spires share common features. These are elements where the *maiolica* part is limited to the visible extremity, featuring variable thickness and length, from 3 to 6 centimetres and from 12 to 25 centimetres respectively. Generally, the same element could be used in different applications with different functions (structural, collaborating, cladding, or simply decorative).
Common feature of all the examined elements, from which the "wedge-shaped" definition comes from, is the presence of a tapering, more or less marked, of the long vertical sides. In some cases, the tapering also occurs on the main horizontal faces to secure the geometric continuity with the shapes originally planned, though most probably to minimise the visual impact of the mortar joint.
On one of its two main faces the brick often features a depression, with variable depth and extension depending on the geographical origin and period of production. The opposite face sometimes features some rifts or blind holes made with specific tools, that is fingers, to improve the mortar adherence.
An in-depth analysis allowed to highlight the smart construction solutions and the refined technical expedients which grant such simple and modest elements sufficient durability and aesthetic value. Examples are the almost invisible horizontal joints and the vertical ones carefully pointed, or the individual bricks configuration which is functional to the observation from below.
Even though the investigation took place in a context of unitary typology, it led to the identification of different practices, as well as innovations and originalities not always linked to shapes and dimensions (Fig. 5).

Fig. 5: Sicily, examples of different geometrical patterns: Aidone (EN), Piazza Armerina (EN), Ciminna (PA), Leonforte (EN).

The most complex aspect certainly pertained to the correct configuration of the bricks, which would serve as protection against the rainwater, decoration, and as structural element in case of self-supporting spires.
Within the same conic spire, up to four types of bricks would be used, identical in the external configuration of the *maiolica* heads while different in total length and tapering angle. This would occur due to the necessity of following the circumference reduction of the horizontal rows of the impost up to the vertex of the structure. Each of the above mentioned typologies was used for a series (more or less numerous) of courses adapting, within the same series, the vertical joints' thickness and the total number of bricks per layer to comply with the geometric variation.
The lowest course features a bigger width on the vertical joints, while the higher courses reduce the joint progressively while maintaining the same number of elements. Higher courses, in fact, develop on circumferences with a decreasing radius on each course, while being staggered by half a brick. When the joint becomes excessively thin, a certain number of bricks are removed and the joint regains width. The limit is reached when the configuration of the single brick is not compatible anymore with the course where it is supposed to be laid on. This determines the necessity of switching to the next type of elements featuring a bigger tapering angle and shorter length.
In domes, the constant double-curve requires each brick to have a double tapering, both on the horizontal and the vertical faces, so that these will face the geometric centre of the structure.
The visible *maiolica* face of the bricks features different outlines: diamond extremity (more or less marked), toric extremity, prismatic extremity with bevelled edges, curved extremity (with more or less

simple orientation). In almost all cases, recurring notches in undercut are present – these would allow the dissimulation of the vertical joint and simplify the grouting operations.

2.3 Geometric patterns

While the main feature meant to catch the eye of the passersby was the steeple's height, which topped every surrounding building, the decorative apparatus, featuring the variously ordered chromatic sequences of the *maiolica* bricks, had no smaller role.
The combination of shape, colour, and pattern attracts one's attention regardless of the positioning or fabrication of the single elements. The visual impact is greatly influenced by the way in which the light bounces off of the external configuration of the bricks and their joints, as well as by their vibrant chromatic quality and strong *chiaroscuro* effects.
The only apparently simple geometrical decorative effect (which basically consists of bands, diamonds, and spiral strips), obtained via the juxtaposition of wedges of different colours, reveals itself as actually quite difficult to realise, to the point that one could hypothesize the use of preparatory *cartoni.* Recurring colours are yellow, copper green, blue, and manganese. The richness of decors and colours recalls the folk carpets called *frazzate*, traditionally woven in Sicily near Erice, in the surroundings of Trapani, and in the Madonie and Nebrodi areas.
One main difference can be established between structures consisting of continuous surfaces (effectively cones, *cupolas*, and double-curved surfaces), and structures where the shape is made of planar faces, horizontal and vertical edges (pyramidal, ribbed, polygonal chains, single-curved surfaces). If the latter ones typically saw the pattern being described within one of the geometrically defined portions, and then repeated on the other similar ones, the decorative project for cones and other continuous surfaces was quite different.
The more complex solutions involved a unique pattern that developed throughout the entire curved surface progressively tapered upwards. While the motif had to contain, on each direction, a multiple number of whole bricks, it also had to be subject to the continuous reduction of the total quantity of elements for each subsequent course moving upwards. For the spiral motifs with ascending diamonds, this implied the reduction of the strips' width wrapping the spire or of the diagonal bands, and a subsequent reduction in the number of same-colour wedges.
Thus, decorative patterns spread throughout the whole external surfaces were rarely employed especially for larger spires and domes. It was preferred to interrupt them strategically with horizontal bands (Fig. 6).
An ongoing observation suggests that this interruption was placed to coincide with the rows where the vertical joint became excessively narrow and, as mentioned before, some wedges needed to be taken out from the overlying layer.
The finishing of simple surfaces granted an increased freedom for the choice of the decorative motif, since the pieces' layout could carry on without having to adhere to the laws of Statics. For spires where wedges were load-bearing and constituted both structure and finishing, vertical joints between two overlapped courses could not be aligned.

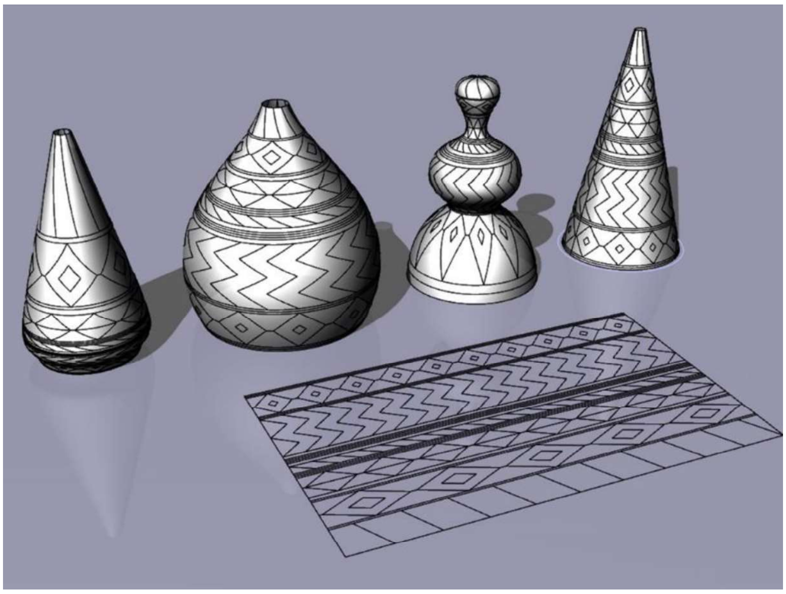

Fig. 6: Virtual simulation of a decorative geometric pattern on surfaces of different geometric types (cones, cupolas, pyramidal, ribbed, polygonal chains and double-curved surfaces).

3. Geometrical analysis and digital acquisition

The integrated application of digital procedures of *Computer Aided Restoration* on chosen buildings, employing current non-invasive technologies, provided useful information to support comparative geometrical and dimensional analyses.

With the aim of preserving the centuries-old know-how heritage, it is crucial to determine operating strategies aimed to restoration, reconstruction and/or maintenance that would take into account both the technological and material features (Fig. 7).

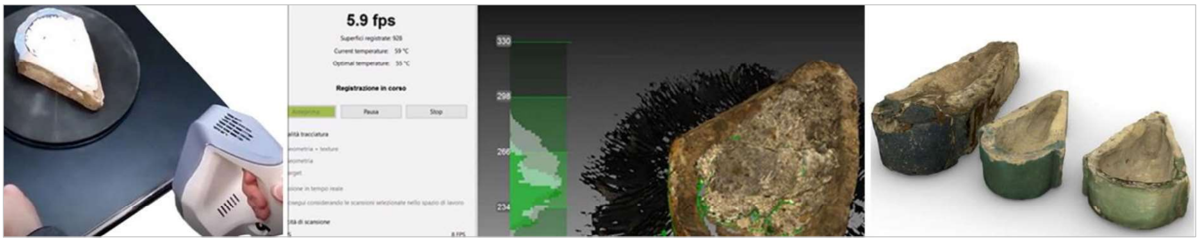

Fig. 7: Digital acquisition phases using by light structured scanner of three different bricks.

Examination of the *maiolica* wedges through surveying and direct analysis has thus required a series of observations regarding the methodology to be employed in order to be able to discern amongst their many characteristics (shape and size; construction technology; layout; manufacturing and finishing).

The heterogeneity of the samples required the cataloguing of the acquired data, while the drafting of summary sheets allowed to identify and compare geometric typologies and predominant characteristics in relation to the geographical and historical context.

The process used on some of the elements is called *Reverse Engineering*, while the technique employed was *3D Scanning.* The non-invasive, non-destructive, information-rich methodology is based on the acquisition of the spatial position of points composing the surface of the real object. A digital 3D model is then returned, characterised by a high geometric correspondence. The specific system used falls within the structured light scanning category, employing light as a surveying tool to extract a 3D scan. The structured light system works through a light source that projects a set of fixed and precise light patterns on the scanned object. The reflected image is then captured by one or more cameras, allowing the determination of each point's position on the surface to be acquired through the analysis of the distortion of the patterns.

The comparison of about ten *maiolica* elements highlights a clear evolution and refinement of the shape suggesting how, starting from simple bricks with a rough finishing of the visible part for the older buildings, they became more and more technologically, structurally, and aesthetically refined.

The acquired digital archive allowed further in-depth studies and new applicative scenarios which contribute to the implementation of operative solutions and to hypothesis of guided restoration operations, while innovating and enforcing traditional investigation methods.

New digital manufacturing technologies allow to replicate even elements with complex shapes (digital prototypes), as well as to integrate missing parts. This can be done through the direct 3D printing of the missing piece, or indirectly via the manufacturing of a cast that is then used to craft the element with traditional materials, which is then connected to the original structure via composite fittings (Figs. 7-8).

3.1 Virtual anastylosis of the Santa Maria «La Fontana» church spire in Petralia Sottana (PA)

Through a new parametric approach, the study allowed the reconstruction of the overall structure of the spire of Santa Maria church in Petralia Sottana, the existence of which is testified by documents from 1770 found in the parish archive, and from the only photographic source dating back to before 1874. The latter shows the spire, probably damaged by the 1818 earthquake, together with the topmost part of the church bell tower.

Both geometric and dimensional features, though incomplete and uncertain, can be partially inferred from the fifteenth century manuscripts.

By setting some initial data (e.g., radius of the spire directrix; number of wedges needed for the supply divided by size; height of each course; width of the vertical joint), it was possible to define a digital interactive model, continuously editable with reference to the initial data and to the transformations and operations linked to it. This provided the presumed value of the original spire's height.

The process of generation of the geometric shape of the spire is controlled by affecting the various elements-wedges and their interaction, which are subject to rules set via a certain number of

parameters. These take into account the correct spatial layout of the bricks; their total number for each course; their geometric variability (length and tapering angle) in relation to the reduction of the circumference of the horizontal courses from the impost until the structure vertex.
The envelope of the spire is subdivided into horizontal strips constituted by wedges courses staggered by half module. The number of wedges is the same for each course, requiring the assembly of smaller elements with an increasing tapering angle after a fixed number of levels.

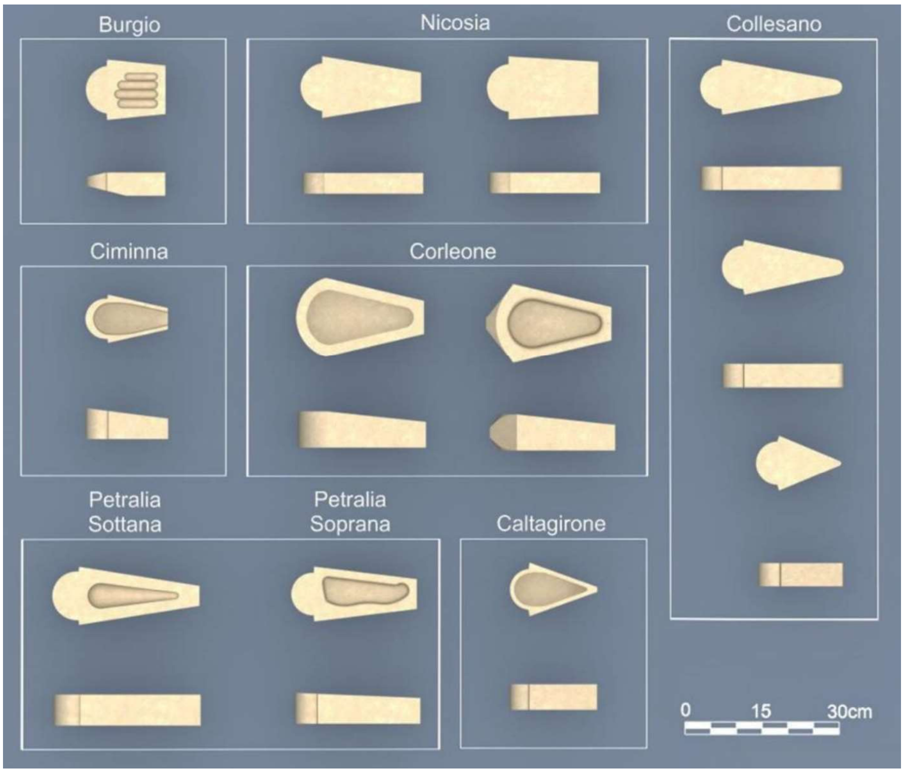

Fig. 7: shaped wedges: three-dimensional reconstructions of some of the most frequent cases.

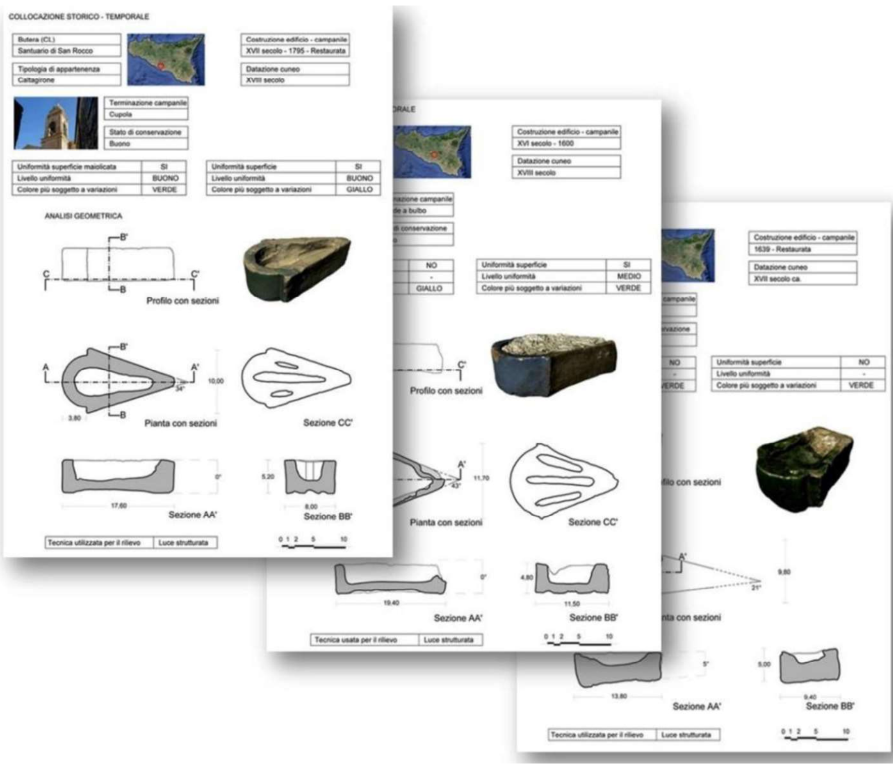

Fig. 8: Collection of synoptic data sheets of some of the most frequent cases.

The generative algorithm, within the Grasshopper plug-in, constitute a valid tool for research, analysis, and control, capable of exploring through a single algorithm the complex spatial articulation of the artefact for the various geometric typologies of spires found (conical, pyramidal, single- and double-curvature surfaces). It describes and controls, through an associative approach, the aforementioned geometric-spatial relations of the elements constituting the whole structure, allowing the exploration of multiple configurations of the system while editing in real time the geometric characteristics of each component (Figs. 9-10).

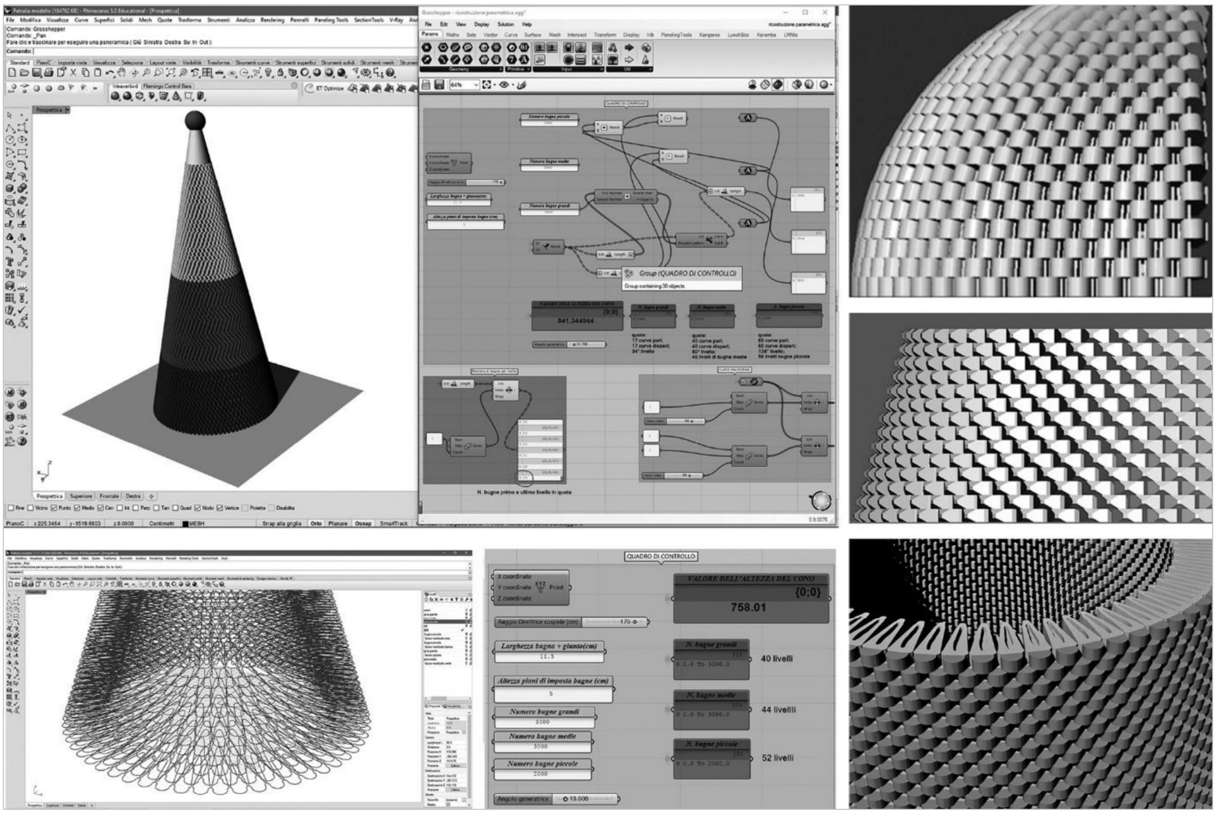

Fig. 9: The representation technique and the parametric procedure adopted for the generation of the model of of the Santa Maria «La Fontana» church spire in Petralia Sottana (PA).

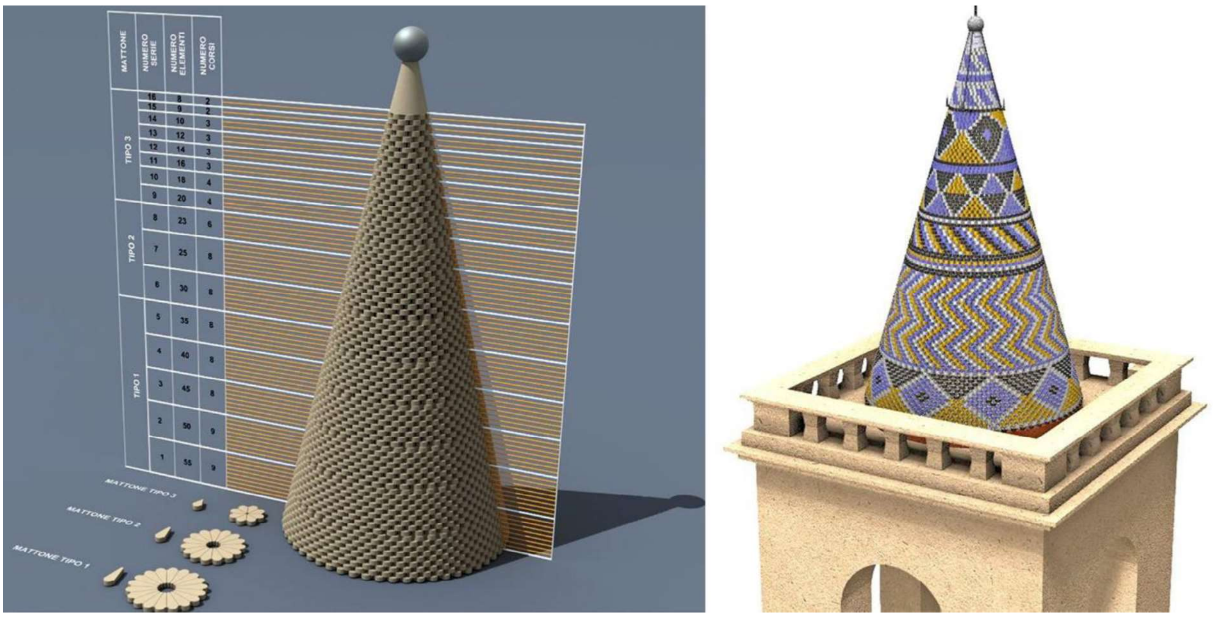

Fig. 10: The representation technique and the parametric procedure adopted for the generation of the model of the Santo Stefano Protomartire church spire in Leonforte (EN).

4. Degradation, instabilities, interventions, and strategies for sustainable valorisation

Human and natural events determined collapses, damages and/or simple deterioration of single pieces or whole portions of the artefacts. We discussed the losses already occurred (documented, hypothesised, or passed on orally). However, factors such as the high altitude, the constant exposition to adverse weather conditions, as well as the manufacturing quality of the *maiolica* bricks, the mortar bedding, and the layout itself, clearly result in a progressive decay. It seems that past interventions resulted mostly in disassembling and reconstructing with similar methods and materials, rather than in visible and strong modifications on the formal appearance and often even on the construction-structural layout.

A relevant number of case-studies has been examined, both in the site surroundings and in the whole region, allowing to identify a record of damages to which these artefacts are usually subject.

Lightning is one of the major causes of spire collapses, both due to their usually sharp shapes and presence of metallic elements on the top. There is a rich documentation of destructive events both quite old and fairly recent ascribable to this natural events.

The most common damage affects the topmost part, where the simultaneous presence of heavy decorative elements such as slabs and banner-holding stone spheres, together with a core made of mortar and irregular earthenware, constitutes a greatly disadvantageous condition of concentrated load on the upper part, especially when subject to seismic actions and wind gusts.

The washout of the joints' mortar, ascribable to heavy rain and seepages – a common damage especially for gypsum-based mortars – determined a gradual reduction of the load bearing capacity of the whole structure and the subsequent formation of localized failures (Fig. 11).

Fig. 11: Human and natural events determined collapses, damages and/or simple deterioration of single pieces or whole portions of the artefacts.

Conclusions

Strains caused by external actions or by structural deterioration are some of the most common damages, causing an evident variation of the overall geometries of some artefacts. The achievement of new equilibrium configurations resulted in asymmetrical and abnormal profiles and buckling, and, where an internal finishing is present, in its detachment from the wedges of the envelope.

The soil deposited in the many gaps between wedges and joints fosters the growth of weeds whose rooting disrupts both the *maiolica* surfaces and the earthenware structure, as well as the mortar inside the joints.

Moreover, the condition of difficult access determined a practically non-existent maintenance for prolonged periods of time, such that grass formations and even large shrubs are not rare. Here, the pushing force from inside the very joints can lead to the collapse of the whole spire.

The insufficient knowledge of these artefacts resulted in interventions (to eliminate rainwater seepages or to consolidate the whole structure disrupted by the weathering of the mortar) that altered both the material and the technological features, as a trade-off for a greater constructive simplicity, endangering a centuries-old know-how heritage.

While acknowledging the objective difficulties, it appears quite clear how maintenance, restoration, consolidation, and reconstruction interventions, both historical and recent, have rarely been respectful of the decorative and technological quality of our spires and domes.

The scarce familiarity towards historical techniques; the superficiality and lack of interest that plagued both designers and bodies responsible for protection for many years; the lacking operational skills of

workers and contractors; the little interest of local communities, who should oversee to conserve the qualifying traits of their own heritage, are all reasons that contributed to the disappearance or to the defacement of many of these *maiolica* artefacts.
Less recent interventions replaced the parts that were beyond recovery with significantly different materials, e.g., simple rough-faced bricks, witnessing an effort to make the replaced parts recognizable at the expenses of the aesthetic unity. Meanwhile, due to the increase in awareness endorsed by Superintendencies, more recent occurrences saw the manufacturing of faithful reproductions of the missing elements by ceramists working to this day in the old production areas.
The on-going study strengthens the idea that Sicilian culture reprocessed various influences coming from outside the island in the field of *maiolica* manufacturing, while generating original and completely new artworks to recognize, promote, and protect both their material features and their overall artistic expression.

Bibliographical References

[1] FATTA; G. VINCI, C. Cuspidi e cupole in mattoni maiolicati nell'architettura religiosa dell'area dei Sicani. In *Manierismo siciliano. Antonino Ferraro da Giuliana e l'età di Filippo II di Spagna* Giuliana (PA). I.L.A. Palma, Palermo, 2010.

[2] FATTA; G. VINCI, C. Laterizi maiolicati nella costruzione delle cuspidi in area siciliana. In *Costruire in laterizio*, 123, 2008.

[3] FATTA; G. VINCI, C. Cuspidi maiolicate nell'architettura religiosa "minore" in area siciliana. In: AYMERICH, C.; DELL'ACQUA, A.C.; FATTA, G.; PASTORE, P.; TAGLIAVENTI, G.; ZORDAN L. *Architettura di base*. Alinea, Firenze, 2007.

[4] FIORILLA, S. Campanili con cuspidi maiolicate nella Sicilia sud-orientale. In *atti del Convegno Internazionale della Ceramica*. Centro Ligure per la Storia della Ceramica Albisola, 1989.

[5] RAGONA, A. *La maiolica siciliana dalle origini all'Ottocento*, Sellerio Editore, Palermo, 1986.

[6] REGINELLA, M. *Maduni pinti*, D. Sanfilippo Editore, Catania 2004.

[7] DI PAOLA, F.; MILAZZO, G.; SPATAFORA, F. Computer Aided Restoration tools to assist the conservation of an ancient sculpture. The colossal Statue of Zeus enthroned. In: *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2/W5, 177-184, 2017. https://doi.org/10.5194/isprs-archives-XLII-2-W5-177-2017

[8] ARBACE, L.; SONNINO, E.; CALLIERI, M.; DELLEPIANE, M.; FABBRI, M.; IDELSON, A.I. and SCOPIGNO, R. Innovative uses of 3D digital technologies to assist the restoration of a fragmented terracotta statue. In: *Journal of Cultural Heritage*, vol. 14 (4), pp. 332-345, 2013. https://doi.org/10.1016/j.culher.2012.06.008

[9] SANTAGATI, C.; INZERILLO, L.; DI PAOLA, F. Image-based modeling techniques for architectural heritage 3D digitalization: limits and potentialities. In: *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XL-5(W2): pp. 550-560, 2013. https://doi.org/10.5194/isprsarchives-XL-5-W2-555-2013, 2013

[10] BARBA, S.; DI PAOLA, F.; RIZZO, G. The Scenography of Serpotta Stuccoes Revisited - Material and Form. In *Conservation Science in Cultural Heritage*, ISSN 1973-9494 (online), pp. 281-297, 2015. DOI: 10.6092/issn.1973-9494/6182.

Table of content

Table of content

CARMINE GAMBARDELLA

UNESCO Chair on Landscape, Cultural Heritage, and Territorial Governance; President and CEO of Benecon SCaRL Research Centre on Cultural Heritage, Ecology and Economy (Consortium of five Universities: University of Campania "Luigi Vanvitelli", Pegaso University, University Federico II of Naples, University of Salerno, University of Sannio). Pro-Rector at the European Polytechnical University, EPU. Professor of Drawing at the Pegaso University and at the University of Campania. President of the International Forum of Studies 'Le Vie dei Mercanti' since its first edition in 2003. Honorary President of the Italian Committee of the Nation Fulbright Sector on Cultural Heritage Sustainable Development, Urban Planning, Architecture and Management of UNESCO World Heritage Sites. Editor and Founder of the series "Surveying is/or Project" and "Knowledge Factory", "Architecture, Heritage and Design". Component of the Scientific Committee of International Class A Magazine 'Abitare la Terra'/ 'Dwelling on Earth'.

During his academic career he has covered various roles including the Pro-Rector of Institutions, Academic Senator, Member of the Board, Director of the Department of Architecture and Industrial Design Luigi Vanvitelli, Dean of the Faculty of Architecture Luigi Vanvitelli, Director of the Department of Culture of the Project, Director of Doctoral School in the Discipline of Architecture, Coordinator of the PhD in Protection, Safety and Representation of the Environment and Structures and Territorial Governance, Coordinator of the PhD Program in Surveying and Representation of Architecture and the Environment, President of the Course Degree in Industrial Design. He has also been scientifically responsible for noteworthy national and international research project. He is author of numerous scientific papers on the important issues of the surveying and representation of the built and natural heritage.

benecon
knowledge network

United Nations
Educational, Scientific and
Cultural Organization

uniTwin
UNESCO Chair on Landscape,
Cultural Heritage and Territorial Governance
BENECON Research Centre of Competence of
the Campania Region for Cultural Heritage,
Ecology and Economy, Naples, Italy

Università
degli Studi
della Campania
Luigi Vanvitelli

PEGASO
Università Telematica

Università
degli Studi
del Sannio

PATRONED BY

UNIVERSITÀ DEGLI STUDI DELLA CAMPANIA
LUIGI VANVITELLI
SCUOLA POLITECNICA E DELLE SCIENZE DI BASE
DIPARTIMENTO DI ARCHITETTURA
E DISEGNO INDUSTRIALE

forum UNESCO
UNIVERSITY AND HERITAGE

UNIVERSITAT
POLITÈCNICA
DE VALÈNCIA

UNESCO
Organizzazione
delle Nazioni Unite
per l'Educazione,
la Scienza e la Cultura

Commissione Nazionale
Italiana per l'UNESCO

FULBRIGHT
THE US - ITALY FULBRIGHT COMMISSION
Linking Minds Accross Cultures

UNIFARCO

DOLOMIA
LUCE, VITALITÀ, RESPIRO

GANGEMI EDITORE
INTERNATIONAL

L'ABACO