SERGIO MUSMECI'S SEARCH FOR NEW FORMS OF CONCRETE STRUCTURES

Lukas Ingold[1] and Mario Rinke[2]

Keywords

History of the building trades or specific builders, history and construction of specific projects, structural analysis and the development of structural forms, experimentation, designing and verifying structure with models, constructing with concrete.

Abstract

The work of the Italian engineer Sergio Musmeci (1926-1981) is based on the ideal of a harmonic relationship between structure and architectural form, which leads to an extensive search for an integral structural form. During the prospering years in postwar Italy and in the shadow of the prominent Italian engineers Pier Luigi Nervi and Riccardo Morandi, Musmeci researches concrete surface structures. He calls for new approaches to form finding, particularly in respect to moldable concrete: "The form is the unknown, not the inner stresses".

Starting in the mid-1950s with first projects for thin, folded roof structures made of reinforced concrete, Musmeci is led by the idea of geometrical surfaces. At the same time he begins to experiment with double-curved surfaces in several designs for bridges and large-span halls. By exploring the possibilities of form finding for these minimal surfaces, he sets his focus away from defined, calculable geometries and towards a simple definition of boundary conditions, from which a form is self-generated by the use of textile or soap film models. This methodical change towards a "form with no name" does not happen abruptly, but can be traced in several steps by the inversion of the relation between form and model. While early folded plate designs derive their form from a simplified linear bending beam model, the form idea of the arch-like surfaces of the Basento Bridge is measured directly from a physical model and then calculated afterwards. This new design approach does not only reflect the understanding of efficient structures as minimal forms but must also be seen as corresponding to the new understanding of plasticity and continuity of concrete.

In contrast to other concrete pioneers Musmeci's work is poorly received both in his time and today, and public recognition is limited to his outstanding main work, the Basento Bridge in Potenza. In an exceptionally short period of time the chronology of several key projects shows his approach for the development of new forms, that relates to the potential of concrete. The concepts and methods of Musmeci are part of the younger history of concrete architecture and engineering and show conflicts and achievements with this construction material between the 1950s and the 1970s.

1 ETH Zürich, Department of Architecture, Chair of structural design, Prof. Dr. Joseph Schwartz, Stefano-Franscini-Platz 5, CH-8093 Zürich, Switzerland, ingold@arch.ethz.ch

2 ETH Zürich, Department of Architecture, Chair of structural design, Prof. Dr. Joseph Schwartz, Stefano-Franscini-Platz 5, CH-8093 Zürich, Switzerland, rinke@arch.ethz.ch

INTRODUCTION

Sergio Musmeci's (1926-1981) quest for a unity of structure and architectural form originates from a specific tendency of engineering in postwar Italy. The social changes and technological progress introduced to Italy during the economic boom are directly manifested in large-scale infrastructure projects and a series of prestigious public projects, such as for the Olympics in Rome in 1960 or the 100th anniversary of the unity of Italy in 1961. The cultivation of these new building commissions is inseparably associated with the development of concrete constructions. This material and its diverse applications flourish in an unprecedented way. While the works of influential protagonists like Pier Luigi Nervi (1891-1979), Angelo Mangiarotti (1921-2012) and Riccardo Morandi (1902-1989) concentrated on modular structures, such as pre-fabricated and systematically assembled constructions, Musmeci focuses especially on methodical strategies of form generating. His philosophy, "The form is the unknown, not the inner stresses" (Musmeci 1979), becomes manifested in his form finding experiments. These new forms are based on textile membranes or soap film models and are related to phenomena of natural sciences (Nicoletti 1999). Musmeci's research for minimal forms explicitly demonstrates the quality of concrete and spurs the question of the essence of this construction material, which can be casted into almost every form due to its moldability. With the Basento Bridge (1967-1976) in the south Italian city of Potenza, Musmeci is capable of transferring this new approach into practice. The qualities of the researched double-curved surfaces yield a membrane-like concrete structure, which he designs and builds in collaboration with Aldo Livadiotti and his wife Zenaide Zanini.

The unique typology of the Basento Bridge is a result of continuous methodical development in the work of Musmeci. This unprecedented form is not directly related to figurative examples or natural references, like in the work of many contemporary engineers, but is based more on the transfer of structural principles to a new vocabulary of forms.

Figure 1: The model-generated form of the Basento Bridge demonstrates the potential of concrete (L. Ingold, 2013).

MATHEMATICAL MODELS DEFINE GEOMETRICAL SURFACES

In the mid-1950s, after graduating in civil and aeronautic engineering and gaining his first working experience in the offices of Pier Luigi Nervi and Riccardo Morandi, Musmeci starts his career with the design of thin folded roof structures in reinforced concrete, a structural type with little attention at that time. These projects are developed in collaboration with various architects. A first conventional folded roof for the gymnastic hall of the National School of Athletics in Formia (1954, with Annibale Vitellozzi) is designed with accordion-like inclined plates. The next folded structures, the Cinema San Pietro in Montecchio Maggiore (1956, with Sergio Ortolani) and the Raffo marble workshop in Pietrasanta (1956, with Leo Calini and Eugenio Montuori), are built with only 8 cm-thin concrete plates, which are based on triangular-polygonal geometries. In defiance of a certain repetitive pattern, the forms develop towards multi-axial and spatial structures, defining a first step towards new forms: “It is my first attempt to adapt the form of a structure to the inner flow of forces” (Musmeci 1961). Here, Musmeci expresses already in his early projects his intent for a search of efficient forms, even if his approach simply follows his intuition. The early designs are based on the bending moment diagram, from which the form is derived (Musmeci 1960). In the course of the economic boom, five projects with folded roofs get built, during a period of only five years (1954-1959). The nowadays best-known project, the foyer roof of Teatro Regio in Turin (1966), follows subsequently as collaboration with the architect Carlo Mollino.

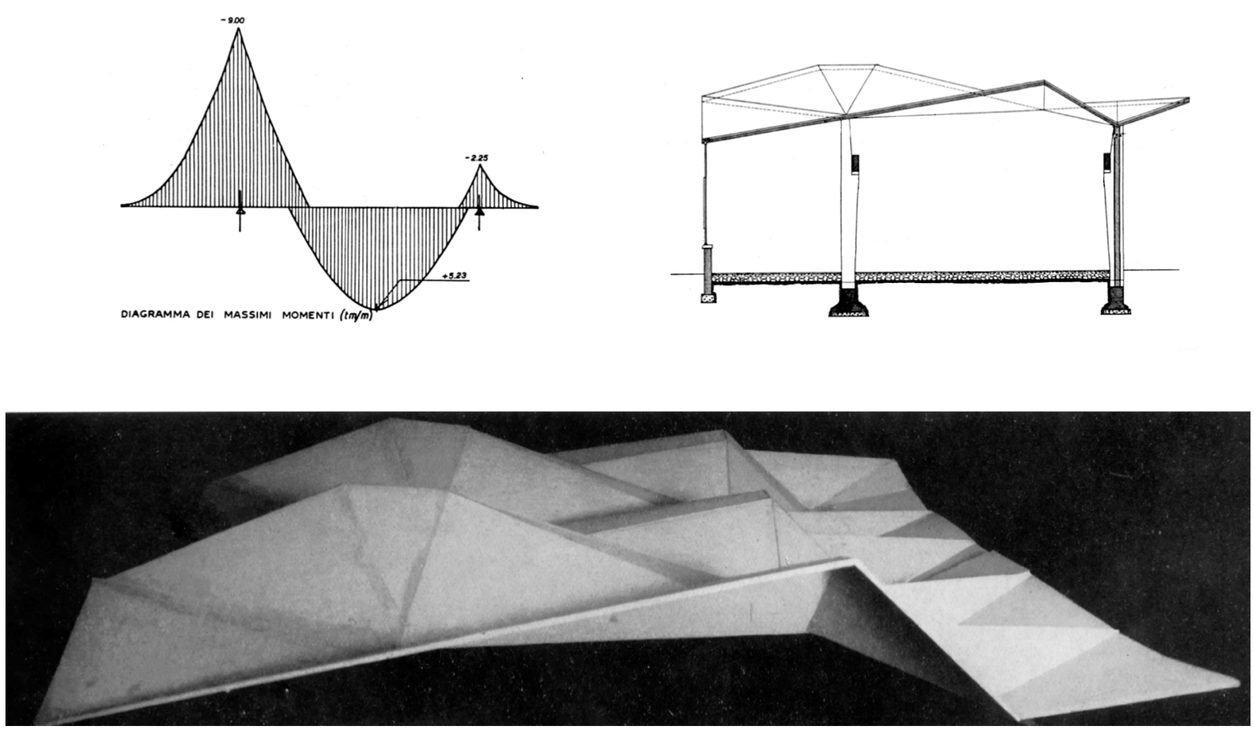

Figure 2: For the Raffo marble workshop in Pietrasanta (1956), the design for the folded structure is based on an adaptation of the bending moment diagram (Musmeci 1960).

FROM FOLDED STRUCTURES TOWARDS DOUBLE-CURVED SURFACES

Simultaneous with the realization of the folded structures, Musmeci starts to experiment with double-curved surfaces in several bridge competitions. With this step, a refinement in the understanding of the structural principles occurs. Musmeci sets his focus away from predefined typologies and simply calculable geometries and towards a simple definition of boundary conditions by relying on design approaches based on the physical model, which allows him to research new form typologies.

In the contribution for the Astico Bridge competition close to Vicenza (1956, with Sergio Ortolani and Antonio Cattaneo), a hanging model with unified distributed point loads traces the basic scheme of a four-hinge arch bridge, which is stabilized by lateral stiffening elements (Nicoletti 1999). The single components of the bridge are designed as thin, membrane-like shells, in order to avoid buckling. With the overlap of global and local load influences, interdependency between the single elements is present, which makes the understanding of the bearing principle inexplicit. The polygonal shape of the Astico Bridge design makes an analogy to the folded structures obvious, while the four-hinged arch scheme relates to the grammar of iron constructions of the 19th century.

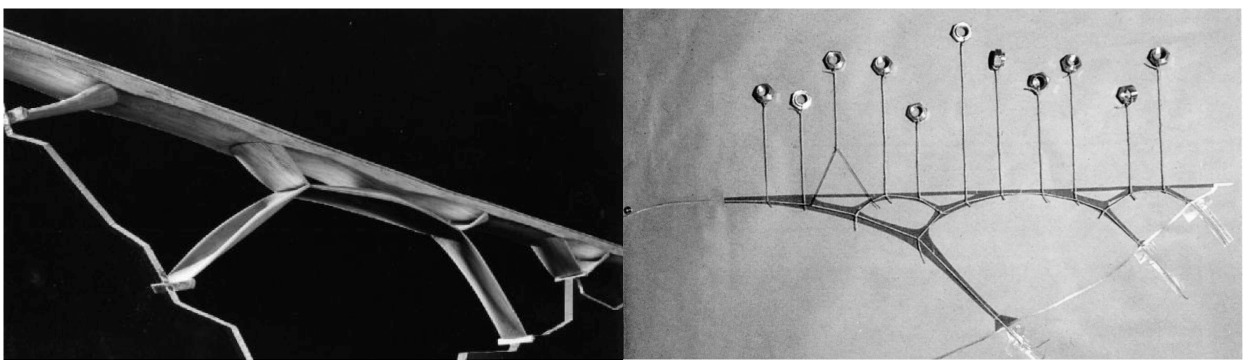

Figure 3: The Astico Bridge (1956) design relates to a combinatorial approach (Guccione 2004 and Nicoletti 1999).

COMBINATORIAL PRINCIPLES AS A DESIGN STRATEGY

The model used as an instrument for derivation of the design demonstrates its relevance in the competition entry for the Tiber Bridge in Tor di Quinto, Rome (1959, with Ugo Luccichenti). The basic form of the pillars is based on the deformed shape of a thin membrane gripped on four points (Nicoletti 1999). Musmeci later uses the same method to generate the form of the Basento Bridge. The Tiber Bridge project is the first of his bridge designs to appear as a continuous shape of a figural unity, and not as an assembly of components; even if the sequential principle is still recognizable in the addition of the pillars, the basic module of this design.

In Italian bridge engineering of the postwar years, the principle of combination is a widespread strategy. With the endeavor to overcome constructive and fabrication-related problems, new techniques like pre-stressing or pre-fabrication get integrated into bridge design. This leads to approaches based on the combination of different components and allows new typologies to appear. The prominent bridge engineers such as Riccardo Morandi and Silvano Zorzi use combinatorial and sequential principles in their works. The Polcevera Viaduct in Genova (1960-1967) and the Sfalassà Viaduct in Calabria (1968-1972), are important examples of this design strategy. In this context, Musmeci attempts to search beyond this strategy for new design approaches in order to produce continuous and integral forms. One of the few exceptions is the proposal of the bridge for the Stretto di Messina (1969), where he once again uses a combinatorial approach.

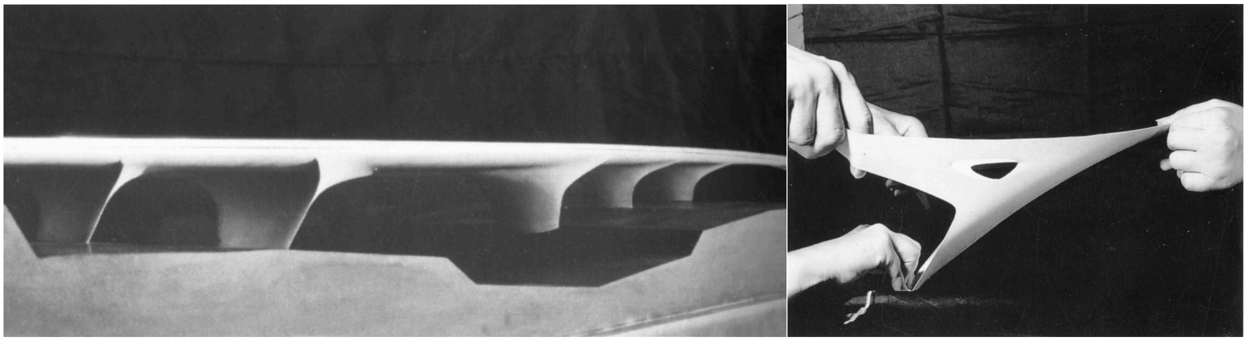

Figure 4: The design for the Tiber Bridge (1959) in Tor di Quinto, Rome is based on studies with membrane models (Musmeci 1979 and Nicoletti 1999).

THE SPATIAL POTENTIAL OF CONTINUOUS SURFACE STRUCTURES

The research on continuous surface structures starts already in an early phase of Musmeci's work, when he mostly uses combinatorial principles for his designs. Examples are the studies for the monumental and saddle-like support of the Palazzo del Lavoro in Turin (1959, with Carlo Mollino and Carlo Bordogna), as well as the curved funnel-like roof for the church of Villaggio del sole in Vicenza (1960, with Sergio Ortolani and Antonio Cattaneo).

With the design of the wholesale trading market in Rome (1960, with Annibale Vitellozzi, Massimo Castellazzi and Giulio Dell'Anese), he develops a continuous and integral building structure for the first time. It is the same motive which also later defines the design of the Basento Bridge. It is a continuous surface, developed along a main longitudinal arch with several transversal arches, which defines the global form. The addition of individual roof elements yields a repetitive pattern, in which, however, dividing joints or transition lines are not visible. The similarity to other projects reveals the adaptability of the method and the motive. Whether considering a bridge or a large-span hall, Musmeci is able to apply the same structural principle and formal language on different architectural situations, scales and programs. The project for the wholesale trading market in Rome only rudimentarily adumbrates the potential of these structures for the perception of these kinds of architectural spaces, which do not allow a clear tectonic differentiation of its primary elements. With the membrane-like structure, the roof, the walls, the supports and the openings get shaped at the same time by one integral form.

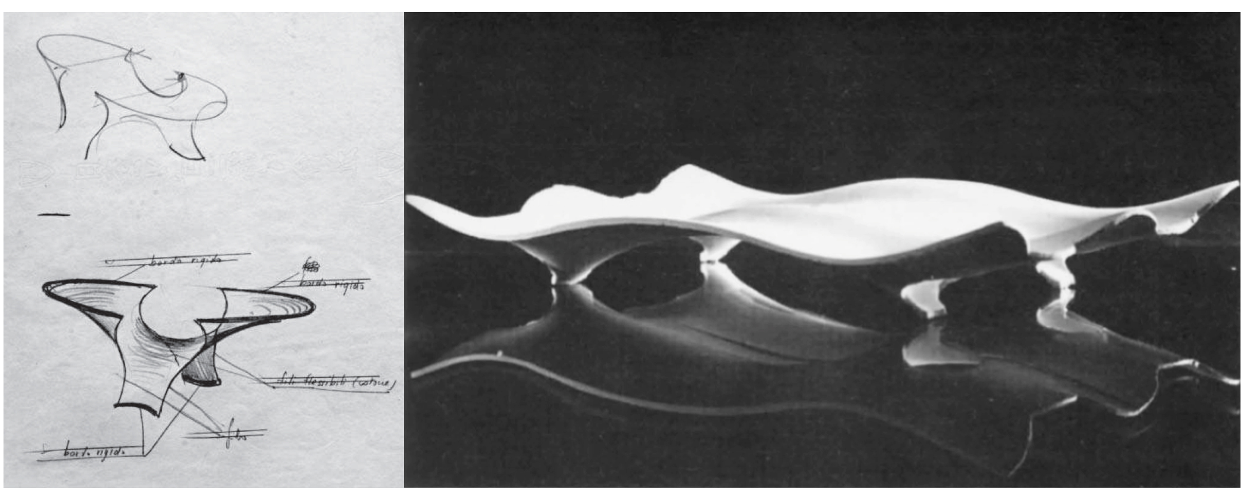

Figure 5: Support studies of the Palazzo del Lavoro (1959) in Turin (Brodini 2013) and roof sequence of the wholesale trading market (1960) in Rome (Musmeci 1979).

THE CONVERGENCE TOWARDS A NEW FORM TYPOLOGY

Another prominent example is the 2nd prize ex-aequo awarded project for the competition of the Lao Bridge (1964) between Salerno and Reggio, as part of the famous infrastructural project "Autostrada del Sole". To facilitate the construction of the large span of 150 m, Musmeci proposes a gridshell structure. The construction consists of prefabricated hollow elements, which are injected with concrete in-situ (Musmeci 1967). Almost identical is the design for the bridge over the Niger, in Ajaokuta, Nigeria (1977) and another discrete structure project is the suspended roof of the Palazzo dello Sport in Florence (1965). The triangular geometry used in these projects recalls his later studies on tetrahedral frames, in line with the work of Richard Buckminster Fuller (1895-1983) or Konrad Wachsmann (1901-1980). With the discrete design for the Lao Bridge, again the same formal motive gets addressed.

This new form typology, which gets evolved and refined since the study of the support of the Palazzo del Lavoro (1959), appears again as a continuous surface structure in the competition for the Basento Bridge in Potenza (1967). In this design, the 286 m-long deck is supported by a double curved surface structure, which stretches over four spans as a continuous concrete construction, with a thickness of only ca. 30 cm. Besides its primary function as a load-bearing structure, the form serves as a covered and accessible space for pedestrians.

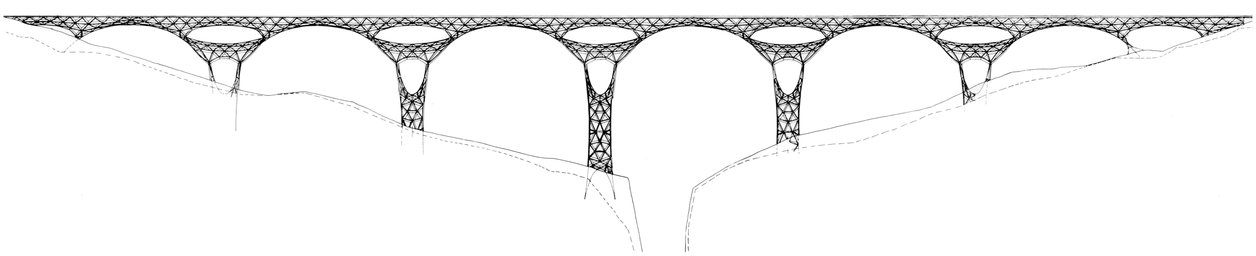

Figure 6: Grid shell structure of the Lao Bridge (1964) as part of the infrastructural project "Autostrada del Sole" (Musmeci 1967).

THE MODEL-EXPERIMENT AS TRANSITION POINT BETWEEN THE MECHANICAL AND DIGITAL AGE

The constant evolution of the form and the notion towards the design for the Basento Bridge goes along with the methodical change in the work of Musmeci. While using a rudimentary two-dimensional bending moment scheme on which the simple controllable geometries of the early folded structures depend, the forms of his later works express in their development emancipation from the mathematical models. The use of physical models allows Musmeci to go beyond the analytical model developed in his theoretical studies (Musmeci 1971). Against the common mechanical understanding, the calculation arises from the model and the model follows out of the experiment. In the model experiments for the Basento Bridge, based on studies with textile membranes and soap films, the structure is generated only with the definition of the boundary conditions. The derived minimal structures are similar to the work of other researchers like Frei Otto (1925-2015) or Heinz Isler (1926-2009).

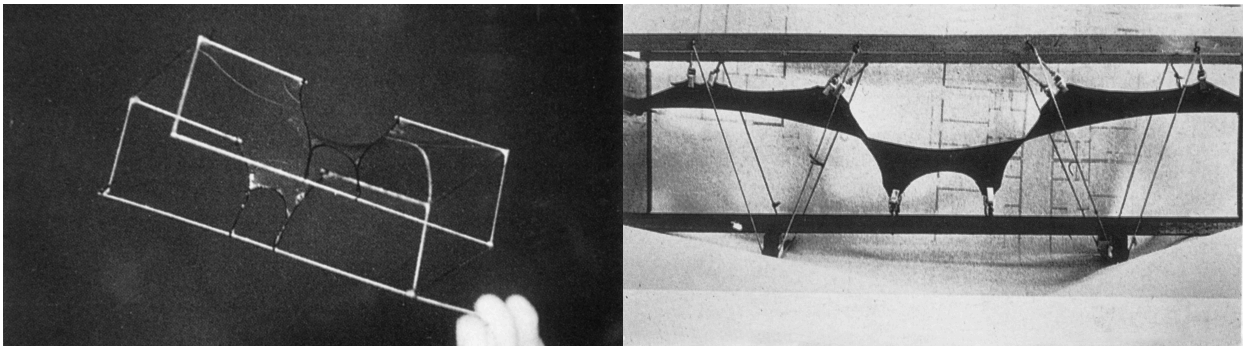

Figure 7: Soap film and membrane model studies of the Basento Bridge (1967-1976) in Potenza (Nicoletti 1999).

Besides being used for form generation, physical models are also employed for the verification of the structural behavior of these novel concrete structures. The model as scientific instrument gets institutionalized thanks to the Istituto Sperimentale Modelli e Strutture (ISMES) in Bergamo with the engineers Arturo Danusso and Guido Oberti and later under the direction of Pier Luigi Nervi (Oberti 1980). The testing laboratory allows one to understand these complex and efficient forms long before the emergence of the computer and numerical methods such as finite element analysis.

In the work of Musmeci, it is possible to observe a change in the design intentions from the search for economic feasibility of the early projects to the quest for material efficiency of his later ones. While the early folded structures are designed and built within a few months, the realization process with the Basento Bridge is prolonged, due to the complexity in controlling and producing the formwork. The minimal forms, generated thanks to the use of physical models and tested with mockups in the laboratory, are still very difficult to build. Questions about the commensurability of the resources are raised due to the conditions of the contemporary rationalized building industry. The research of Musmeci tends to proclaim a new understanding of form, which becomes self-evident with digitalization one or two decades later. His concepts and methods represent a transition point between the mechanical and digital age.

SEARCH FOR A HOLISTIC APPROACH FOR STRUCTURAL FORMS IN CONCRETE ARCHITECTURE

Musmeci's research gets applied to numerous designs for bridges and large-span halls, which remain unrealized, except for Basento Bridge. His strive towards new typologies of form, the so called "form with no name" (Nicoletti. 1980), exemplifies the plastic potential of concrete.

The development of the young history of concrete architecture and engineering reveals the gradual overcoming of known archetypes and the abandonment of figurative languages. The early adapted formal patterns, according to wood and iron constructions, vanish after World War I, with the technological development of the construction material and the reinforcement, as well as with the optimization of the building process. New technologies and new production methods shape the formal appearance of concrete structures. Emerging engineers tend to focus their research on single detail aspects; Robert Maillart (1872-1940), for example, invents the mushroom slab, which brings a new expression with its repetitive character into architecture. At the same time, holistic approaches for concrete structures are commonly based on well-known typologies; Eugène Freyssinet (1879-1962) uses parable-arched roofs, Robert Maillart arch-bridges and Pier Luigi Nervi or Eduardo Torroja (1899-1961) dome structures. By ignoring questions of production and economic feasibility, Musmeci succeeds in expressing a novel vocabulary of forms for concrete structures in an integral understanding at the end of the prospering boom years.

CONCLUSION

Sergio Musmeci calls for new experimental design methods, which lead him to a new form typology related to the plastic potential of concrete. Beyond common cultural norms and aside from Cartesian thinking, a unitary integration of structural and architectural form gets established in Musmeci's work, which allows, on the cusp of postwar modernism and early postmodernism, a new interpretation of the architectural space.

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