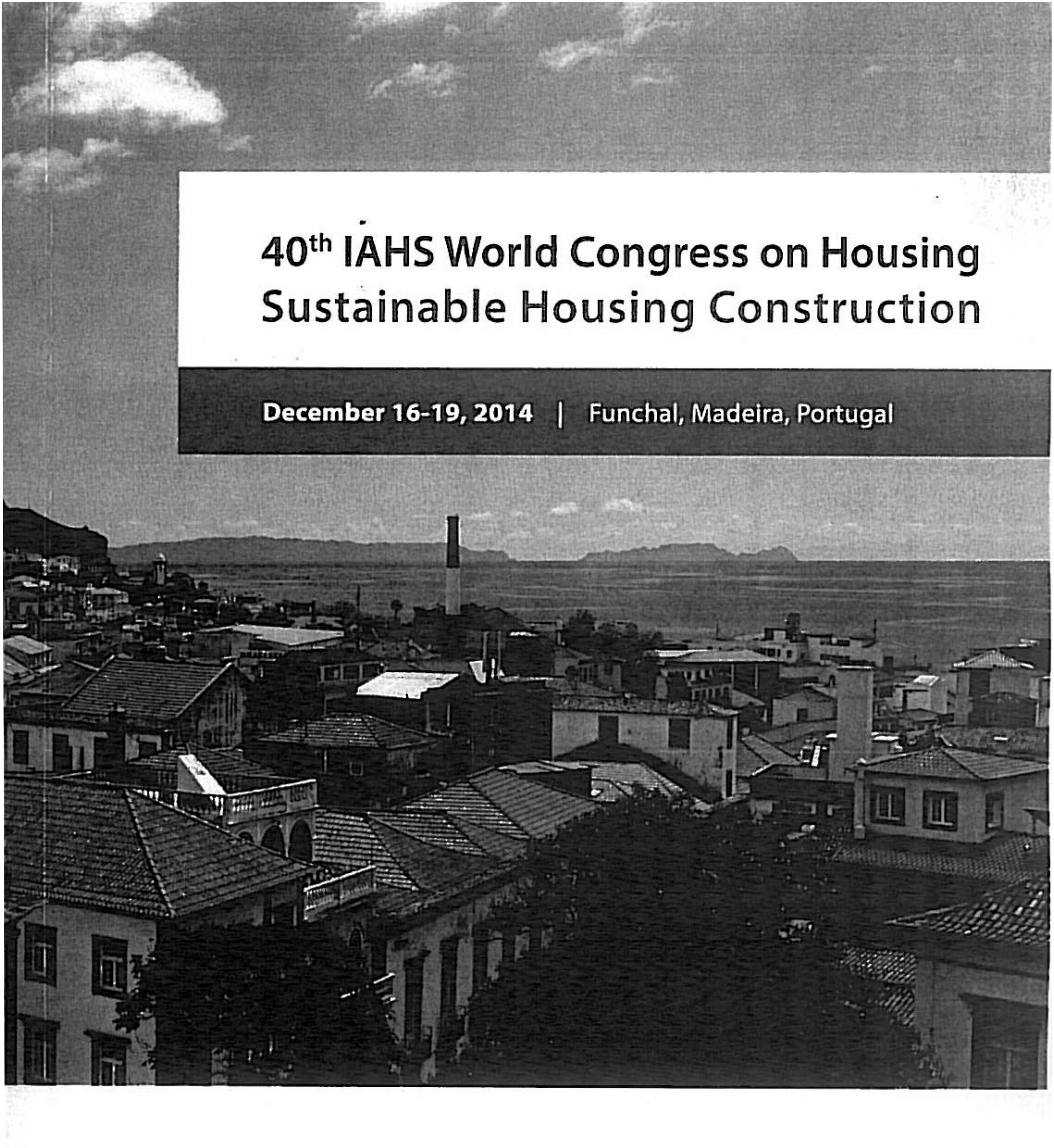
40th IAHS World Congress on Housing
Sustainable Housing Construction

December 16-19, 2014 | Funchal, Madeira, Portugal



ITeCons

U C

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

International Association for Housing Science
IAHS 1972

PREFACE

This book contains abstracts of the papers presented at the 40th IAHS World Congress on Housing held at the city of Funchal from 16 to 19 of December 2014.

Under the theme "Sustainable Housing Construction" we have gathered a Scientific Programme which brings the broad scope of the International Association for Housing (IAHS) series of congresses to focus on today's major concerns with energy efficiency and sustainability in the construction sector.

The success of this Conference, as evidenced by the contents of this book is a demonstration of the interest shown by different researchers in the recent advances and future trends on housing sciences. This is a multi-disciplinary field attracting architects, engineers, planners, physical scientists, sociologists and economists, all of them showing their expertise towards developing houses better suited to the future of humankind.

The Editors are grateful to all authors for their excellent contributions, as well as to the members of the International Scientific Committee and other colleagues who helped select the studies included in this book.

The Editors
Funchal
2014

40th IAHS World Congress on Housing – Sustainable Housing Construction
Proceedings, 2014
António Tadeu, Derin Ural, Oktay Ural, Vitor Abrantes
ITeCons – Instituto de Investigação e Desenvolvimento Tecnológico
em Ciências da Construção (Ed.)

ISBN: 978-989-98949-0-7

Depósito Legal: 385114/14

MASS-PRODUCED ELEMENT IN STRUCTURAL GLASS: "ARTIFICIAL VINEYARD"

Antonio De Vecchi, Nunzio Scibilia, Simona Colajanni, Elsa Sanfilippo, Angela D'Araio, Marianna Di Salvo

Dipartimento di Architettura
Università degli Studi di Palermo
Viale delle Scienze (building n. 8)
e-mail: {antonio.devecchi;nunzio.scibilia;simona.colajanni;elsa.sanfilippo}@unipa.it,
web: http://www.unipa.it
PADesign srl
e-mail: { angela.daraio; marianna.disalvo}@padesign.com
web: http://www.padesignsrl.com

Keywords: Structural glass, Modular system, Building Design, Flexibility

Abstract *The aim is to design an architectural element flexible and easily adaptable to different urban situations using a material such as glass that, for the last years, is being employed as a structural element.*
The mass-production is rarely applied to glass construction systems that instead are usually designed case by case.
The paper reports the results of a research carried out by the Dipartmento di Architettura and Dipartimento DICAM (Dipartimento di Ingegneria Civile, Ambientale, Aerospaziale, dei Materiali), of the University of Palermo, within the project "VESTRA" (POFESR 2007/2013 - Action Line 4.1.1.1), that aims to the experimentation of mass-produced elements in structural glass.
The prototype was designed to satisfy different urban contexts (public transports, rest areas, pedestrian path, etc.) ensuring the protection performances (from solar radiation and rainfall) required in these cases.
The main achievable benefits are:

- *The design flexibility: from the basic module of 4 sqm it is possible to compose different elements obtaining surfaces of about 25 sqm.*
- *The possibility of taking advantage of the characteristics of materials that, thanks to modern technology, can provide superior performance to other materials commonly used. Furthermore, glass is a recyclable material almost 100% and, unlike many other materials used for serial production can be recycled indefinitely;*
- *The easy and quick assembly, allowed by the die-cast aluminum joint systems that simplify the implementation.*

The prototype may provide suggestions to use materials and technologies not yet used in the industrialization field.

1. INTRODUCTION

The mass-production in construction industry aims to realize repetitive elements that provide to lower the production costs and, therefore, the final cost. Unlikely the mass-production has been applied to glass systems construction which usually are designed case by case.

The development of innovative materials and the increase of sophisticated machinery, used for glass processing, have allowed the diffusion of the glass as a structural element.
This feature is new to an ancient material and requires special attention in the sizing and deployment.
Glass building should be considered specific aspects related to its intrinsic fragility, which makes it highly vulnerable structure.
The compressive strength is much greater than the tensile strength, theoretically can reach very high values in the order of 900-1000 N/mm^2, however, in reality only in particular conditions it can reach them; also the mechanical strength traction of the glass is greatly influenced by environmental conditions of humidity and depends on the micro-surface defects due to the processes of plates manufacturing. The design must follow different criteria from those used for materials such as steel or reinforced concrete. In Italy there are currently no legal references that govern the design of structures made of glass, the only point of reference is the proven CNR-DT 210/2013 "Guidelines for the Design, Execution and Control Engineering with Structural Glass Elements " which summarizes the scientific knowledge necessary for a conscious design of glass structures.

Figure 1. Apple Store, Fifth Avenue - New York, NY.

Some examples of construction, the last decade, have shown that the new glass features can guarantee the design of flexible architectural elements and easily adaptable to various urban situation.

2. DESCRIPTION OF THE PROJECT

The proposed work is part of the research project "VESTRA" - structural elements in laminated glass for use in civil engineering and design – PO-FERS Sicily 2007/20013 - Line of Action 4.1.1.1.

The aim of this study was to design a fully glazed platform-roof adaptable to different urban situations (public transport stop, parking areas and recreation and covered walkways, etc.) ensuring the protection prerogatives (solar radiation and rainfall) that in such cases are required.

The conceived prototype, *artificial vineyard*, is constituted by a vertical element like an "L" composed by five parts that support a roof constituted by a flat plate.
The connection between these two elements is made with stainless steel joints; the connection between the glass structure and the soil is carried out through a die-cast aluminum base connected to the foundation.
For greater adaptability to different situations, a laminated glass sheet, connected to the top of the foot, has been provided to realize a small sitting useful for short moments of pause.

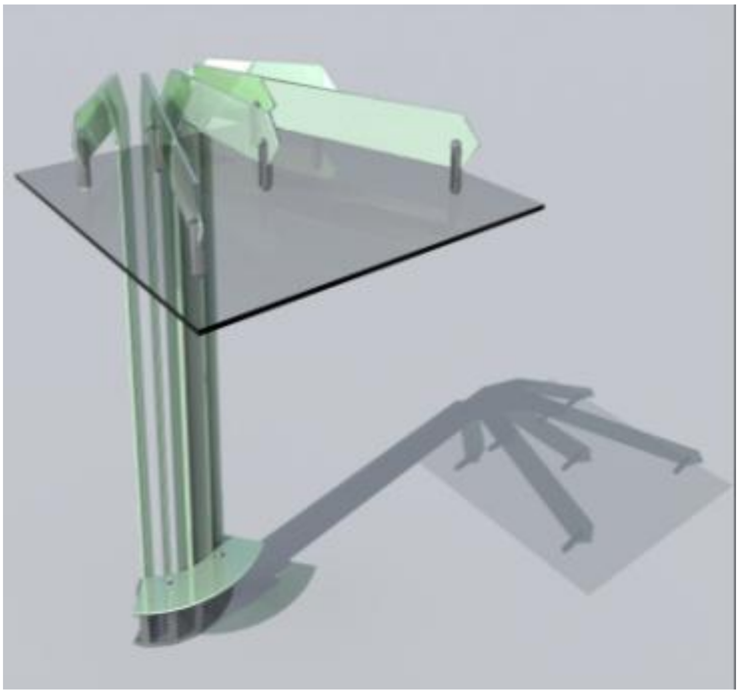


Figure 2. Render of platform roof.

2.1. Construction, materials and shape of the elements

The **support structure** consists of five arms of laminated glass with a radial support to cover a laminated glass plate. Each arm consists of a vertical part of height 2700 mm and depth 200 mm and a horizontal portion having a height of 200 mm and different length as a function of its position. All the arms are composed by five laminated glass sheets: two external sheets are thermally tempered glass, of 8 mm thickness, and the three internal plates are hardened glass of thickness 6 mm. For the stratification an interlayer SentryGlass Plus (SGP) has been used; the SGP has a thickness of 1.52 mm. The thickness of the platform roof arms, in correspondence of the horizontal portion, is variable along its length because the number of sheets is reduced from five to three, depending on the static response. The glass section is reduced from 340 mm to 180 mm removing the two outer sheets of tempered glass and keeping constant the only three internal sheets of thickness 6 mm. The central arm, shorter than the others, presents a single anchor while the other four longer have two anchors to ensure greater stability. The three inner layers are also the type extra light to lighten visual perception.

The **cover sheet** has a square shape of side 2000 mm and is constituted by two hardened sheet of 6 mm and by a thermally tempered of 8 mm except the interlayer. To mitigate the effects of solar radiation and to ensure a greater adaptation to the different environmental situations a screen-printed has been designed; this is a pergola consisting of branches (in the arms) and leaves (in the cover plate). This design was also inspired from the location in which the platform-roof will be located, as a prototype. It is a garden with precious plant species.

Figure 3.Screen printed glass, plan and vertical view.

For the connection of the structure to the ground has been designed a **die-cast aluminum foot** that provides superior resistance to aluminum, and nearest to steel and it is also more lightweight and unalterable. The material cost can be reduced by a mass-production. An accessory element is the seat located over the base, also made with laminated glass. Where the platform-roof performs the function of a mere protection of a path, the seat is not be included, while is introduced if the platform-roof is placed in a meeting place and resting. The inclusion of this element does not alter in any way neither the form nor the static nature of platform-roof.

Figure 4. Prototype of the base.

3. STANDARDIZATION BENEFIT

3.1 Material Performance

The glass properties, enhanced thanks to modern technology, can ensure performance of mechanical strength superior to other materials used in serial production.

During the design, in addition to structural characteristics, were also taken into account the issues of environmental sustainability.
One of the environmental problems considered has been the solar radiation.
The treatment of the screen-printed foreseen in the cover plate has, in fact, the purpose of decreasing the passage of solar radiation and improve comfort below the glass cover.
This treatment allows to lower the intensity of solar radiation about 65% even in the hottest season. The screen-printed has been designed representing a pattern of leaves in the cover and branches in the vertical arms, also has the function of integrating an artificial object in a natural environment or retrieve the vegetation in urbanized contexts. Another aspect, that makes the product sustainable, is the recycling of the material.
The glass is in fact one of the few almost 100% recyclable material that does not require pre-cleaning processes or parts selection.

3.2 Material optimization

In the design phase, the optimizing of the glass plate has been provided to minimize material waste also during processing phase. Also this aspect has been designed to obtain a sustainable element and a fast realization without waste of material and resources.

All elements of the prototype can be cutted out from a single glass plate of standard dimensions 3210 x 6000 mm. The configuration of the prototype requests the use of waterjet cutting by joints cutting thin that allow to cut with precision the required shapes. This type of cut does not transmit vibrations on the glass, does not cause HAZ (Heat-Affected Zones) and leaves no rough edges, allowing no more stages of reworking.

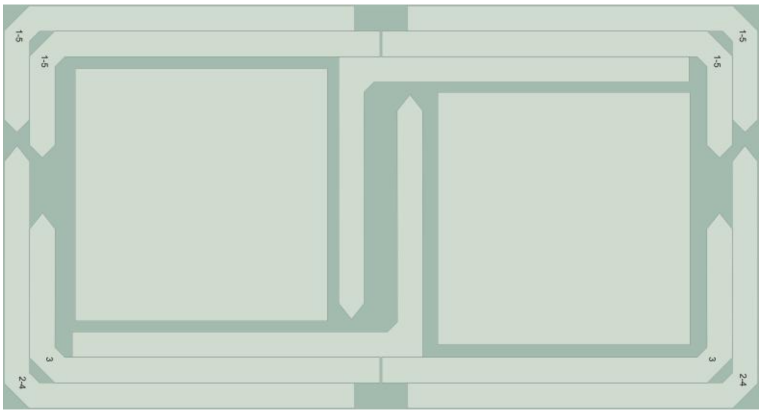


Figure 5. Cutting optimization of the glass plate.

3.3 Easy assembly

The realization of systems of stainless steel and die-cast aluminum joints allow a dry assembly that makes the execution of the installation quick and inexpensive for the substantial reduction of manpower. Furthermore, the use of this materials, if it is produced individually require high costs, allows a reduction of the price due to series production.

3.4 Adaptable design

Artificial vineyard has been conceived as a repeatable module that allows, through the use of multiple identical elements, the creation of different spatial configurations: the basic module covers an area of 4 square meters, by it may be obtained by different conformations and surfaces up to about 25 square meters. In addition, smoothing or changing the shape of the plate cover (square, trapezoidal, etc ..), it is possible to adapt the module according to the different spatial requirements.

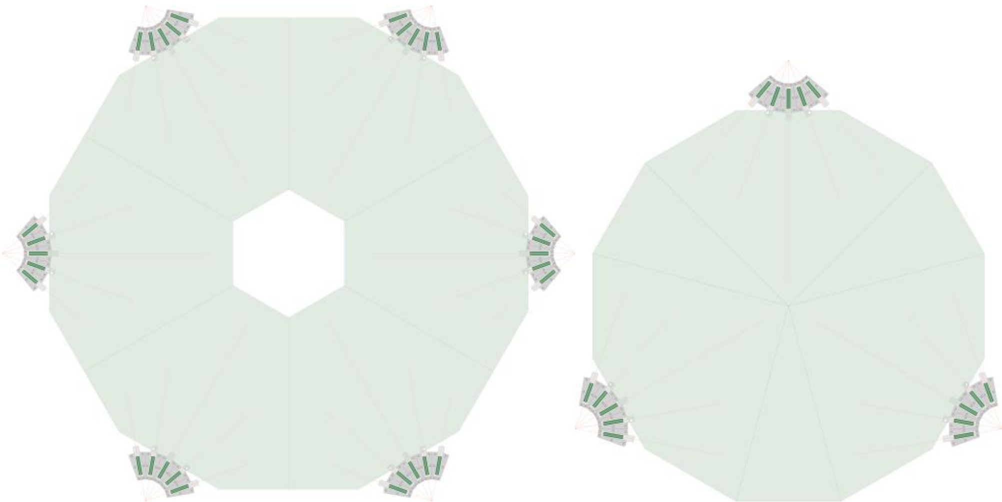


Figure 6. Obtained schemes.

4. STRUCTURAL PERFORMANCE

The design indications, obtained for the realization of the prototype, are derived from a continuous comparison with the data obtained from a series of calculations for the structural dimensioning and verification of the mechanical performance of the different elements.

This phase has been developed at the Dipartimnto of DICAM (Dipartimento di Ingegneria Civile, Ambientale, Aerospaziale, dei Materiali), Università di Palermo, and was edited by prof. N. Scibilia, Coordinator of the Research Project VESTRA, together with his team. Starting from the study of the state of the art, the structural glass aspects (as strength, stability, stiffness, feasibility and dimensioning) have been studied in deep.
To define the final configuration have been evaluated various possible combinations of laminated glasses, checking step by step, the mechanical resistance of assemblies of glass proposed and the joint reactions.

Figure 7. Destructive testing laboratory.

The study has been referred to the current legislation (CNR DT 210-2013 for structural assessment). The theoretical calculation has been validated by laboratory tests, still in progress, to test the strength of the arms and the joints systems.

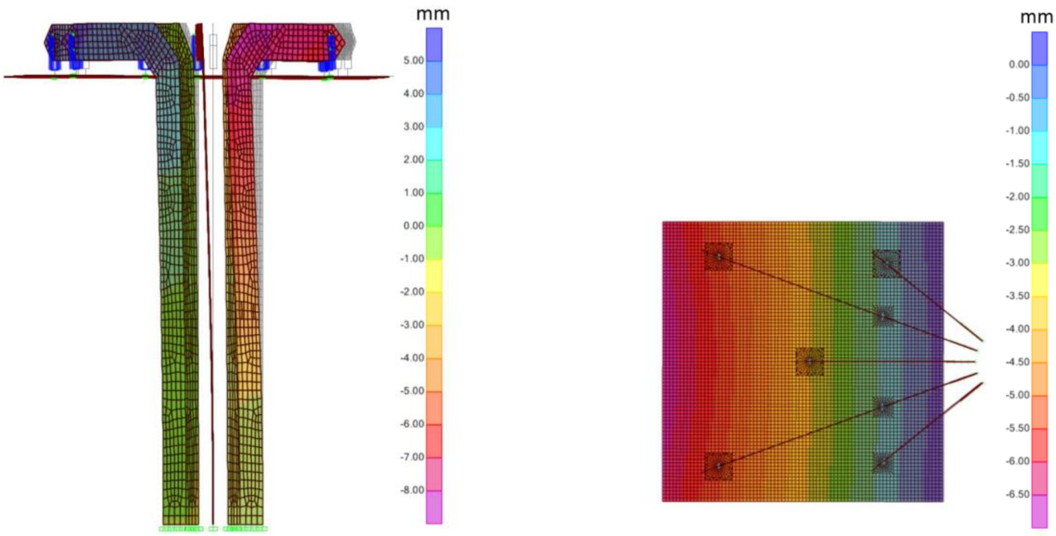


Figure 8. Structure deformation under the wind action in horizontal direction (left) and wind pressure (right).

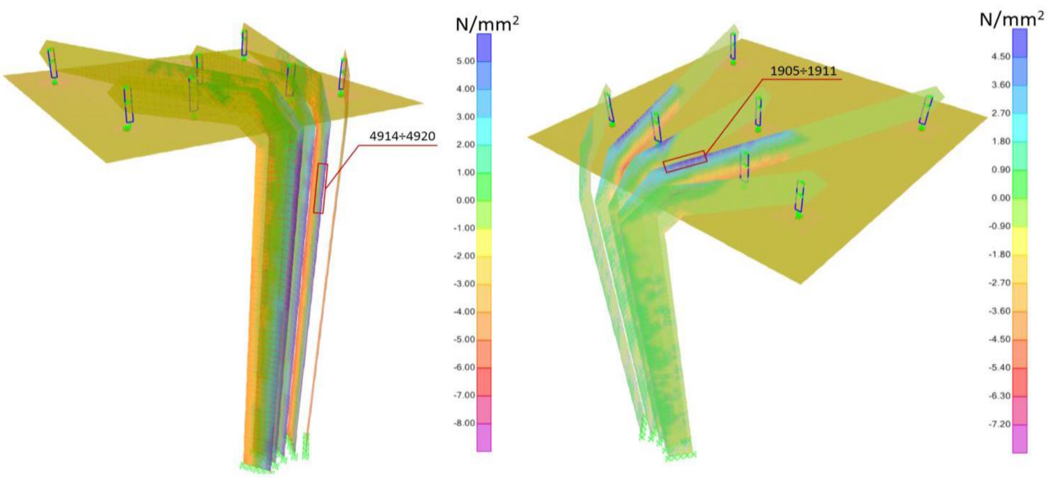


Figure 9. Principal stresses σ22 (left) and σ 11 (right) under the action of its own weight.

5. CASE STUDY APPLICATION

The *Artificial vineyard* work has been verified for the construction of a walkway path to connect the Education Faculty and the Faculty of Arts in the University Campus in Palermo.

This location is characterized by complex morphological and environmental factors that have given us the opportunity to test the adaptability of the assembled spatial prototype in a real situation. The design of the path has been developed in an existing garden, characterized by very fine plants, with a distribution of ground altimetrically articulated. Twenty-one *Artificial vineyard* will be organized to obtain a continuous walkway path, designed according to different ground levels to provide protection from the rain, and most of all, to give protection from solar radiation, in a particular geographic location as Palermo.

Figure 10. View and plan of the project area.

Figure 11. Views of the walkway path.

The particular conformation of the prototype, supported by a single column, allows to minimize the foundations execution, which in this specific case will be realized by micro piles.

The walkway path has been designed also to have some rest areas organized by the composition of two or more *Artificial vineyard* arranged to use the sitting at the base of the column.

6. CONCLUSIONS - DESIGN STRENGTHS

Innovation has achieved very high performance levels in the field of structural glass by applying design standardization criteria.

The solution strengths are:

- Main structure realized completely in laminated glass with mechanical properties comparable to conventional systems;
- Architectural system composed by easily producible elements in series;
- Wide range of transport for the small size and weight of the building elements;
- Quick and easy assembly by the use of dry systems;
- Flexibility and adaptability to different contexts and needs, both functional, dimensional integration with the context.

REFERENCES

[1] A. Aksamija (2013): Sustainable Facades. Design Methods for High-Performance Building Envelopes - Published Wile and Son, Canada.
[2] C. Schittich, G Staib, D Balkow, M. Sobek (1999): Glass Construction Manual - Birkhause Publishers, Base.
[3] E. Re (1997): Trasparenza al limite. Tecniche e linguaggi per un'architettura del vetro strutturale – Alinea.
[4] J. Wurm (2007): Glass Structures Design and construction of self-supporting skins-Birkauser, Berlino.
[5] J. Achenbach (2000): Glass: Structure and Technology in Architecture (Art & Design)- Prestel, 2000.
[6] M. Patterson (2011): Structural Glass Facades and Enclosures - Publisher Wiley.
[7] P. Loghran (2003): Falling glass problems and solutions in contemporary architecture-Birkhauser-Publishers for Architecture, Base-Berlin-Boston.
[8] E. J. Nieuwenhuiijsen, F. P. Bos, F. A. "Veer, The laminated glass column", in Proceedings of the 9th International Conference Glass Processing Days, Tampere, Finland, 31th August, 2005.
[9] M. Haldimann, A. Luible, M. Overend, "Structural Use of Glass", *Structural Engineering Documents*, IABSE, Zürich, 2008.
[10] R.A. Behr, J.E. Minor, M.P. Linden, "Load Duration and Interlayer Thickness Effects on Laminated Glass", *Journal of Structural Engineering*. 112, 6, 1441-1453, 1986.

GOLD SUPPORT

INSTITUTIONAL SUPPORT

SILVER SUPPORT

MEDIA PARTNERS

ISBN: 978-989-98949-0-7