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The Re-use of Traditional Architecture through the Use of Innovative Corrugated Cardboard Architectural Components System

By Irene Di Stefano[*]*, Gianluca Rodonò*[±] *& Vincenzo Sapienza*[°]

In this work, that we want to show you, was exploring the possibility to employ a new constructive system for architectural purpose, who is based on the use of corrugated cardboard envelop panels. Especially, this system is applied to recover existing buildings. This study is part of a research on sustainable and eco-friendly architecture solutions that can match to many needs of the potential users. If has been developed by the authors, from some time by now. Specifically, in the paper the application to the case study of Archicart technology, which has been invented few years ago by an innovative Start Up, in partnership with the University of Catania, will be presented. The lightness of the base component, that is a panel in corrugated cardboard, guarantee an easy transportability; moreover, the use of prefabricated products, ready for a dry set-up allow to control the building time. In addition, Archicart guarantees the reduction of the construction intrusiveness in the site and the reversibility of the operation. So, those features make the constructive system suitable to historic architectures refurbishment, which are in fragile or difficult-to-access places. The chosen case study is a traditional, ruined building in the Aeolian islands. In particular, itis located on Filicudi, one of the most charming isle of the Aeolian archipelago.

Introduction

Recently, there has been an improved interest in the architectural component based on paper and cardboard. This is mainly due to the ecological and sustainable nature of these materials, as well as their lightness and versatility. This resurgence of interest is also influenced by the works presented since the end of the last century by the famous Japanese architect Shigeru Ban.

However, the lack of information on their mechanical, thermal, and acoustic performances could be a vulns in the use of these materials. Thanks to the increased use of cardboard in industry and rising enthusiasm in university research, we can observe a boost of the experimental tests of these products, as found in the scientific literature. Although there are not tests strictly connected to their use in the AEC (Architecture Engineering and Construction) sector. Another insufficiency lies in the technical regulation framework, which currently does not allow the use of corrugated cardboard as load bearing material.

To fill this gap, numerous researchers are interested in designing components and architectural system, including the realization of scale-down or full-scale

[*]PhD Student, University of Catania, Italy.
[±]Researcher, Department of Civil Engineering and Architecture, University of Catania, Italy.
[°]Full Professor, Department of Civil Engineering and Architecture, University of Catania, Italy.

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prototypes. Among them, there are the four prototypes called THEC[1] and created by Latka with the Wroclaw University; and also two building systems developed by the University of Catania called ICARO[2] and Archicart[3]; the latter one has been developed in partnership with the local company Area.

On the other hand, a significant improvement in this sector comes from the design simulation of these components. In fact, these kinds of constructions cover a wide range of possibilities, such as housing for lower-incoming groups, migrants, temporary pavilion for exhibition or other cultural events and so on.

This paper specifically would like to demonstrate a specific application of one of the constructive systems mentioned before. It was used for the refurbishment of a traditional existent building, assumed as a case study. The selected technology is Archicart, and the chosen case study is located in the isle of Filicudi, that belongs to the Aeolian Archipelago.

Literature Review

On the market, there are already some buildings that are almost entirely realized in corrugate cardboard. The first commercialized was the Wikkel House (Figure 1)[4] made by Fiction Factory, a major proponent of this kinds of technologies. These light, modular, easy-to-assemble small flat allow close contact with the environment and the surrounding nature. It has a life expectancy of fifty years. The building is composed by several modules, with an area of 5 m^2 each. Every module is made by 24 layers of single wall corrugated cardboard glued and wrapped around a steel plate; all of these are reinforced with a central wood frame. Once the layers overlap is completed, it is necessary to wait, since the complete drying of the parts. The interior finishing is formed by a plywood coating, while from the external side there is a waterproofing cloth. The wall is completed with a ventilated façade of wood strips. The different modules are assembled with threaded rods passing through the wood frame spaces and the modules themselves. The front and the back walls are large windows in glass and wood directly linked to the wood frame. Thanks to the prefabricated, modular and lightness features, the producer ensures the daily placement of a Wikkel House equipped with a bathroom, a kitchen and an air-conditioning system.

The literature review shows that many tests has been carried out over the last twenty years to create cardboard components for temporary structures, analysing different types of cardboard (such as paper tube, honeycomb and corrugated) and their possible combinations. An example of this, could be represented by the TECH prototypes developed by the Wroclaw University. These are emergency shelters that

1. Jasiolek M, Latka J, Brzezicki M. (2021). Comparative analysis of paper-based building envelopes for semi-permanet Architecture. Journal of facade design & engineering, 9(2).

2. Sapienza V, Rodonò G. (2022). ICARO - Innovative Cardboard ARchitecture Object: sustainable building technology for multipurpose micro-architecture. Sustainability 2022(14).

3. Distefano D, Rodonò G, Sapienza V. (2016). Le nuove frontiere dell'architettura di cartone. IlProgettoSostenibile, 38.

4. Jasiolek M, Latka J, Brzezicki M. (2021). Comparative analysis of paper-based building envelopes for semi-permanent Architecture. Journal of facade design & engineering, 9(2).

are easy to transport; they use the columns-beam system, eliminating the need of skilled labour. During the various editions of the TECH project, several improvements has been made both to the structural system and to the type of protecting painting. The latest prototype, called TECH 04 (Figure 2)[5], was made by A. Jasolek et al. in 2018. This is a modular system made by cardboard sandwich panels which are folded on site to create an external envelope that is simultaneously the wall and the roof. Each panel consists of a double wall of honeycomb cardboard (25 mm thick) held by two walls of four BC-wave corrugated cardboard (7 mm thick). Inside the shelter, the walls are finished with self-adhesive PVC, while the outside the finishing is a painted aluminium plate. The external coating ensures the waterproofing and at the same time increase the fire and mechanical resistance.

Some years ago, the University of Catania developed a mixed wood-cardboard system, called ICARO (Figure 4)[6]. This technology meets the needs of light, easy to build and disassemble structure that require no skilled workers and have minimal impact on the surrounding environment.

Specifically, the supporting structure of these panels is made with a wood frame, while the corrugated cardboard work simultaneously as a wind brace for the structure and as infill for the panel itself. Moreover, compression is applied to the system by pulling two threaded rods throughout the wood beams and the box shaped cardboard. To test the potential use of this system in fragile context, the archaeological site of Megara Hyblaea was selected as test-site[7]. There the Experience Pavilion was realized, based on ICARO technology. It is the first of many other pavilions, that has been designed to help visitors understand the archaeological site of Megara, which is the oldest Greek colony on the South-East Sicilian coast. In particular, the Experience Pavilion was designed to remind the projection of the ancient Stoa, one of the main monuments of the agora of Megara. Finally, a special external finishing was realized using a charred wood slats along with the Japanese waterproofing technique called Shou Sugi Ban.

Another technology based on the use of cardboard was recently developed in Catania. It is the Archicart technology[8]. It springs from combining several cardboard box-shaped held by another external layer of cardboard. This system allows the creation of modular panels whit customizable dimensions, to some extent, depending on the application case. The potential of these materials is demonstrated with the construction of two 25 m^2 residential prototypes (Figure 4), continuing to be

5. Jasiolek M, Latka J, Brzezicki M. (2021). Comparative analysis of paper-based building envelopes for semi-permanent Architecture. Journal of facade design & engineering, 9(2).

6. Sapienza V, Rodonò G. (2022). ICARO - Innovative Cardboard ARchitecture Objetc: sustainable building technology for multipurpose micro-architecture. Sustainability 2022(14).

7. Sapienza V, Rodonò G. (2023). Innovative building technologies for sustainable architecture in heritage site: detailed design of two full-scale prototypes in the ancient Greek colony of Megara Hyblea in Sicily. Athens Journal of Architecture, 9(1), 83-106.

8. Archicart Lifehouse project. Provided from https://www.dicar.unict.it/it/progetti-di-ricerca-nazionali (accessed on June 2024).

explored through assumption of use and application to various cases, with the ongoing efforts of the producers to improve itself and gain a greater market presence[9].

All these examples illustrate the versatility of corrugated cardboard as material to build lightweight, easy to transport, assemble, and disassemble structures with minimal impacts on the surrounding environment where they are placed. Thanks to these performances, the cardboard elements seem to be very useful also in the refurbishment of the traditional buildings following environmental sustainability values and every thermal and acoustic standard[10].

Moreover, with attention to fragile and difficult to approach contexts, the features of prefabrication, lightness, and easy transportability are essential.

Figure 1. *Wikkel House*
Source: https://wikkelhouse.com/.

Figure 2. *TECH04*
Source: Journal of facade design & engineering 2021.

9. Romano R, Belardi E, Gallo, Distefano D. (2022). 4.0 low-tech building system. BIM-based product innovation for corrugated cardboard prefabrication. International journal of Architecture, Art and Design (12).

10. Distefano D, Gagliano A. (2018). Thermophysical characterization of a cardboard emergency kit-house. Mathematica modelling of engineering problems, 5(3).

Methodology

Figure 3. *Experience Pavillion*
Source: authors.

Figure 4. *T-Box*
Source: https://www.archicart.com/en/prima-casa-di-cartone-ondulato/.

The study that is presented here is divided into the following phases.

1. Choices of building technology.
   The literature review on corrugated cardboard, on the creation of residential modules, on the construction of temporary pavilions and so on, aimed to simplify the choice of a compatible technology for the case study; the overview was completed by focussing on the rehabilitation of historical buildings in inaccessible area. After that analysis, the Archicart system was chosen for its features; the main performances are the lightness of the panels, the prefabrication of the component, the modularity of the system, the reversibility of the final output.
2. Choices of case study and its survey.
   To verify the effectiveness of this system, a fragile and difficult to reach plot has been chosen. Specifically, Filicudi Isle was selected, which belongs to the Aeolian archipelago, in Sicily. A residential complex in Portella, one of the island's shires, was selected due to its perfect fit with the traditional Aeolian architecture. Thick vegetation, debris, and collapsed parts of the main structure made it impossible to access on some areas of the building for a direct survey. Moreover, from the survey, it was found that the structure was more complex than initially assumed. Therefore, lidar scanning technology provided by Mac PRO devices was used to obtain a mesh of most of the building. Data extracted from the mesh, satellite images, and a photographic survey were used to create

drawings of the current state of the building. The mesh also allowed for the creation of a digital model of the building with the modelling software Rhino, enabling simpler drawings of plans and sections.

3. Uses of the refurbished building.
   To ensure a new and longer-lasting life cycle for the building, several solutions were explored. Considering the site's features, which attracts every year numerous tourists from all over the world, advanced hospitality systems, such as diffuse hotel and home restaurants, have been considered. These systems foster closer contact between tourists and locals, promoting the repopulation of this fragile residential area and the spread of local culinary traditions.
4. The architectural project.
   The project was developed in two phases. The first one, focused on the restoration of the existing load bearing walls though the strengthening of the masonry; in the second phase, the fallen parts have been completed and new volumes have been created, in order to enlarge the building. For this porpoise, the Archicart technology has been used.
5. Small-scale prototyping.
   Given the high level of innovation of this proposal, some advanced 3D prototyping techniques were used to facilitate the readability of the project drawings, for potential investors.

Materials

Archicart Technology

The Archicart technology was developed by the innovative start-up Area, located in Catania (Italy, Sicily). The project was developed in partnership with the University of Catania. The basic building component is a prefabricated panel made of boxes in corrugated cardboard; the boxes are held by an external one, again in corrugated cardboard. The panel is completed at the top and at the bottom by a wood beam with bumps that ensure a better bond between the box shaped and the beams. These elements ensure also a better distribution of the loads throughout the panel (Figure 5). To guarantee a good thermal insulation the inside of the cardboard tubes is filled with cellulose fiber or similar once[11].

The panels dimensions can vary according to customer needs, and it is possible to make holes for doors and windows, with a minimum panel dimension of 100 cm. Generally, the corrugated cardboard is a two waves type; for stronger element, a triple wave could be used.

The system was patented in 2015[12]. In 2018, a first prototype was created in the area of the Building Construction and Architectural Engineering department of the University of Catania. The module had a surface area of approximately 25 m^2

11. Distefano D, Gagliano A, Naboni E, Sapienza V, Timpanaro N. Thermophysical characterization of a cardboard emergency kit-house. Mathematical modelling of engineering problems, vol. 5, n. 3, 2018.
12. Sapienza V, Distefano D. (2015). Italian patent n. 151592248.7-1604/2015.

and it consisted of a single room, with a pitched roof, with a window frame on the entrance front. It was called T-Box (test box) (Figure 6) because, for 12 months, its indoor comfort conditions were observed and monitored. After this period of observation, it was disassembled and reassembled in the service area in front of the company. This prototype is currently undergoing tests and evaluations to create an even more sustainable and efficient product.

In 2020, another prototype was built at the University of Pauli (in France, Corsica) (Figure7). It is similar to the previous one, but there the link joint was improved, where steel replacing the wood. As mentioned earlier, the choices made aimed to tests the worth of this technology while gaining a better understand of the margins of improvements through further analysis and tests.

Archicart technology uses modular panels with customizable dimensions within established limits: the average height is 240 cm for panel and 480 cm for the finished building; the width of the panel can change from a minimum of 60 cm to a maximum of 180 cm. These dimensions depend on some extent on the manufacturing process of corrugated cardboard that is assumed to facilitate the production of the panels.

Figure 5. *Archicart Panel Compositions*
Source: www.Archicart.com.

Figure 6. *T-Box in Catania during the Construction*
Source: www.Archicart.com.

Figure 7. *T-Box Built in Corsica*
Source: www.Archicart.com.

The panels currently feature a mechanical connection to assure the easy assembly and disassembly. Moreover, to guarantee minimal and reversible actions on the existing building, this typology of connection was used to link the existing structure to the new components, planning to use two types of connection: panel to wall and panel to slab.

Location

The island of Filicudi (Figure 9) is one of the seven islands of the Aeolian archipelago (Figure 8). It is located in the southern Tyrrhenian Sea, not far from the northern Sicilian coast. Like the rest of the Aeolian Islands, it has a volcanic origin. It is a peculiar and full of asperity place with arid characteristics and a unique architecture, where the inhabitants have to make the most of what the nature provides.

Figure 8. *Location of Aeolian Archipelago*
Source: Google earth.

Figure 9. *Filicudi Island*
Source: Google earth.

The Aeolian architecture[13] is completely adapted to the area's features: it uses local materials to best meet the various climates conditions (like aridity, excessive hot, wind) and to meet the seismic activity of the site. From these needs, you have the characteristics of the Aeolian houses[14].

The shape is regular and squared. The openings are small; typically, they are limited to a single front door and a small top window to ensure a good ventilation of the inner space. Multiple residential units are often found clustered together, vertically too, usually independent between them but linked with outsider stairs. The lack of water on this small island led to the use of flat roof to collect and store the rainwater in underground tanks located outside the house. The building envelope was constructed with shapeless volcanic stones for the foundations and the elevated walls, wood, reed mats, pumice stones and floor for the roof. The masonry is thick, both due to construction technique and the need to withstand the seismic and wind force that occur in this area. Usually, the thickness is around 60 cm for the first elevation and of around 50 cm for the second one. The foundations are made by broadening the wall thickness. Generally, the first-floor slabs are vaults made in pumice stones and lime, while the roof had a load bearing structure of wood beams; a 25 cm diameter cross beam supporting smaller orthogonal beams of 15 x 15 cm spaced 35 cm apart, embedded in the masonry for 2/3 of their height. Reed mats lie on the smaller beams, as shuttering for the upper lime based, pumice stone, concrete; it had been repeatedly beaten to extract the water and so to make it waterproof[15].

The daily took place outside, so there was always a terrace in front the house, called *Bagghio*. A typical characteristic of these places are same masonry columns called *Pulerji*, to support the wood shading structure. Another feature is the masonry seats called *Bisoli*, which also limit this area[16]. The lower floor usually is used as storage space during nighttime for the product left to dry under the sunlight, or

13. Calvagna, S. Gagliano A. (2020). Innovative multidisciplinary methodology for the analysis of traditional marginal architecture. Sustainability 2020(12).

14. Sapienza V. (2012). Spontaneous architecture and energetic sustainability: the Aeolian homes of Filicudi Isle. In: Noguchi M. ZEMCH-12, ZEMCH Network: Glasgow.

15. Polverino F. (1999) Tra lastrici e terrazzi. CUEN: Neaples.

16. Trovato C, Tropea G, Piccitto G. (1985) Vocabolario siciliano, Centro di Studi Filologici e Linguistici Siciliani, Palermo.

animal shelters. This place is called *Pinnata* and usually it has a vault ceiling and do not present a front wall, but it is opened to the *bagghio*. The houses have also a stone oven, that could be placed outside, maybe with the mouth opened to the fireplace area of the house. The toilet, generally later added, was placed in a small, room, that is separated from the main building.

To preserve the peculiarity of this area, local authorities have imposed restriction on new constructions, while they head toward to the rehabilitation of the existing buildings and their unique features.

Case Study

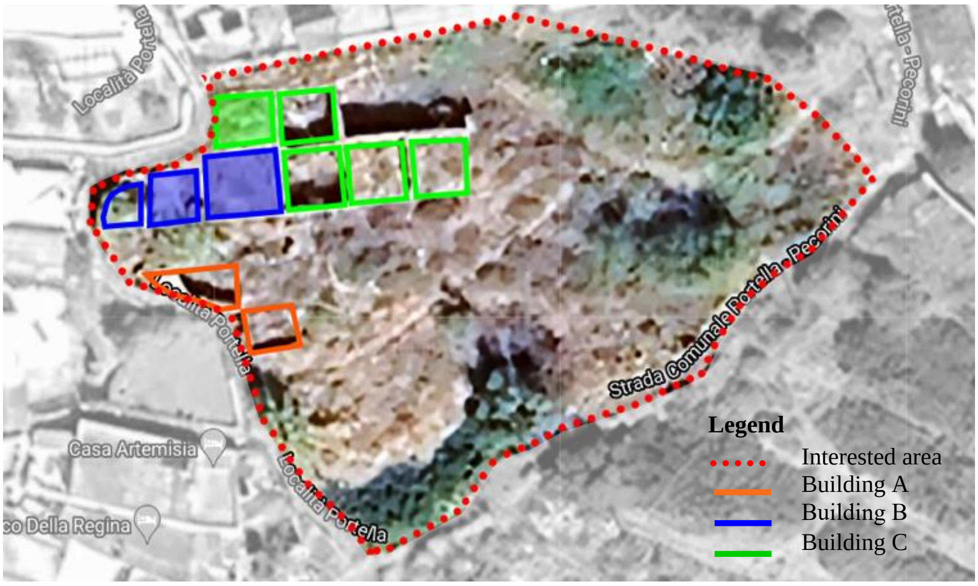


Figure 10. *Location and Identification of the Case Study*
Source: Di Stefano Irene, background from Google Earth.

The building, that has been chosen as case study is located in Contrada Portella ad it is reachable troughs the vehicle accessible road on the island. However, the building is about a hundred meters away from this road; this is common in Filicudi because you have a very small number of roads there. So, the final distance must be walked through one of the mule-truck paths of the isle.

The building is composed by several residential units, developed on multiple floors and levels interconnected by external paths and stairs.

In the area of interest, three distinct buildings can be identified. From above level there are: Building A, Building B and Building C.

- *Building A*. This is a one room building that has partially collapsed (is missing the rooftop and parts of the walls). The presence of recesses on the masonry suggests that this place had a residential use. Furthermore, another place located higher, given its proximity to the first, suggests that it was also part of building A. Also, based on its shape and dimensions, probably it was used as shelter for animals or a small storage.

- *Building B*. In this building, three room can be identified. Specifically, two of them are connected internally and maintained the original roof, while parts of the third room, which has collapsed, shows a stone arch typically used to support the rooftop of secondary places, such as animal shelters. In front of the building, there is a large outdoor space where remnants of a lost *bagghiu* can be seen, i.e. some beam holes in the front masonry, the base of a *pulerij* and the presence of the *bisoli* on its border. Between two masonry seats, the aperture of a cistern was found.
- *Building C*. This building has a double elevation. From the finish of the façade of upper floor its residential nature can be evinced. On the other hand, the lower level consists in four room; all of them have a vault in pumice stones. While the upper floor presented inside and outside finishers, the lower ones have a rustic finishing; the first room has a front wall, while the other two ones exhibit the features of a pinnata. This fact suggests that there was a *bagghiu* in front these two rooms; this idea is supported also by the presence of a collapsed *pulerij* at the border of this area. Further away to the view, there is a fourth vaulted space, partially hollowed into the stone connected to the first and second lower spaces. The upper floor, that was the house of the owner, is composed of five rooms, all of them are connected to each other. Only one room has maintained the original roof. From the outside, is possible see the volume of the oven, which has the mouth in one of the rooms. Due to the collapse of two façade and past of the lateral wall, the external walkway connecting the rooms is lost.

The links between these buildings are mostly deteriorated, but some parts can still be seen: a steep stairway links building A to the path leading to the storage of building A and the other two buildings; stairs also connect the lower floor of building C with building B, and other stairs depart from the *bagghiu* of the Building B, leading to the lost walkway of the upper floor of Building C.

In the local strategic plan, the case study is marked as a historical building, which means there are several restrictions and obligations, such as the prohibition of demolishing parts or the entire building and increase the height or volume of the original structure. Exception can be made for structures like terraces or porches, or all of that spaces that maintain their external nature.

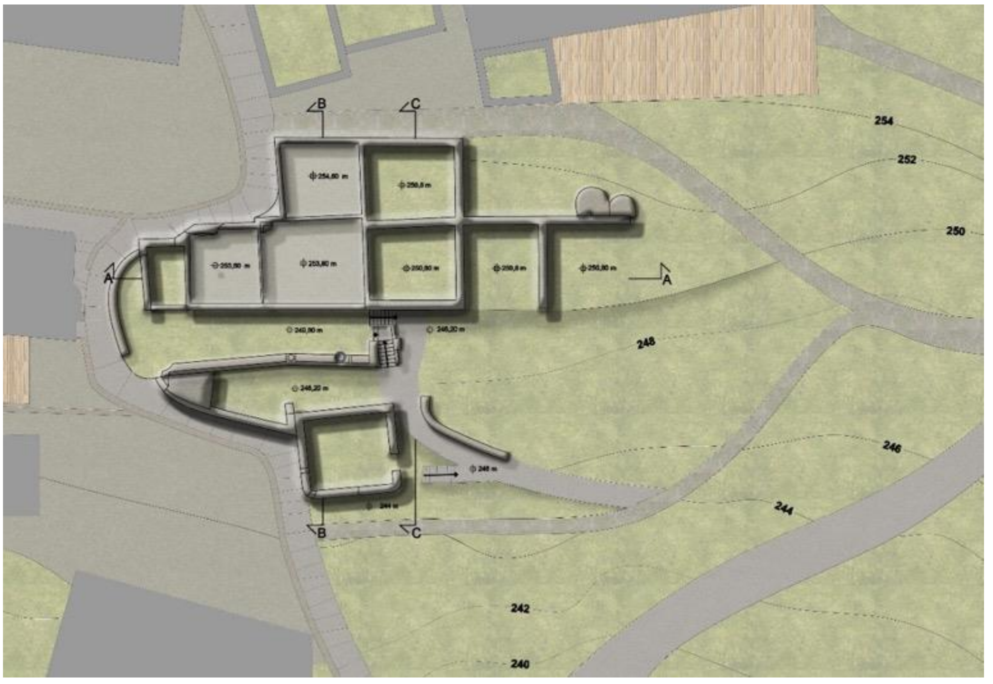


Figure 10. *Plan of the Actual State of the Building*
Source: Gianluca Rodonò.

Figure 11. *Mesh*
Source: Di Stefano (2023).

Figure 12. *Digital Modelling of the Building*
Source: Di Stefano (2023).

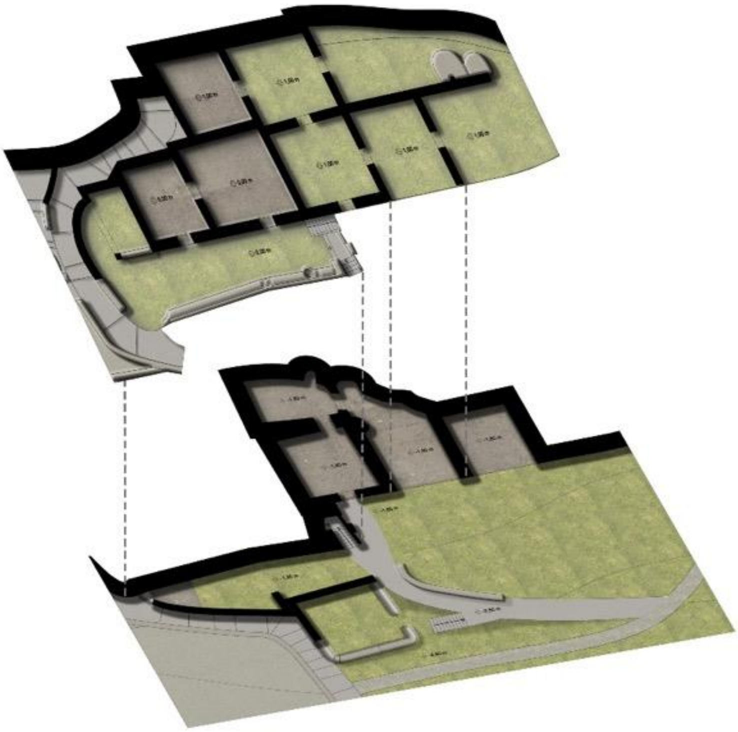


Figure 13. *Building's Level*
Source: Di Stefano (2023).

Refurbishment Project

With the aim of giving the building a new life, several possibilities were explored. The choice fell on the maintaining its original function, i.e., the residential, interpretating it in view of the touristic vocation of the place. Considering the requests of the urban planning tools and the nature of the building, innovative hospitality systems have been used. Specifically, the new destination was a diffuse hotel with a home restaurant. These seem to be the most appropriate choice for the case study.

- *Diffused hotel*
  This is an innovative way of touristic hospitality[17]. Following the local technical regulations[18] a minimum of 6 residential units is required, in addition to the host's home. The units could be spread in an area within 200 m radius long from the main hall. This space limitation arises because the breakfast and food services, as well as common spaces, need to be in the main building, and they must be managed by the host. The rental of the studios must be shorter than three months. Every house owner, in the 200 m radius area, can offer his home

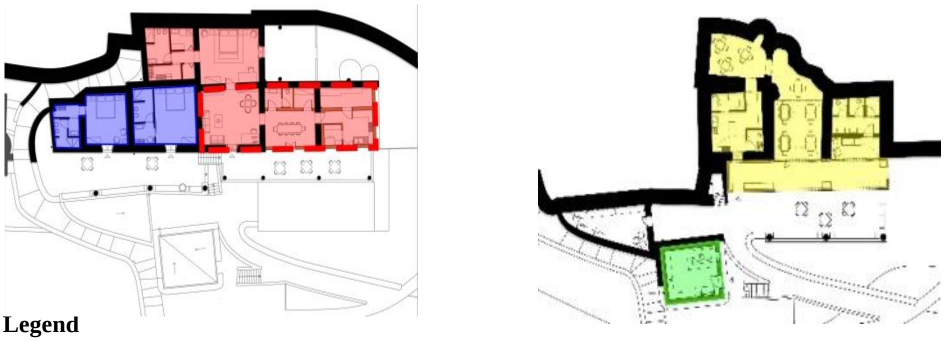
17. Alberghi diffusi Association. Provided from https://www.alberghidiffusi.it/?lang=en (accessed on June 2024)

18. Regione Sicilia (2013). L.11/13. https://pti.regione.sicilia.it/portal/page/portal/PIR_PORTALE/PIR_LaStrutturaRegionale/PIR_TurismoSportSpettacolo/PIR_Turismo/PIRAreetematiche/PIR_Strutturericettive/PIR_ClassificazionealberghieraNorme/PIR_Albergodiffuso (accessed on June 2024)

for the hotel activity. According to the requirements of the law, the case study has been divided in four areas, each one with a specific function.

- The upper floor of building C, which has five rooms, has been designated as the main house, i.e. the house of the host.
- The lower floor of building C will hold the common area for breakfast/ lunch, also serving as a bar and refreshments area.
- The building B has been divided into two residential units for the diffused hotel business.
- The Building A has the hall and a shopper corner for local agri-food products.

- *Home restaurant*
  This type of innovative restoration service has a limited number of pax for year and a maximum limit for annual profits. Booking and payment are managed by a national platform. This activity must take place in the host's home, with the aim of this venture is to spread the traditional local cuisine.
    - It locates in the building C and consists in a large dining room, related to the kitchen. The central position of the room makes this space suitable for room that can host everyone who will enjoy the Home Restaurant activities. The available space will be divided by a second inner Archicart wall, creating a restroom and a storage space.



Legend

Host's home
Home restaurant
Residential units
Breakfast/lunch area
Reception and selling point

Figure 14. *Distribution Scheme*
Source: Di Stefano (2023).

Building Work

The masonry which forms the historical building has been strengthen by using glass fiber nets[19]. Where parts of the walls collapsed, an extremity brickwork has been performed. Due to the high thickness of the masonry a four head warping is the most suitable. For the remaining roof, a consolidation will be executed proceeding by short parts. Where there is no longer a roof, the old wood beam system has been

19. Cascone S, Sapienza V. (2016). Fiber-reinforced polymer nets for strengthening lava stone masonries in historical buildings. Sustainability2016(8), 10.

maintained. This is possible because the beam slots are still visible in the masonry, with a depth 1/3 of the beam's high. On the beams, two OSB structural panels have been laid, with a series of interposed shaped purlins to give slope to the roof.

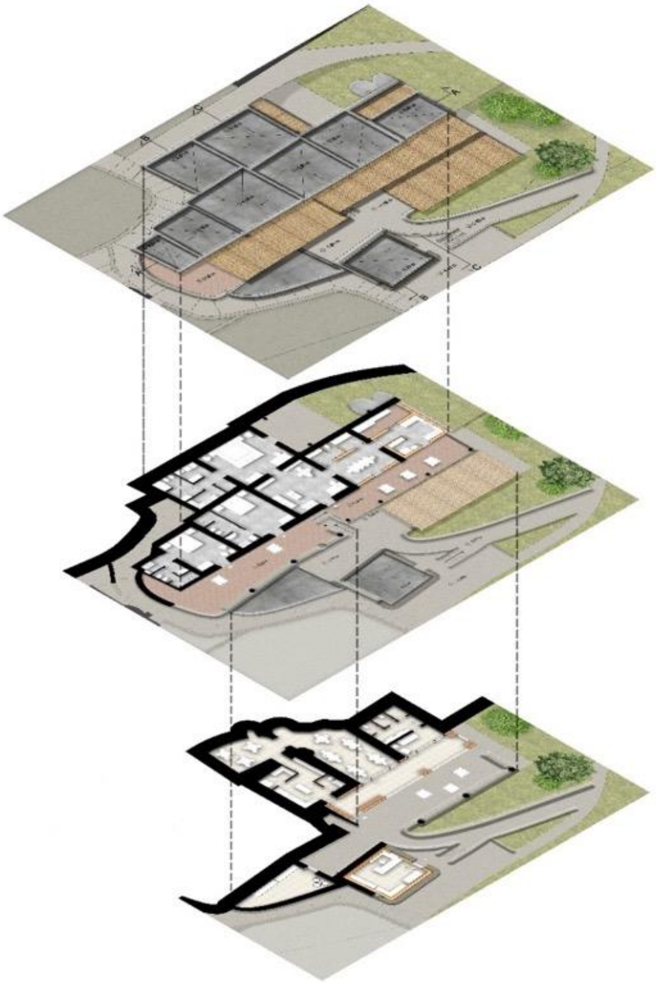


Figure 15. *Building Design*
Source: Di Stefano (2023).

This slope has been used to direct water in the cistern, so it can be collected.

The original existent stairs have been recovered through the repositioning of their components and the installation of new decking.

The two rooms that had partially collapsed, the walkway of the building C, and the building A almost totally collapsed has been replaced with the innovative technology Archicart.

1. Building C: South wall and inner partition (Figure 16).
   The mesh masonry of this room was broken by the overturning of the front wall. The east wall is the weaker one, so it will be reinforced with extremity brickwork with four head warping. A threaded rod has been embedded in the brickwork to fix the Archicart panel to the masonry. The same method has been used in the

front masonry to achieve a closed fastening. Chemical anchors are used to avoid threaded rods slippage. Five Archicart panels have been used to create the exterior wall. Both side of the panels present the same stratigraphy: a 40 mm air chamber for the passage of systems, realized with 4 x 4 cm wood pillars that also supports the fibre cement slabs finish. The partition will be made with triple wave corrugated cardboard panels 10 cm thick.

Figure 16. *South Wall and Inner Partition*
Source: Di Stefano (2023).

2. Building C: Independent module for the kitchen (Figure 17).
   In this room, only two walls have not collapse. The northern one features the mouth of a stone oven, hence the decision to use this space as a kitchen. It is formed through Archicart technology. Between the cardboard panels and the existing masonry there is a gap 3 cm large; in the north side, has been left a 2 m large open covered flexible space, useful for the stone oven. The module dimensions are 350 x 500 cm plus another 200 cm wall that serves to divide the oven space from the outsider, ensuring the visual continuity of the Aeolian cell. Its structure is connected to the existing slab with anchor bolts to ensure a minimal intervention and its reversibility. To the anchor bolts, U shaped steel elements are screwed to the lower part of the panel for better contact between panels and slab. To prevent possible overturning, panels have been secured with hold down. The module roof will also be made with Archicart panels laid horizontally. These panels have wood beams throughout the cardboard box shape, which strengthen the horizontal structure. Some beams will extend out to support the oven space roof in reed mat. The roof stratigraphy included a 3 cm layer of structural OSB on top of the horizontal panels, shaped rods to create the inclination and an exterior fiber cement panel finished with waterproofing. The exterior finish is also made with white plaster.

Figure 17. *Kitchen Module*
Source: Di Stefano (2023).

3. Building C: Box-shaped system for the walkway (Figure 18).
   The walkway with its own bagghio, probably rested on the extension of the Pinnata vaults, which in turn rested on pillars or pulerji. Nothing remains of the original structure, so the Archicart system will be used to recreate it. A box structure of 200 x 1400 cm has been set up. A double line of Archicart panels support the slab made by 13 cm thick and 5-layer X-Lam panel laid horizontally, this thickness provides a sufficient bending stiffness with low weight. To be loyal to the traditional architecture, arches will be made between the pillars. Since an arch structure strong enough whit the Archicart system is not currently possible, two shaped X-Lam panels have been used and to make an easy transportation, they are divided in three parts each one. The parapet has been also made with cardboard panels. Vertical and horizontal structure will be connected with metal square screwed together, and the connection to the ground will be obtained through hold down.

Figure 18. *Walkway*
Source: Di Stefano (2023).

The inner and the outer faces of the Archicart panels are finished on site. From the internal side, there is an air gap, also useful to fit technical installation; it is obtained by screwing several wood strips, generally 4 x 4 cm. These also support the fiber cement panels for inner spaces to which the finishing (smoothing and painting) will be applied. On the outside, there is a smaller air gap, and the external fiber cement panels will be finished with white plaster to maintain continuity with the existent masonry. To clearly distinguish the addition, the new external wall has been set back 15 cm compared to the existent one; an expansion joint cover is placed between the masonry and the cardboard walls (Figures 23, 24). The parapet and the walkway structure will be covered with waterproofing and also finished with white plaster fiber cement panels on the outside, while the new semi open space under the walkway will be painted (Figure 22). The kitchen roof stratigraphy included a 3 cm layer of structural OSB on top of the horizontal panels, shaped rods to create the inclination and exterior fiber cement panels finished with waterproofing (Figures 19, 20).

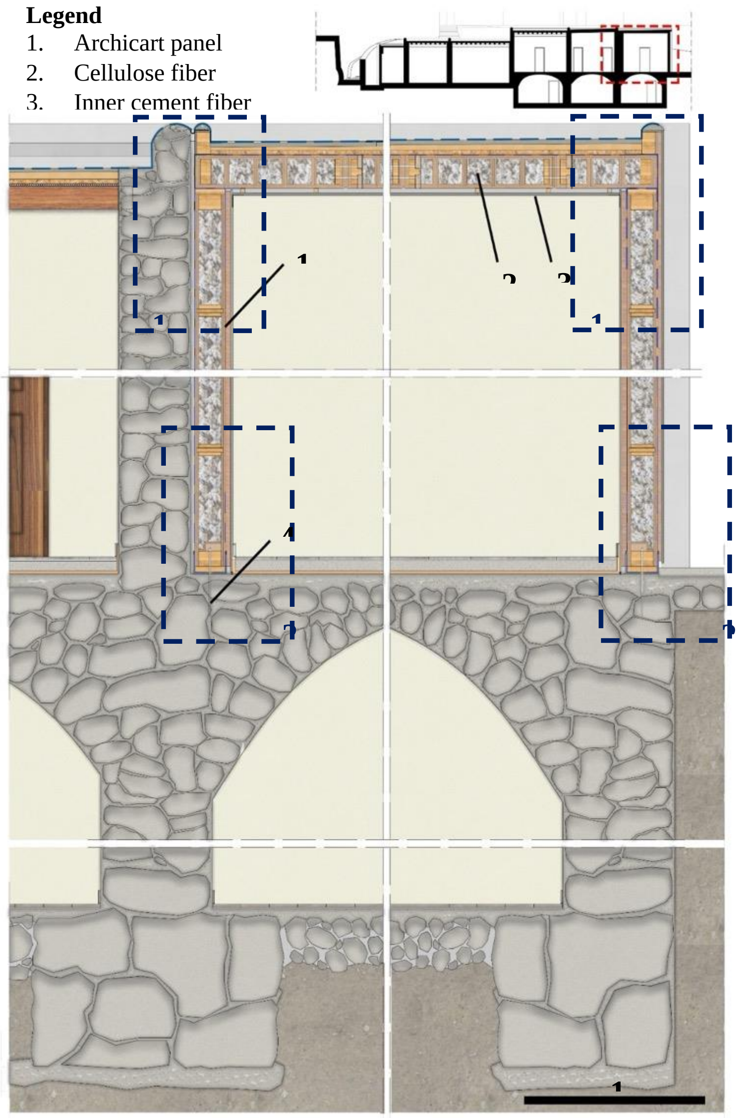


Figure 19. *Constructive Section with the Position of Details 1 and 2*
Source: Di Stefano (2023).

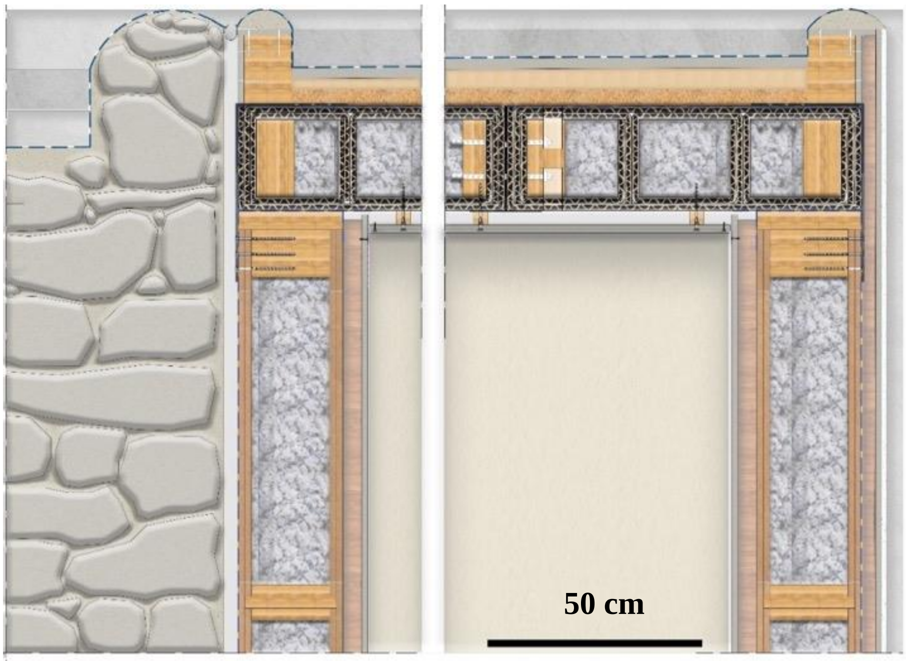


Figure 20. *Constructive Section Detail 1*
Source: Di Stefano (2023).

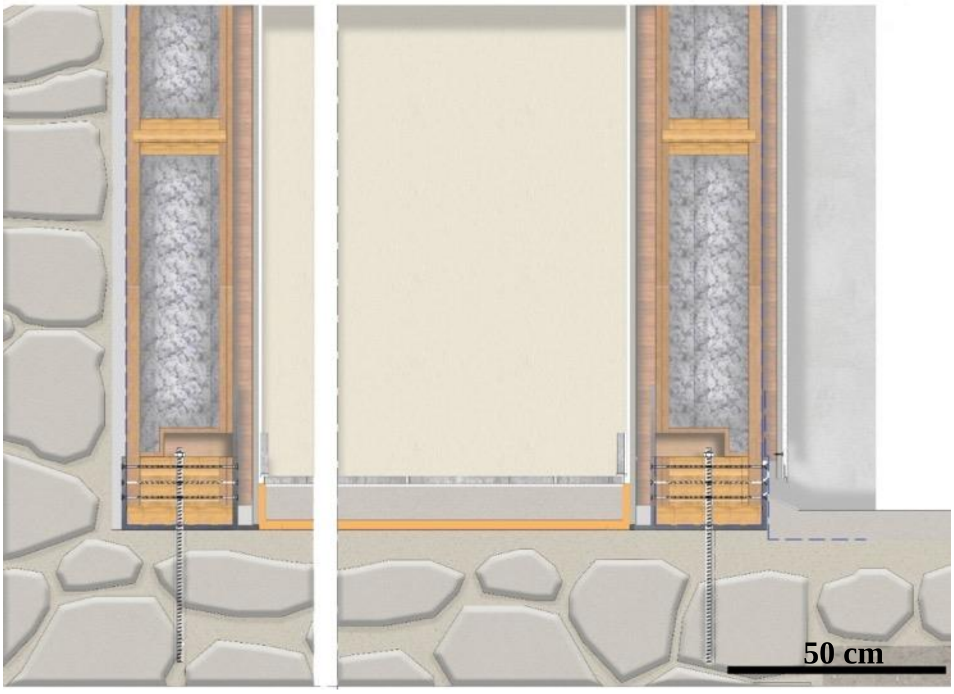


Figure 21. *Constructive Section Detail 2*
Source: Di Stefano (2023).

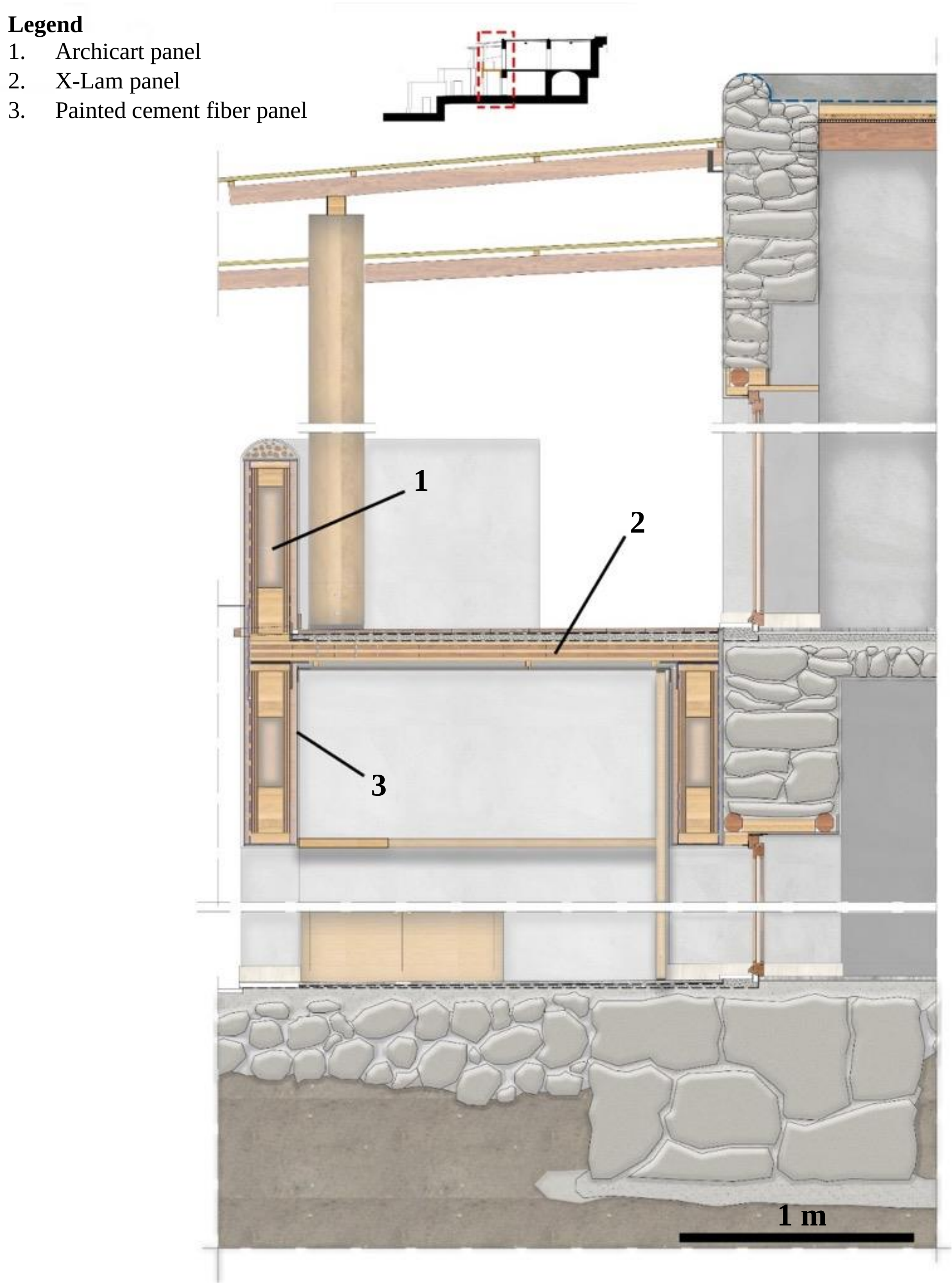


Figure 22. *Walkway Constructive Section*
Source: Di Stefano (2023).

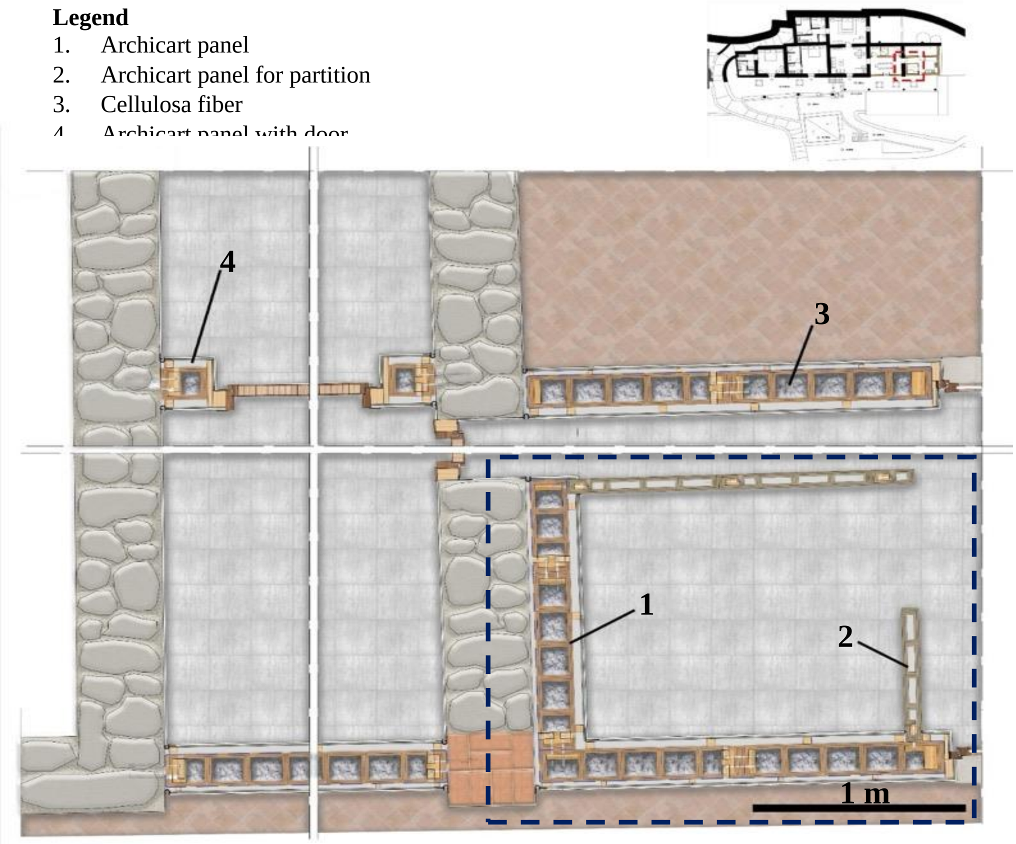


Figure 23. *Horizontal Constructive Section with the Position of Detail 3*
Source: Di Stefano (2023)

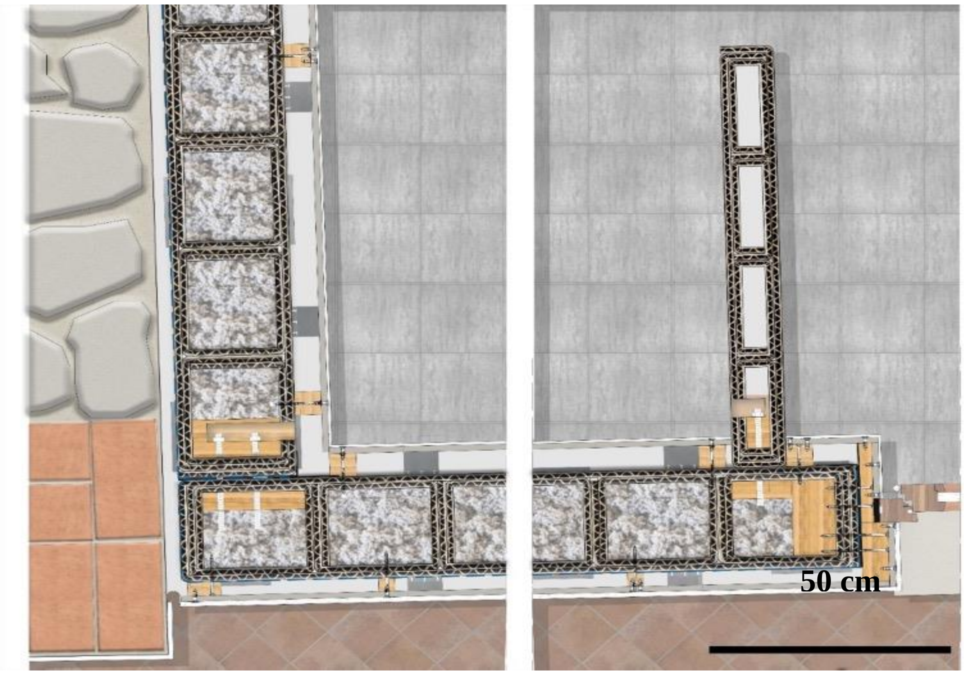


Figure 24. *Horizontal Constructive Section Detail 3*
Source: Di Stefano (2023).

To ensure a better understanding of this system, a scale section was made using prototyping technologies. Specifically, a lase cutter (Figure 25) was used to cut cardboard and cross laminated timber pieces that were glued together (Figure 26) to make the prototype (Figure 27).

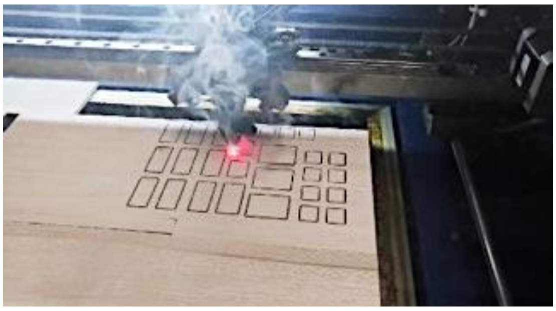


Figure 25. *Laser Cutter Process*
Source: Di Stefano (2023).

Figure 26. *Building Phase*
Source: Di Stefano (2023).

Figure 27. *Final Elaborate*
Source: Di Stefano (2023).

Results and Discussion

Among the several building types present in Italian areas, Aeolian buildings have unique features derived from the nature of the site and its needs. This is a skilful example of human ability to adapt to hostile contexts. Due to the gradual depopulation, the municipality of Lipari strives to preserve the culture and authenticity of this places, especially through architecture, pushing for reuse and refurbishment of ruins located on the islands of its competences. This drive to reuse can become fertile ground for the experimentation of new technologies, more sustainable and compatible with the wild nature of the Filicudi Island. Moreover, reconsidering these places allows for meeting the new needs of the tourism industry, which tends to shift from wild tourism to a more sustainable concept focusing on tourists, the places themselves, their culture and habitants. Switching from a concentrated service in a single building to dispersion across multiple buildings allows fully enjoy the places while giving new life to this desolate small villages. For this purpose, a case study was chosen on Filicudi Island, where multiple ruins and vacant houses still retain some of their typical aeolian features despite their abandonment and neglect. The case study selected is a ruin located in a "contrada Portella" that is marginal and far from the principal touristic areas currently on Filicudi. However, the context and boundary conditions allow the realization of innovative hospitality systems that ensure a new, more durable life cycle for the building. The actual state of the building makes experimentations with innovative building technologies possible. Specifically, using corrugated cardboard components for completing or extending existing buildings. This possibility confirms the validity of these systems. The prefabrication of corrugate cardboard panels offers the benefit of lighter components, easier transportation, and dry installation that minimizes construction time. These also guarantee minimal contact with the existing building, allowing also the reversibility of the interventions if becomes necessary to restore the building to its original state. The design of the panel, which is alveolar, allows the adaptation to the specific climate conditions. In fact, the panel may be infilled with different thermoacoustic insulating materials, in order to optimize its performance. Another benefit of prefabrication is the development of knowledge of the industry 4.0. From a digital survey of the existent building, is possible to create meshes and digital models that are the base for digital experimentations and applications of this innovative building technology. Specifically, parametric models of the Archicart system were made, allowing in the design phase to identify the dimensions of individual panels, further shortening the industry producing time. The use of mixed techniques for the representation of the building nodes makes easier to understanding the technical design solutions which have been adopted.

Conclusion

The Aeolian archipelago has a strong inclination to reuse its local architecture to redevelop marginal areas. Moreover, the redevelopment and refurbishment of these areas could be achieved using innovative technologies that are more sustainable, and innovative forms of tourist exploitation. There is a growing interest in the building industry in the possibility of use corrugated cardboard as a building material, specifically for making temporary shelters in emergencies. Therefore, the use of corrugated carboard was considered to develop lighter and more sustainable building components. This technology, combined with the innovative tourist hospitality, guarantees coexistence and close contact with the place and its inhabitants. Additionally, the validity of using digital technologies for existing designs was confirmed, demonstrating how the Archicart technology proves to be a good alternative to the traditional building materials, ensuring grater sustainability, lightness and shortened construction time.

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