Sustainability and innovation in constructions intended for emergency housing

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Highlights

Emergency situations are increasing dramatic due to climate change. The occurrence of emergency conditions has led to the development of innovative and sustainable housing. The present research aims to obtain a modular shelter, “self-constructible” and easily transportable, based on the use of an anodised aluminium frame and prefabricated panels. The shelter can be expanded and personified according to the number of users and their needs.

Abstract

The research aims to give a response to the emergency housing that occurs after catastrophic events by proposing a low-cost solution through innovative constructions. The illustrated solution - based on a living module composed by four adjacent sections that can be connected to each other or to new ones - combines the concepts of minimum and affordability with those of efficiency and sustainability.

Keywords

Catastrophic events, Emergency housing, Innovation, Sustainability, Modularity

1. INTRODUCTION AND BRIEF HISTORY OF EMERGENCY HOUSING

The concept of temporary housing dates to the first archetype of housing of primitive populations, i.e. the tent, featured by temporariness and sustainability [1]. A basic turning point in the field of temporary housing is certainly given by the prefabrication. The concept of prefabrication as understood nowadays has its origins in the nineteenth century and consists in the off-stage preparation of those elements that, once conducted in situ, are objects of connection and assembly.

In those same years, the problem of colonial housing and minimum housing...
addressed to workers emerged [2]. These cases were followed, in more recent times, by the problem linked to the shelter units addressed to the war and post-war emergency [3].

Concepts related to the home destined for emergencies - such as temporariness, housing criteria and minimal comfort and speed of construction - have accompanied the architectural landscape since the beginning. Recent experiences [4; 5, 6; 7; 8; 9] have paid more attention on issues related to the thermo-hygrometric well-being of the housing and the sustainability of the component elements, showing that the emergency housing must reflect - despite the temporary nature and the reduced size - the needs of a contemporary home. Therefore, the research illustrated in this work is suitable for a well-defined architectural panorama and an historical period characterized by natural disasters which, although occurred also in the past, nowadays affect a more substantial built heritage than in the previous centuries. In the last 20 years, catastrophic events have suffered - also due to climate change - a significant increase, with a consequent growth in costs for administrations. This, in conjunction with the events of anthropic origin (i.e. war events, environmental disasters, etc.), has involved the presence of countless people in the world who are currently in a state of poverty [10].

To respond to an emergency, it is necessary to adopt solutions that act effectively and in a relatively short time to the specific needs of housing assistance, based on the concepts of prefabrication and self-sufficiency, as well as able to offer acceptable levels of comfort and safety. In recent experiences, the requirement of temporariness - for political and socio-economic problems - has often been lost, making a dwelling destined to a short stay a semi-permanent accommodation. It is therefore essential, in the context of emergency homes and from the planning stage, to include those characteristics of permanent housing, such as comfort and safety that last over time.

2. THE CONTEMPORARY SITUATION AND EXPERIENCES

In recent years, the numerous catastrophic events affecting the entire planet and our country have caused a huge number of victims, partly forced to abandon their homes, which were destroyed or considered uninhabitable. In Italy seismic, hydrogeological and volcanic risks overlap and the concomitance of their presence with poor prevention lead to a difficult emergency management, reflected in the presence of many displaced people housed in hotels, tents or containers. Furthermore, according to the CNI (National Council of Engineers) study center, the scarce investments made in Italy for anti-seismic prevention caused huge costs associated with post-
earthquake reconstruction. Some virtuous examples in the panorama of contemporary experiences are reported.

The reCover shelter (Fig. 1), designed by M. Malone, A. Goldberg, J. Metcalf and G. Meacham in 2008, is a portable emergency micro-structure. Easily transportable, it is characterized by lightness and strength. The self-supporting structure is in Coroplast, which consists of a corrugated cardboard sheet covered in polypropylene, which can be recycled at the end of its life.

Once conducted in situ, the “hybrid” structure can be completed by non-specialized users by adopting local materials and can be used as emergency shelter, medical center or warehouse.

The Recycled Pallet House (Fig. 2), designed by I-Beam, was born as emergency shelter for the refugees from Kosovo, who could have used them during the reconstruction. Based on the use of the pallet - which can be combined with insulating materials, is readily available, light and manageable - this housing can be built with self-construction and does not generate any environmental impact either during the construction phase or during the life cycle. The house, once its function is over, can be easily disassembled and recycled in its components.

3. THE PROJECT

3.1 THE DESIGN CONCEPT

The present research aims to obtain a modular shelter, “self-constructible” and easily transportable.

This shelter was primarily based on a building system capable of minimizing need for storage of the finished product or its components, so as to limit the “immobilization” of resources during the period of non-use which, in the case
of building systems able to face the emergency, can be of several years. This prerogative also conspicuously allows to save the use of the soils and the areas meant to receive the buildings during the storage phases, as well as a drastic reduction of the associated maintenance costs. Another necessity, to which this shelter can respond, lies in the possibility of assembly and construction using raw materials and products widely distributed throughout the territory, in order to minimize costs and to allow their assembly directly in the geographical area of destination. This condition reduces emergency management times and costs related to economic and environmental transport, in accordance with the principles of the LCA. The Life Cycle Assessment is a procedure based on the evaluation of energy and environmental impacts related to a product/process/activity, performed by identifying the energy and materials used, as well as the waste released into the environment, which includes the entire life cycle of the product, process or activity [11, 12].

The dimensions and the weight of the component elements have been reduced to minimize the volume size of the components of the building system during transport, while guaranteeing their maneuverability and the possibility of transport with multiple types of vehicles. The elements making up the shelter also guarantee robustness.

The use of easily assembled and mountable elements - combined with the simplification and reduction of the construction phases - makes the refuge of rapid installation and intended for assembly even by non-expert users. In fact, the assembly - based on the principle of interlocking and juxtaposition - needs limited use of tools.

The principle of sustainability is reflected - in addition to the aspects previously illustrated - in the use of recycled and recyclable, or reusable, components or materials for subsequent uses. The dry assembly of the construction components makes possible to dismantle and re-assemble the shelter even in different areas, thus guaranteeing its global re-use. In the design phase, environmental compatibility was also measured with the capacity of the housing module to adopt - as far as possible - the local architectural language: so, a degree of interchangeability of the components enough to guarantee the use of materials and construction techniques was contemplated.

![Figure 2. Design concept: transport and installation phases.](image-url)
3.2 THE CONSTRUCTION ELEMENTS

This section illustrates the construction elements used in the project, installed in the order in which they are shown below (Fig. 4).

3.2.1. THE FRAME

The frame of the proposed shelter is entirely made of anodized aluminum and equipped with an epoxy coating, a treatment that makes the material more resistant and gives it a color that, in the proposed case study, has neutral tones. The steel has been used for its mechanical performance, for its high resistance to fire as well as for the recognized lightness, a characteristic that contributes to facilitate the transport and assembly phases.

The carrying capacity of the shelter is given by the frame: the components that constitute it are bars with a square or rectangular section in standard sizes that allow a modular extension of the shelter.

In particular, the pillars consist of bars with a square section of $50 \times 50$ mm, 2.2 m long and 3 mm thick. These bars have lateral “fins”, which constitute the “negative” of the joint and, connected horizontally by joists, constitute a bracing.

Instead, the beams have a length of 0.9 m; those on the board, both upper and lower, have the slots for the panels, which will be fixed with bolts charaterized by a round head and a hexagonal hole. The beams forming the flooring follow the same principle of the pillars but, in this case, they are connected with the floor panels.

The components of the frame are pre-holed and therefore can be easily connected to each other by bolts and screws to be inserted in the relative holes following the mounting methods shown in the attached instruction booklet, as happened in some previous examples [13]. The connection is made through aluminum joints, which are available in different formats (corner, double or triple) based on the number of elements to be connected.

In this case, the anchoring to the ground occurs by using concrete weights of dimensions $200 \times 200 \times 120$ mm, which are connected at each node of the elements of the base floor and can be partially or entirely buried according to the level of the walking surface.

This design choice also facilitates the ease and speed of assembly, as well as the adaptability of the shelter: the inerts of the concrete, in fact, are of several types in order to adapt to different wind conditions.
3.2.2. THE PANELS

The frame is completed by a system of prefabricated panels, used as horizontal and vertical closures. The bamboo and squared-shaped panels forming the floor rest on the joists that have a 90 cm pitch and, at the anchorage points, tongue-and-groove systems.

The panels used for the pitched roofing, composed of 4 sub-panels mutually interlocked in order to avoid the passage of rainwater, ensure good thermal insulation thanks to the external covering in polypropylene (highly resistant to high and low temperatures) and to the thick inner layer in wood fiber.

Once the base and roof panels have been installed, the panels forming the wall are assembled (Fig. 3). They are “sandwich” type because they consist of an outer layer of polypropylene and an inner layer of wood fiber, interspersed with an air chamber and a polyester sheet, the use of which guarantees a good thermo-acoustic insulation to the environment.

The panel-wall is alternated with the panel-door and panel-window variants, which have the same basic structure and include prefabricated frame with double glazing, having a width of 50 cm and a height of 70 cm.

Figure 3. Stratigraphy of the external panel.

Figure 4. Assembly phases of construction elements.
The internal wall panel, also of “sandwich” type, has wood fiber sheets on the outside and, as inner layers, an aluminum supporting structure and an expanded polystyrene panel. The internal door panel can be connected to the internal wall panel, which allows to use different rooms created with the partitions.

To ensure good protection against atmospheric agents and to hide the imperfections caused by the system of screws and bolts, the addition of gaskets is provided in correspondence with the joints. Made of polypropylene plastic of variable color depending on the function, they hide the unfinished structural element.

3.3. THE ELEMENTS FOR THE PLANTS

In order to create a complete housing unit with the minimum requirements of habitability and comfort, the shelter has some special elements - mainly consisting of wall-panels - designed for the passage of electrical and water systems.

These elements are properly drilled. The passage of cables, for aesthetic and safety reasons, is made with prefabricated wooden skirting boards (Fig. 6), which run along the perimeter of the house going up, where necessary, along the vertical elements, allowing the connection of suspended lighting bodies and also becoming a finishing element.

In order to create the water connection of the shelter, a system to lift the walking surface has been studied and allows the installation of the pipes of the plant (Fig. 5). A system of pillars and joists, raising the treading surface by 30 cm, also allows to create the minimum slope necessary for water disposal.

Figure 5. Providing water and electrical system.
The difference in height that is created is compensated for by a panel-staircase composed of two steps of a rise equal to 14 cm and a tread of 30 cm (Fig.7). The connection of the sanitary blocks to the pipes can be made after drilling the bamboo panel, thanks to the grid which also makes possible to arrange the toilet and the sink in both side and central positions. By the same principle, the kitchenette can be positioned with extreme flexibility.

### 3.4. MODULARITY AND CUSTOMIZATION OF THE ENVIRONMENTS

The shelter, in its basic configuration (3.85m × 3.85m × 3.26m), is a minimum housing unit for 2 to 4 users. By respecting the principles of versatility of the environments and of their personalization, the design solution provides for the possibility of extension in the case of family units with a greater number of components and/or the possibility of dividing the internal surface into more rooms by using the internal wall panels which, together with the internal door panels, are fixed on an anodized aluminum structure mounted on the guidelines laid out along the structural elements making up the frame and hidden by gaskets. The possibility of customization allows to give to the environment its own identity, in view of the uncertainty associated with the time that will be spent by the user.
Figure 8. Six-section combination for two people with bathroom.

Figure 9. Nine-section combination addressed to family, with bathroom and living room.

Figure 10. Eighteen section combination addressed to family, with bathroom and living room.
Figures 8, 9 and 10 show different combinations made with multiple sections, intended respectively for two people and having a bathroom (Fig. 7), to a family and equipped with a bathroom and living room (Fig. 8) and a family and equipped with bathroom, living room and kitchenette (Fig. 9).

4. RESULTS

The numerous catastrophic events that have affected entire countries - and especially our peninsula - as a positive response to the architectural panorama, have led to the study of new housing solutions designed to face the emergency. Although innovative, these solutions recall the homes of nomadic tribes, inspired by their principles of transportability, lightness and sustainability [14, 15].

Therefore, the role of the “emergency” architecture is to create a synthesis between past and present, by studying transportable and flexible living modules, which at the same time succeed in satisfying the requests for minimum accommodation resulting to the occurrence of an emergency and the standards of living comfort. The research conducted and illustrated in this contribution, in implementation, proposes a modular housing solution capable of uniting the well-being of the user with the fundamental requirements of rapidity of installation and environmental sustainability.

5. REFERENCES

[12] ISO 14040 Environmental Management - Life Cycle Assessment - Principles and
