High standard temporary buildings for housing emergency

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Highlights

From the analysis of the problems and the criticalities emerged in the answers given so far to housing emergencies as a result of disastrous events, the need arises to propose more suitable design solutions. The aim of this work was to identify the criteria on which to impose project requirements in order to create modular living systems that, although temporary, can ensure a high performance standard in terms of comfort and energy efficiency, as well as at the same time guarantee the possibility of use in the widest possible range of action and in rapid execution times.

Abstract

The project proposal consists of modular living systems made with dry technology, temporary, re-usable and energy efficient. The concepts of standardization and modular coordination are applied in order to minimize the production and execution times of the modules. The latter, taken together with the criteria of temporariness, reversibility, flexibility and energy efficiency become basic requirements for the project and allow the achievement of standards, levels of comfort and above all performances comparable to those of sustainable buildings of the latest generation.

Keywords

Sustainability, Temporary modular systems, Dry technology, Energy efficiency

1. INTRODUCTION

The situations of emergency housing that occur anywhere in the world as a result of natural disasters, humanitarian emergencies, health or as a result of armed conflicts or in the presence of migratory flows, require adequate and immediate responses.

The European Environment Agency has mapped out three different types of disasters, such as weather, geophysics and technology [1], for the years from 1998 to 2009, and provided data referring to 32 countries taken into consideration, of which 27 EU member states and Iceland, Liechtenstein, Norway, Switzerland and Turkey. The mapping showed that the number and impact of disasters in Europe has increased, causing more than 100,000
As regards the criterion of reversibility, which if applied allows the module to be subject to the different seismic, volcanic and hydrogeological risks, [2] were added the in act climatic changes [3] which, especially in the cities and in some parts of the territory, contributed to amplify exponentially the risk to the population.

Consequently, precisely in Italy the various emergencies caused by natural disasters (earthquakes, landslides, floods, exceptional snowfall, etc.) have occurred more frequently, occurring in some cases even simultaneously (earthquake and heavy snowfall) and on the basis of experience of the numerous calamitous events that have affected the Italian peninsula in the last 50 years, it has always been noted that it is necessary to give an immediate response to an unexpected housing demand [4] and how this response should also be differentiated according to the climatic conditions [5] related to the context.

The responses to emergencies [6] were analyzed, in particular in relation to the numerous seismic events that have affected our territory [7] [8], according to the criteria of temporality, flexibility reversibility and energy efficiency, finding for each of these unresolved problems. The choice fell on these criteria because it was found that they are precisely those that most qualify the answer itself.

Directive 2010/31 to Article 4 sets minimum energy performance requirements for buildings or housing units in order to reach optimal levels in terms of costs, but leaves Member States the option not to apply the minimum requirements for some building categories including temporary buildings, considered as such when the time of use does not exceed two years.

Therefore, as regards the criterion of the temporary nature of the housing solutions adopted, related to energy efficiency, based on the consideration given, it is not mandatory to provide any minimum energy performance requirement.

However, it is noted that the temporary solutions adopted in many localities have always exceeded the period of two years, considered a time limit for a temporary building. For example, in the case of the earthquake in L’Aquila in 2009, nine years after the earthquake, the MUSP, the Modules for Provisional School Use are still in use.

As regards the criterion of reversibility, which if applied allows the module
to be completely removed, it is noted that in many cases analyzed, have been used reinforced concrete foundation slabs which have a significant impact on the environment and are difficult to remove.

As regards the criterion of flexibility, evaluating the solutions adopted for the city of L’Aquila, as part of the C.A.S.E. (Sustainable and Ecocompatible Antisismic Complexes), we can notice in some cases the impossibility of diversification of the housing units, presenting all the same functional-spatial articulation.

In many cases the solutions analyzed are not designed to guarantee and do not guarantee energy efficiency, as can also be seen for the MAP (temporary housing modules) adopted for the earthquake that hit Emilia Romagna. In this specific case the situation occurred in which the expenditure related to electricity consumption is so high for each family, as both the appliances and the heating are electric, that obliged to the Emilia-Romagna region to intervene in order to stipulate with the Enel (National electricity board) a specific agreement on tariffs [9].

From what has been observed is still current the need to elaborate a project proposal that can respond to the needs dictated by the emergency and at the same time to the needs of reversibility, space flexibility and energy efficiency, but also taking into account that the reconstruction time greatly exceeds the two years. The use of housing units, which can be implemented quickly, designed to be adaptable to different settlement contexts, can be a good solution to meet the multiple needs that can be delineated in the various geographical areas in which the emergency may occur.

2. THE PROJECT PROPOSAL

The proposal concerns the project of temporary, high energy efficiency, residential modules, made of modular cross laminated timber (clt) wood panels, which are able to respond to the different needs of users and can be used in different emergencies; this means to provide its use in different possible locations and in different climatic contexts. The peculiar character of building in an emergency requires that the building phase be as fast as possible. The dry construction process is undoubtedly the one that most responds to this need.

But another important factor is the following: the emergency can occur in the most dissimilar geographic areas, consequently the possibility of transporting the components becomes a fundamental element in this type of building. It is therefore necessary a more in-depth study of the interaction between this aspect and the design conception. This research would have a positive impact on the quality of the design, on the simplification of the construction site, the
rapidity of the construction of the works and finally on the extension of the range of action in the use of this type of construction. For these reasons, the project proposal, which assumed which project requirements the functional and spatial flexibility, the reversibility and the energy efficiency, to meet these requirements, moves from the production process of the components, whose transport unit has been established to be the container. The modular dimensions of the panels can not be separated from the dimensions of the container, as this is the only mean capable of containing the products that can travel by road, train or ship. The land marks described above also produce consequences in the execution phase of the housing modules, which thus becomes a procedure for the assembly of independent products or a series of elements corresponding to the different elements of the construction. The study identified a 120 cm base module (multiple of 30 cm) on the basis of which the panels in plan and in elevation were designed: slab panel and wall panel, Figure 1. For the slab there are two types of panels, one 120x120 cm and one 240x120 cm, while three different types in elevation: a 120x300 cm base panel, a door panel and a window one.

It is noted that the choice of the modular dimensions of the component carried out, took into account the following aspects:

• allows to have on the market a large number of producers able to satisfy the possible request of production also if massive, as it does not require an endowment of special machinery;
• allows an easier retrieval of the product on the market from the quantitative point of view;
• from an economic point of view, the increased competition has an impact on the determination of a lower panel price.

From the study of the component we moved on to the study of the spaces of the environmental units. In fact, having identified the modular dimensions of the panels, we proceeded with the study of their aggregation aimed at forming five different environmental units, consisting of: living room, kitchen, double

Figure 1. Slab panel and wall panel.
bedroom, single bedroom and bathroom. Furthermore, a “filter space” has been added at the entrance between the external and the internal environment.

The design of five environmental units Figure 2, thanks to the use of modular panels in plan and in elevation, allows a considerable flexibility in their aggregation.

The environmental units can be joined together in various ways, giving rise to a different home every time.

This allows an important flexibility not only spatial but also functional, being each unit diversified from the others according to its function. The environmental units can be aggregated according to the needs of users and the climate in which they will be built, giving rise to different types of housing. In relation to the needs of users it is possible to predict the appropriate number of environmental units and in relation to the climatic context it is possible to foresee different forms of aggregation that vary from the most compact to the most complex.

The models available are many; in demonstration of this, Figure 3 shows 4 aggregation models, in a compact and/or articulated form. For the last model taken into consideration, there are 2 diagrams in an articulated form, demonstrating that the formal solutions that can be obtained can be multiple.

Figure 4 shows the assembly scheme of an aggregate housing unit in compact form and in an articulated one.

In Figures 5, 6, 7 and 8 the design solutions related to 4 possible models are shown in compact and articulated form, respectively.
Figure 4. Assembly scheme of the panels of the aggregate housing unit in compact form.

Figure 5. Model 1 compact form.

Figure 6. Model 1 articulated form.
Figure 7. Model 2 compact form.

Figure 8. Model 2 articulated form.

Figure 9. Model 3 compact form.
In relation to the requirement of reversibility, the project proposal was oriented towards the choice of a technological system, for each class of technical element, made dry and modular. Specifically, it is observed that the best solution are the foundations on poles fixed by screwing, made of hot-dip galvanized steel, available in different sizes both in height and in diameter, possibly equipped with propellers depending on the load capacity of the ground and the operating loads. These types of foundation are easy to install, to remove and to reuse and they are particularly versatile for temporary use, representing in different cases a valid alternative to concrete foundations. The installation of foundations on poles fixed by screwing, can be carried out in different ways, using mechanical means such as a mini-excavator or a mini-shovel equipped with a hydraulic auger, see Figure 13. The further advantages of this type of foundations are: the possibility to load foundations immediately after their realization; the non-use of benthic mud, the limited vibrations.

![Figure 13. Installation of foundations on poles fixed by screwing (https://goo.gl/images/mBTuSs).](https://goo.gl/images/mBTuSs)

The last aspect addressed is the energy efficiency of the housing units, which can be reached by choosing technical elements consisting of wall and slab stratigraphy using structural panels in clt, pre-coupled with insulating panels in stone wool and through the use of photovoltaic systems and integrated thermal solar panels, respectively for the production of electricity and domestic hot water with electric heat pump generator. Figure 14 shows the technologies of vertical closure and bottom horizontal closure.
For the purpose of improving energy efficiency, particular attention was paid to the stratigraphy of the envelope as shown in Figure 3, and for the frames, a Uw of 1.5 W/sqm value of thermal transmittance was considered. Due to the high degree of insulation of the envelope, it is considered necessary to provide for controlled mechanical ventilation with heat recovery. The energy performance verified for the housing modules falls back in the energy class A4. The results of the verification related to model 4 are shown below in Figure 15.
From the verification of the energetic performances it is possible to see that at the same square meters (sqm), the surface with a compact form has a non-renewable energy performance index EP gl,nren equal to 3.41 KWh/sqm per year, while in the case of the articulated form the index of non-renewable energy performance EP gl,nren rises to 11.66 KWh/sqm per year. These results show in particular how the shape of the building, at the same technological choices, thickness of the layers and equal surfaces, has a central role in achieving the objective of energy efficiency and therefore in more general terms the role of integrated design is decisive for achieving the expected results.

3. CONCLUSIONS

The proposed work shows how the design in case of emergency can not be limited only to the project of the modular-building product system, but must take into account the entire production process of the component elements, taking into account above all the following factors: wide range use, speed of construction site set-up and realisation, possibility of planned dismantling and reuse. It is not therefore a matter of designing a modular system, but of defining and dimensioning the components of the system in such a way that from their aggregation it is possible to obtain a range of solutions for living modules capable of responding to the different needs of future users and usable in different emergency contexts. The resulting housing modules are able to meet the requirements of functional and spatial flexibility, reversibility, and energy efficiency. The temporarity, one of the factors taken into account in the design of the modules, has been considered a determining element in view of their subsequent reuse, and therefore has determined the adoption of those devices that allow it, such as screw poles. This criterion has not, however, been used as a disincentive element for permanence, because in brief it is not acceptable the combination short time-lack of comfort, as the lack of comfort goes in the direction of the non-sustainable economic management of living modules.

4. REFERENCES

Maggioli editore, 2010.
