

STUDY ON MODULAR HOUSES DESIGN

Abstract: In the field of civil engineering, in the last period emerged and developed the idea of modular constructions, which is in consensus with the alert rhythm of the present times that we are going through, while responding to the requirement of economic efficiency. In this paper the authors present a project for some modules that can be assembled in several ways so that according to the destination and the requirements of the clients they can be personalized to meet their needs and expectations. Obviously, special attention has been paid to the technology of joining modules, solving the covering surfaces and other execution details required to ensure comfort in the habitat area.

Key words: modular buildings, prefabricated houses, conceptual design, assembly, flexibility.

1. INTRODUCTION

Modular constructions are used in many industrial areas such as: metalworking, furniture and toys, modular devices etc.

In the field of civil engineering, prefabricated elements, such as diaphragm walls, reinforced concrete floors, prefabricated installations, even so-called completely equipped spatial bathrooms (at the Construction Company of Cluj-Napoca), were used during the communist period. Certainly, in this way productivity was high and met the need for housing estate that was so necessary in the transition period from an agrarian economy with a predominantly rural population to a industrialized economy characterized by a massive population movement in the urban area. Due to the velocity of the execution and of the uniformity of the design, the quality of the construction was doubtful and unsatisfactory, which is why after 1989 people had hesitations about this way of building and gave it up. As a matter of fact, the big companies were divided and dissolved.

Over time, leaving aside the emotional aspect, thinking rationally, pragmatic, following the fast pace of the times that we go through and aiming at economic efficiency in all areas, the idea of modular constructions subtly reappears. Modular buildings are best suited to small houses, whether they are holiday homes, social homes or quickly built in disaster areas. Why small size? Because they can be transported by road or rail with no major efforts - if infrastructure exists.

At the same time, they are characterized by low energy demands, both in the execution stage and in the exploitation phase.

In this paper the authors present a project for some modules that can be assembled in several ways so that, according to the destination and the requirements of the clients, they can be personalized to meet their needs and expectations.

The work is based on a government funded project within the Start Up Nation Project, and besides the conception part - to which the authors contributed, it also benefits of a production line.

2. OPTIONS PROPOSED FOR MODULAR BUILDINGS

If the construction of houses is desired in areas where qualified workforce lacks and the supply with materials that comply the codes and standards is difficult, resorting to off-site modular constructions [3], built in specialized workshops, represents a viable option. In addition, future beneficiaries, who can be busy persons, save time without having to supervise the works. In this context, the project proposed in the above-mentioned competition was accepted, considering that there is a good chance that the business will be successful.

The design of these houses was based on conceiving a module having the projection in the horizontal plane a rectangle with the dimensions of the sides 5.80 x 2.55 m, resulting a constructed area of 14.79 m² - see Figure 1. One opted to choose modular dimensions. Besides, there is an international recommendation that all the dimensions of building and construction parts that are mutually conditioned should be modulated, so that they integrate into the construction, as a whole, with minimal adjustments, allowing their replacement with others, of different nature, without modifying the respective plans.

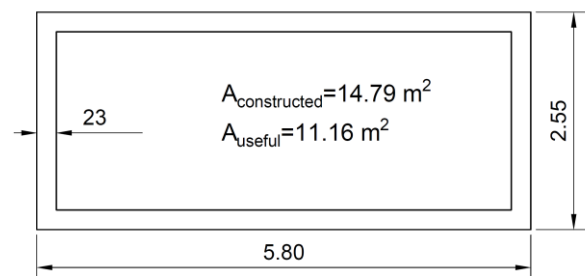
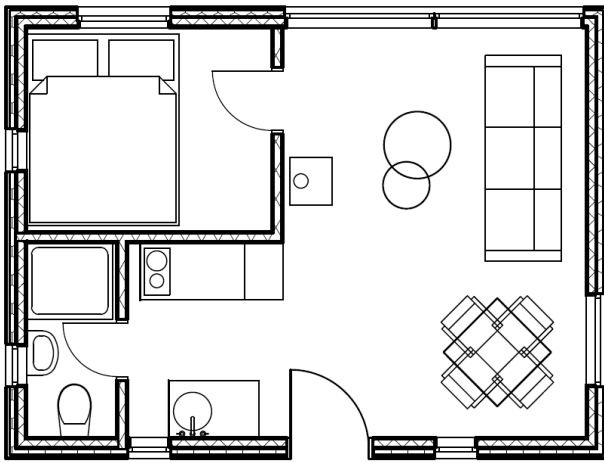


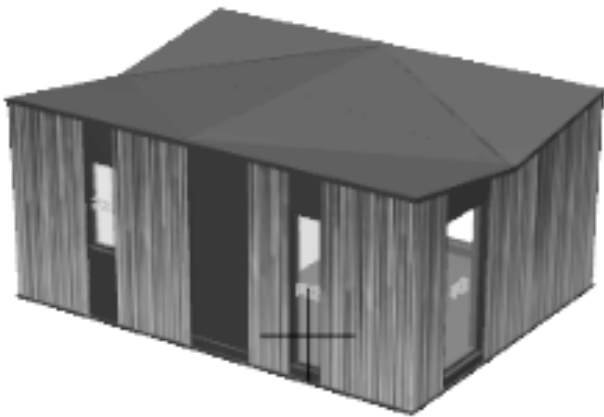
Fig. 1 Dimensioned floor plan of a module.

Using a single module is possible but has limited destinations. For example, it is suitable, for construction sites organization, for a cottage placed in a garden or for temporary used buildings. It can be a solution for modern camping lovers [6].

Figure 2 shows a version of the construction with two modules, respectively the floor plan in Figure 2a and the three-dimensional representation in Figure 2b. By partitioning, rooms with the following destinations were provided: living room, bedroom, kitchen and bathroom.



a. Floor plan



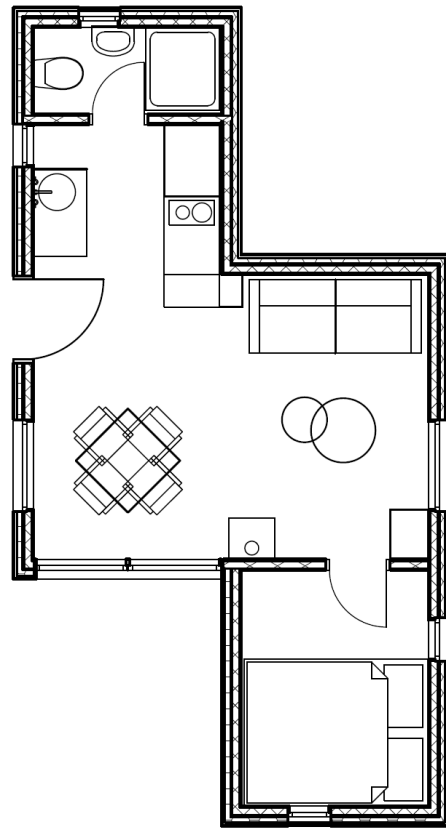
b. 3D representation

Fig. 2 Two modules construction – Version 1.

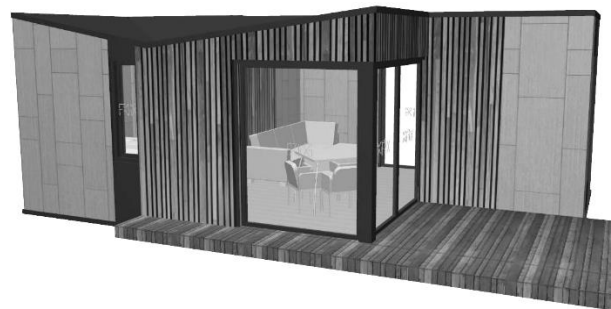
Similarly, Figure 3 shows another way of assembling two modules resulting from their staggering. It results in this way, a different design that makes it easy to install a sheltered terrace. As can be seen in the floor plan from Figure 3a, the space destinations are the same as in the previous version. For a better view of the assembly, Figures 3b and 3c give the 3D representations of the construction from different angles.

By assembling three modules, the partitioning possibilities increase. One can choose for a more spacious living room, a separate kitchen or an extra bedroom.

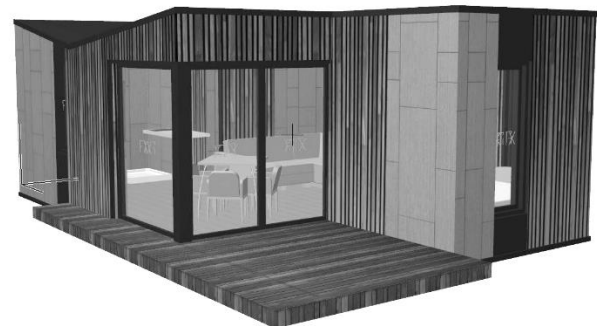
Figure 4 shows a plan consisting of three modules composed by joining them on the long side. The result is a more spacious living room and a second bedroom. Figure 4b shows the 3D representation of the house.



a. Floor plan

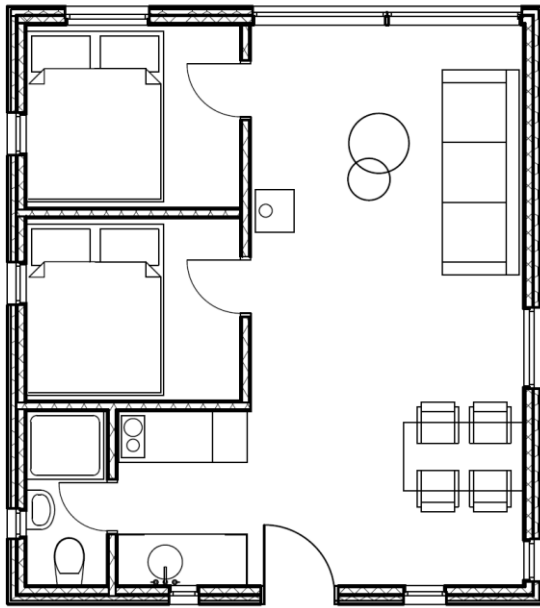


b. 3D representation [5]

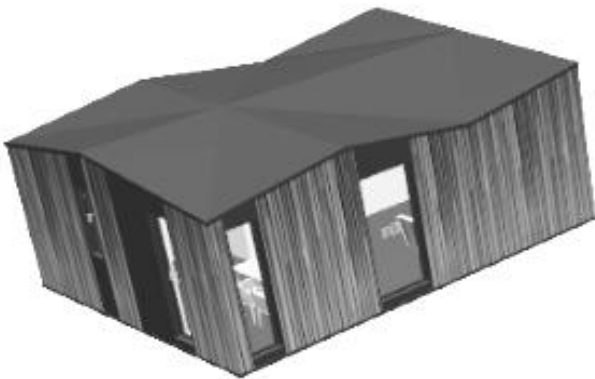


c. 3D representation [5]

Fig. 3 Two modules construction – Version 2.



a. Floor plan



b. 3D representation

Fig. 4 Three modules construction.

The construction of the modules takes place in an industrial hall organized to follow the next technological flow:

Storage of materials → Cutting of metal bares → Anticorrosive painting → Welding metal structure → Cutting of wood bars → Treatment of wood material → Assembling of bearing structure (fixing of wooden bars through bolts/metallic screws) → Construction of exterior walls → Construction of interior walls → Cutting gaps for windows and doors → Building the roof → Plating the facades → Installing windows and doors → Interior decoration and finishing works → Storing the Module for Transport.

The factory must be organized to allow a natural flow of materials, energy and/or information and should consider the proposed objectives [1].

Figure 5 represents a print screen of the load-bearing structure for the modular construction shown in Figure 3. As one can observe it consists of steel and wooden bars having the cross-sections of 50x100 mm.

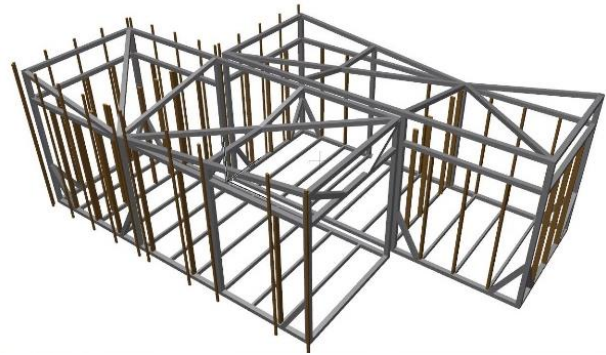


Fig. 6 The load-bearing structure for a modular construction.

Special attention was paid to solving the envelope and other execution details of the construction elements, necessary to ensure comfort in the habitat area. For example, in Figures 6 and 7 are presented the structure of the external walls, that are plated with wooden sidings – see Figure 6, respectively with metal panels – Figure 7. The support wooden bars used to fasten various elements have the cross section 60 x 40 mm. It was chosen to combine these two types of facades for aesthetic reasons. Also, one may use other types of exterior finishes, such as architectural fiber-cement panels.

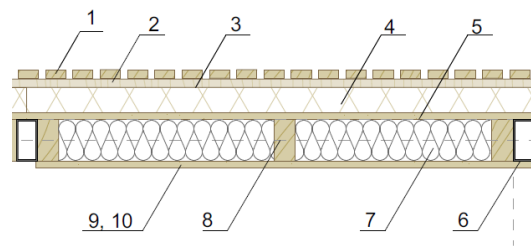


Fig. 6 External wall structure - wood paneling: 1- Thermo-treated wood siding, 2- Anti-condensation sheet, 3- Support batten, 4- Rigid thermal insulation - polyurethane foam 60mm, 5- Chipboard, 6- Metal structure, 7- Rockwool thermal insulation 100mm, 8- Wooden structure, 9 – Vapor barrier membrane, 10-Gypsum wall board.

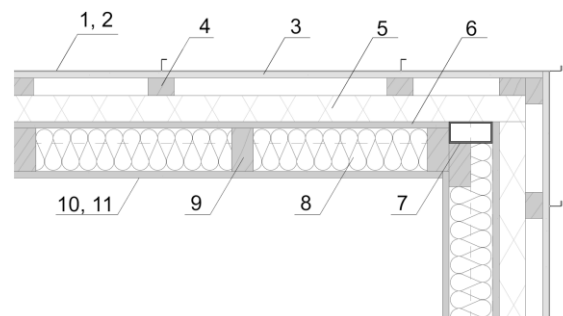


Fig. 7 External wall structure – metal panels paneling: 1- Metal panels, 2- Anti-condensation sheet, 3- Support chipboard; 4- Ventilation batten, 5-Rigid thermal insulation - polyurethane foam 60 mm, 6- Chipboard, 7-Metal structure, 8- Rockwool thermal insulation 100mm, 9- Wooden structure, 10 – Vapor barrier membrane, 11-Gypsum wall board.

As one can observe in Figures 1, 6 and 7, a small thickness of the outer walls resulted, which is advantageous from several points of view:

- efficient use of space;
- low construction weight;
- easy handling during transport.

The reduced wall thickness is possible due to the combination of polyurethane foam and rockwool thermal insulation layers that provide a high specific heat resistance respectively a low thermal transfer coefficient, which is in agreement with the thermo-energetical policy regarding the envelope insulation of buildings.

For transportation, a system that allows the crane to load and unload the modules was designed.

Another challenge is the technology of connecting the modules, which takes place in situ, so that results a compact and stable structure. It can be observed in Figures 2, 3 and 4 that by joining the modules one proposes to obtain generally roofs with equal slopes. Small angles were used, respectively 7° , in accordance with the minimalist style of the modern architecture. Joining the slopes is done after ridges, rafters or valleys, to ensure both the collection of precipitations and a simple and pleasant design.

In order for the beneficiaries of these houses to be convinced that the surface resulting from the combination of the modules allows an adequate endowment, the interior designers who have worked on this project have proposed to the customers solutions for the layout of the furniture, which denotes taste and refinement. Figure 8 shows the interior design of a part of the house presented in Figure 3, namely the living room and the kitchen area. The proposed furniture is also modular type, allowing the assembly according to the needs and functions [2].



Fig. 8 Example of interior design

The ultimate goal is to obtain constructions that meet the quality requirements of Law no. 10/1995, modified by Law no. 123/2007 and which refers to: mechanical and stability resistance, fire safety, operational safety, hygiene and health protection, noise protection, energy saving with respect to the thermal insulation of the envelope, durability and easy maintenance [4]. Also, these constructions should integrate perfectly with the environment, without having any negative effects on it.

3. CONCLUSIONS

Modular constructions represent an efficient and economical alternative to build, in which the beneficiary of the work can have the certainty of a quality construction, carried out in conditions optimized by specialists in the field, at a price agreed by both sides, without further adjustments.

These constructions respect the new concepts of sustainable development using ecological building materials (such as wood) or recyclable materials (eg metal, rockwool).

Finally, are synthesized the main advantages of this way to build, as follows:

- High productivity;
- Efficiency, respectively reducing the execution time;
- Use of materials that satisfy the present codes and standards, which provides safety both to the construction and to the residents;
- Proper management of materials;
- Affordable price.

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