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Procedures and Methodologies to Assembly and Mounting the constructive system called “Panel for Building”

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Highlights

The focus of the research is to engineer a new constructive system called “Panel for Building”. The new system is based on a load-bearing panel like the xlam technology, but in this case, the structural section consists in a steel frame. Other layers of the system help improve overall performance. Panel for Building allows house with high-energy performance at low cost, and high assembling speed in the factory and on site. This new constructive system can be used for the construction of residential and tertiary buildings with excellent energy performance.

Abstract

The paper describes the progress of the research that was introduced in a previous article titled “Panel for Building: a new typology of platform frame”. In this phase of the research, the goal is to define the best technological solution for the assembly of the individual layers of the panel, concentrating in particular on the structural section. In parallel with the previous objective, the research analyzes the construction of Panel for Building on site, with reference to the foundation node and the connections between the panels.

Keywords

Panel for Building, Mounting, Assembly, Steel frame

1. INTRODUCTION

The following contribution describes the developments in the Panel for Building research, focusing on the panel manufacturing and mounting ergonomic aspects.

The aim is to identify the best process for assembling individual layers of the panels in the production phase and to define the connection systems to be used during site mounting.

The analysis of the connection systems is a fundamental step in the design of dry constructions.

To build homes with prefabricated panels, the connections must be dimensioned with more accuracy to ensure uniform structural behavior (“box” structural behavior) [1].
The study and design of the assembling and assembly system starts with the definition of panel composition [2,3,4]. The system analyzed in the previous phase of the research has allowed obtaining an integrated system, which carries both the structural and the involute role. In this way, you can quickly locate the stratigraphy, the individual components that play the different roles. In detail, the panel can be divided into three sections: a structural section, external counterwall and internal counterwall.

The structural section represents the core of the panel, in fact, is disposed in central position with respect to the two other section. Its primary function is to resist the vertical loads and the horizontal stresses acting on the building, with a structural scheme defined in load-bearing panels. From the first analysis, considering a Single Family building with two floors in a low seismicity zone, has been defined a frame width of 256 mm. The steel frame is composed of two main elements: vertical uprights and horizontal guides. The uprights are U profiles with a width of 250 mm and thickness of 3 mm, and they can have a different wing length (50 or 90 mm) depending on the position inside the panel. These are normally disposed at a distance of 60 cm from each other, except at special points (presence of openings, intersections of walls) where they can be placed at shorter distance. A particularity of the uprights is the presence of a series of holes made on the core of the profile, which allow reducing the transmittance of about 20% with respect to a full section profile. This feature is indispensable for improving the global behavior of the panel from the thermal point of view.

The guide is made with the same type of upright profile, but with a core width of 256 mm and a wing height of 90 mm. The guides are two one upper and one lower, in such a way as to enclose the uprights and create a single frame. From the structural point of view the uprights transfer the vertical loads, while the guides ensure a homogeneous distribution of the stress over that a homogeneous behavior of all the individual uprights.

The structural section is completed by two plaster fiber plates with a thickness of 18 mm that are applied on the two sides of the steel frame acting as braces. The thickness was determined by considering the actions (wind and earthquake) that can act on a building such as that described previously. The function of the plates has to react to horizontal forces, transferring the shear stresses to the foundation. To improve further the thermal behavior of the panel has been inserted between uprights an mineral wool insulating layer with a thickness of 250 mm with two different densities, to improve also the
acoustic behavior.

The external counterwall has the function of isolating the panel and subsequently the building, it creates an external coat and a different surface of finish from that of the structural section, that protecting it from the weather. It consists of three elements: wood autoclaved strips with square section 50x50 mm anchored to the plaster fiber panel; wood fiber insulating layer with a thickness of 50 mm interposed between the strips; cement-based plate with a thickness of 12.5 mm anchored to the strip to close the external counterwall. The internal counterwall has two functions: it creates a space plant and increase the overall wall insulation. It’s composed of four different elements: plasterboard sheet with brake steamed with 12.7 mm thick anchored directly on the gypsum fiber slab; plasterboard steel profiles with C-section of width from 50 mm; mineral wool insulation panel with a thickness of 50 mm inserted between the steel profiles; two plasterboard plates of high density each with a thickness of 12.5 mm anchored to steel profiles. The double slab creates a robust and resistant inner surface, as well as attenuate the transmission of sound and improving the overall comfort.

3. ASSEMBLY TECHNOLOGY

After the definition of the stratigraphy of the panel, the research has focused on the definition of the individual components assembly technology. The goal is to define what the machinery, the equipment and which steps are required to get the Panel for Building in its final configuration, in order to obtain in a
simple and fast-standardized assembly process [5,6,7,8].

3.1. ANALYSIS OF ASSEMBLY SYSTEMS

The first step to define the best procedures for the assembly is to study what technologies are used to realize similar structures. The technology more similar to the subject of the research system is the “Steel Frame” construction. The buildings are made of bearing steel frames composed of uprights, guides, horizontal brackets for the control of the instability and traditional systems of upwind to react to horizontal stress. The frames are assembled in the factory through the manual joining of the individual profiles by means of connecting plates or rivets by different operators, or using a computerized process and mechanical robots.

Subsequently the panels are loaded on a truck and transported to the site where they are mounted directly in the final position. The individual profiles are placed on large works tables where two operators positioned at opposite sides of the panel connect the ends of profiles to the guide. In this process is advantageous lightness of the frame that allows easy movement, in contrast to the numerous works to finish the panels on the construction site that require high time of completion of the building.

Another technology less similar to materials used but more in line compared to the final product is the “Platform frame” construction. The buildings are made with load-bearing walls formed by a wooden frame made up of uprights and guides completed by wood-based plates or plaster fiber plates. This type of panel is very similar to the stratigraphy analyzed in the research system, as it contains both a structural section that insulation elements. In the wooden construction sector, there are different companies that produce this kind of...
panels, in particular in Austria, Germany and Switzerland. The production of the panel in this case is more complex because the number of elements to be assembly is greater than the steel frame constructions. During the research, we have examined different production processes that can be more or less steps depending on the size of the company. In general, we can identify five stages:

- **Phase 1**: assembly wooden frame;
- **Phase 2**: assembly of the brace plate on a wooden frame side and overturning of the panel;
- **Phase 3**: insertion of the insulating layer between the wooden profiles;
- **Phase 4**: assembly of the brace plate on the second side of the frame;
- **Phase 5**: the panel is covered with waterproof protection and storage.

A To the previously listed steps it is possible to initially add a stage of production and cutting of the individual profiles which form the frame, while at the end of the process it is possible to add a step of installation of another plasterboard sheet and on the side of an insulating layer on ‘other side. Additional finishes can also be realized in the factory such as the laying of plaster on both sides of the panel and the insertion of the doors and window within the openings previously achieved. When the panel is completed is loaded with automated systems directly on the truck and covered with waterproof sheeting until it arrives at the construction site, where it is directly assembled in their final position without further storage. In this case, the production process is articulated but it consists of simple operations; the result is then a panel that does not need further working on site.

Figure 3. Example of process to production the platform frame panel.
4. MOUNTING TECHNOLOGY

The panel production process has to be analyzed considering the subsequent installation phase on site. The choice of such components should be assembled in the factory is a function of the techniques and systems used for the mounting of the building. The research has focused on the definition of the assembly procedure, and then on the study of mounting systems, which best can adapt to this type of panel [9,10,11, 12].

4.1. ANALYSIS OF MOUNTING SYSTEMS

In the first analysis, we have observed the dry building technologies and studied which are the elements that are used to make the different connections.

They studied the connection systems of the steel frame, which in this case are not applicable. In fact, the connection between the panel and the foundation is made with screws, which clamp the guide below the base beam. In the alternative solution, the structure is a closed wall not accessible, and then the lower guide cannot be connected directly to the foundation.

Analyzing the constructive system platform frame and that Xlam was possible to identify different types of connections that could be adopted for mounting the Panel for Building. Traditionally the mounting of this type of panel is obtained using connecting plates that are able to resist the shear or tensile stress, according to their geometry.

This type of plates, of L shape, is used for the connection between the panel and the foundation. Plates are positioned along the perimeter on both sides and are fixed with screws on the one hand to the panel and the other to the foundation. Usually the panel is not placed directly on the foundation, but is placed in an intermediate wood element defined “root or dormant” which has the function to create a basis for a more uniform support. The major disadvantage of this type of connection are the numerous screws necessary to ensure the connection.

Another technology that partially solve this problem is the “Alufoot” system, which replaces the wooden root with a box-section aluminum, which presents a groove on the edges where to insert the connecting plates. The box is anchored to the foundation with bolts; the panel is then placed at the top and anchored by means of plates, which in this case are linear. The number of screws used is reduced, but not significantly. The aluminum box ensures a good seal to water but increases the heat transmission wall.

The connection between the walls and between walls and floor is made with linear connection plates that connect the two elements, avoiding that there are e coperto con teli antipioggia fino ad arrivare in cantiere, dove viene direttamente montato nella posizione definitiva senza ulteriori stoccaggi. In questo caso il processo di produzione risulta articolato ma composto da operazioni semplici, e il risultato finale è un pannello che non ha bisogno di ulteriori lavorazioni in cantiere.

4. TECNOLOGIA DI MONTAGGIO

Il processo di produzione del pannello deve essere analizzato considerando la fase successiva di montaggio in cantiere. La scelta di quali componenti devono essere assemblati in stabilimento è funzione delle tecniche di connessione e dei sistemi utilizzati per il montaggio dell’abitazione. La ricerca si è concentrata sulla definizione della procedura di montaggio del pannello [9,10,11, 12].

4.1. ANALISI DEI SISTEMI DI MONTAGGIO

In prima analisi sono state osservate le tecnologie di costruzione a secco, studiando quali sono gli elementi che vengono utilizzati per realizzare le differenti connessioni. Si sono studiati i sistemi di connessione dello steel frame, che risultano poco applicabili. Infatti il collegamento tra pannello e fondazione è realizzato con viti che servono la guida inferiore alla traverse di base. Nella soluzione alternativa, la struttura è una parete chiusa non accessibile, quindi la guida inferiore non può essere connessa direttamente alla fondazione.

Analizzando il sistema costruttivo platform frame e quello Xlam è stato possibile individuare diverse tipologie di connessioni che potrebbero essere adottate per il montaggio del Pannello per l’Edilizia. Tradizionalmente il montaggio di questo tipo di pannello avviene mediante l’utilizzo di piastre di connessione che sono in grado di resistere alle sollecitazioni di taglio o di trazione, in funzione della loro geometria. Questo tipo di piastre (di forma ad L) viene utilizzato per il collegamento tra pannello e fondazione, vengono disposte lungo il perimetro da entrambi i lati e sono ancorate per mezzo di viti da un lato al pannello e dall’altro alla fondazione. Usualmente il pannello non poggia direttamente sulla platea, ma viene collocato un elemento intermedio in legno definito “radice o dormiente” che ha la funzione di creare una base di appoggio più uniforme. Lo svantaggio maggiore di questo tipo di connessione sono le numerose viti necessarie per garantire il collegamento.

Un’altra tecnologia che parzialmente risolve questo problema è il sistema “Alufoot”, che sostituisce la radice in legno con una sezione scatolare in alluminio, la quale presenta sui bordi una scanalatura dove inserire le piastre di collegamento. La scatolare viene vincolata alla platea per mezzo di viti, successivamente viene poggiato il pannello superioremente e ancorato tramite piastre che in questo caso sono lineari. Il numero di viti utilizzato risulta inferiore ma non in maniera considerevole. Lo scatolare in alluminio garantisce una
differentiated movements between the individual elements, transferring the efforts agents from the cover to the foundation in a linear way. Even in this type of connection, the number of screws is considerable, in particular in the case of complex and articulated geometries.

Another newly developed technology is the possibility to connect only the corners of the panel, thus reducing to a single point connection and consequently the number of screws to be used. This type of system is ideally applied to the structures in Xlam, as they have a uniform behavior and a better distribution of stresses within the panel. The connection called “X-rad” is composed of a steel sheet folded with inside a wooden element. This is constrained by means of screws on a corner of the panel and can be used for the transport and the movement of the panel. Once in position the panel is connected to the base plate or to another panel by means of two screws, which are inserted into the holes in the upper part of the steel sheet.

The potential of this type of connection are many because it reduces the number of connection and the number of screws to be inserted, reduces the critical points from the structural and thermal point of view.

5. RESULTS

5.1. ASSEMBLY PROCEDURE

According to the analysis done on the production technologies of the panels it has been possible to define a suitable production process than the goals set forth in the initial phase. In particular, it is planned:

- Phase 1: assembling steel frame with connection plates. The profiles are cut previously;
- Phase 2: assembly of plaster fiber plate on a side of the frame;
- Phase 3: external counterwall assembly (wooden sleepers, wood fiber insulating layer, cement slab) and overturning the panel;
- Phase 4: mineral wool insulation insertion within the structural frame;
- Phase 5: assembly of plaster fiber sheet on the second side of the frame;
• Phase 6: internal counterwall assembly (gypsum plasterboard with steam brake, steel profiles and eventual plants, mineral fiber insulating layer, high density plasterboard sheets);
• Phase 7: storage of the panel and preparation for transport.

5.2. INSTALLING PROCEDURE

The connection between the panel and the foundation has been designed according to traditional mounting systems platform frame structures (fig. 6). Especially after realizing the foundation, it was laid an autoclaved wooden root linked by anchor screws. Above root is placed the panel that is connected with cut and traction L-plates to the dormant and to the foundation. In this way, it is ensured the correct transfer of forces from the panel to the foundation.

The connection between panel and floor slab has been designed using linear and angular connecting plates (fig. 7). On the bottom panel is positioned a wooden slab linked to the top guide of the panel. On the slab they are placed a continuous beam along the entire perimeter of the building (which allows to better distribute loads from the upper floors), and the steel profiles supporting the wooden floor 50 mm thick bound by screws to the beam. The floor wood is placed on the edge beam creating a structural continuity between the two elements (wall-floor). Finally, the top panel is positioned at the node between the floor and lower wall. This is connected internally in two ways: with traction angular to the lower panel by means of a through screw in the floor, while with cutting angular to the floor slab. Externally the top panel, the lower panel and the beam are connected by a series of steel plates.

![Figure 5. Detail of foundation node - Detail of floor node.](image)
The designed connection allows obtaining an efficient transmission of forces from the higher floors to the foundation, also the insertion of a wooden element reduces the generation of thermal bridges in the wall.

The connection between the two corner panels is designed by inserting a wooden element at the ends to one of the panels. In this way, through a series of linear external and inner corner plates it is possible to connect the two panels.

To increase the resistance near of the connection the distance between the profiles of the structural section to 30 cm has been reduced, to increase the air of action of the forces.

The design of the nodes needed for the assembly of the panels gives rise to some considerations as regards the definition of the panel assembly procedure. The connections are made on the structural section of the panel, which is located in a central position, for this reason it is not possible to install in the production phase of a portion of inner and outer counterwall. This involves that will be necessary to make completion works on site, which are however lower than those of the technology steel frame or of a traditional construction.

In order to validate the feasibility of the procedure adopted, a theoretical study was carried out on a real case application. In particular, the construction of a series of terraced villas was studied using the constructive system Panel for Building [13]. The first step was to subdivide the envelope of the building into panels by creating an abacus to which a series of technical sheets associated.

\[ h \text{ [mm]} \quad \text{Tolleranza [mm]} \quad l \text{ [mm]} \quad \text{Tolleranza [mm]} \quad s \text{ [mm]} \quad \text{Tolleranza [mm]} \quad \text{Peso kg]}
\]

\[
\begin{array}{cccccccc}
2850 & +1 & -1 & 7205 & +1 & -1 & 286 & +1 & -1 \\
2614,22 & & & & & & & & \\
\end{array}
\]
Subsequently, assembly procedures were applied to determine the construction process of the residences. A sequence of activities has been defined: installation of the base beam (dormant), panel mounting, edge beam mounting, floor mounting, second floor mounting, edge beam mounting, floor mounting, mounting cover beam and finally mounting the cover.

The aim of this study was to analyze from the technical and temporal point of view the procedures adopted were correct.

The theoretical simulation applied to a real case validated the system adopted for construction. It has been verified that the procedures adopted ensure a high degree of realization and a period of completion of the minor work, with a substantial reduction in the activities carried out on site.

6. FUTURE DEVELOPMENTS

Future research will have as objective to validate design choices, through structural laboratory tests that verify the resistance to the stresses of the configured nodes and the correct behavior of the panel, avoiding brittle failures or unexpected failures.

7. REFERENCES


