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THE "SUSTAINABLE CONDOMINIUM", A SIX STOREY TIMBER BUILDING IN FLORENCE

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ABSTRACT: Following the sustainability policies of the Regional Council of Tuscany, Casa SPA a public company located in Florence which is in charge of designing, constructing and maintaining the social housing real estate of the whole Florentine area, started a project which will lead to the construction in a central area of Florence of three multi-storey buildings, one of which is a six storey building, which will be entirely constructed using timber load bearing structures with the cross-laminated panel system.

Particularly, the six storey building, which will be totally constructed with timber cross-laminated panels as bearing structures, including walls, floors, and all stair and lift cores, will be the first pioneer construction of such a tall residential timber building in a seismic area in Italy.

In this paper the details of the project are presented, focusing particularly on the architectural, structural and sustainability issues. The construction will start in summer 2010.

KEYWORDS: Cross laminated timber, multi-storey buildings, social housing.

1 INTRODUCTION

Casa SPA, a public company owned by the city of Florence and by other 33 surrounding smaller cities which is in charge of designing, constructing and maintaining the social housing real estate of the whole Florentine area, started a project which will lead to the construction of three multi-storey buildings, two of which, respectively 4 and 6 storey, are residential, with a total living space of 3200 square meters and 45 living units, and a third two-storey building of 600 square meters which will include a public recreation center for children and a center for services to the citizens. The three buildings will be constructed in the Ex Longinotti area, along Viale Giannotti, close to the river Arno in Florence.

Being the project half funded by the Italian Ministry of Construction according to a special law for social housing aimed also to foster the construction of energy-efficient and sustainable buildings and following the sustainability policies of the Tuscany Region, an innovative and sustainable construction system has been chosen: the cross-laminated timber system.

Particularly, the six storey building will be totally constructed with timber cross-laminated panels as bearing structures, including walls, floors, and all stair and lift cores. The final aspect of the building will be that of a modern architecture, with an exterior cladding made with wood-cement panels and plaster, perfectly integrated in the surrounding city area. It will be the first pioneer construction of such a tall residential timber building in a big city in Italy.

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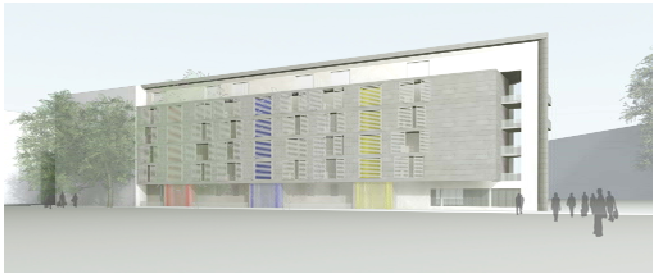

Figure 1: *Perspective rendering view of the six storey timber building to be constructed in Florence*

2 BUILDING DESCRIPTION

For the six storey building the construction will be made with:

- reinforced concrete foundation and basement floor;
- a six storey structure entirely constructed in timber (including walls, inter-storey floors and roof, stairs and lift cores) with steel connections;
- traditional finishing with plaster and exterior cladding in wood-cement panels, gypsum wall board interior wall cladding, ceramic tiles flooring and gypsum ceiling.

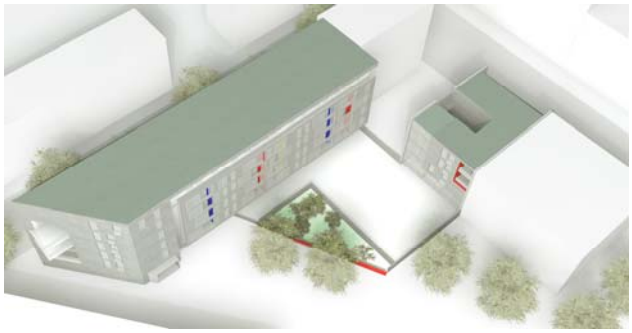

Figure 2: *Perspective rendering view of the six and four storey building*

The building shape will be that of a modern architecture, with a special care for architectural features and perfectly integrated in the surrounding urban context. The exterior cladding (plaster and ventilated wood-cement cladding) will cover the wooden structures, which will be left uncladded, as a witness of the wooden skeleton of the building, only in the inside front-office at the ground floor, behind a glass cover.
This building, originally conceived in reinforced concrete, will be the first example of such a tall multi-storey construction being built entirely in timber in a seismic zone in Italy, and the first experience with such construction system for CASA Spa, whose previous experience was with reinforced concrete and masonry buildings. Keeping the same level of safety and thermo-acoustical performance of previous experiences, the expected advantages are significant:

- construction speed greatly increased, thanks to the almost completely dry construction process;
- less environmental impact, in terms of CO_2 emissions, energy consumption, and use of raw materials.

The first aspect will have a fundamental importance in order to make a comparative evaluation of construction costs in comparison with traditional construction in Italy. The reduction of construction times is in fact a primary goal of many public and private constructors, which already, for the case of timber construction, enable significant savings in financial terms leading to low construction costs.

The project have been completed, taking into account the experimental feature of the whole construction, according to severe and ambitious requirements, far over the minimal standards requirements, with particular reference to the fire and seismic safety, the energy efficiency and the acoustical insulation.

3 ARCHITECTURAL DESIGN

The three buildings will be constructed in a highly urbanized and populated area, of the nearby surroundings of the centre of Florence, close to the Arno river, which have been subjected to some restoring interventions in the last years.
The design procedure, being the building originally conceived with a RC frame structure with tile brick partitions, required an ongoing process of adjustment of the bearing wall cross-laminated structural system to the flexibility issues imposed by the original frame structures.
The same flexibility, which was reached through the use in some cases of short width walls and steel and glulam beams in order to support floor panels, with the location of main walls between the living units and along the common corridors and the outer walls, enabled the almost free composition of the internal space of each living unit and of most of the external facades.

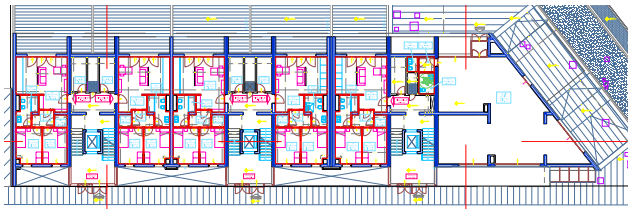

Figure 3: *First storey plan of the six storey building*

Each living unit, whose dimension have been determined according to the local urbanistic rules for social housing, was designed according to two different typologies of houses, meeting the experimental requirements of the Ministerial special Law for social housing conceived to foster the integration between different social categories.

The external facades covering will be a mix of traditional and modern materials, i.e. plaster and grey coloured wood-cement panels, with the grey panel covered box represented by the 2nd to 5th storey structure coming out on two opposite sides from the white plaster covered box of the 1st and 6th storey, as can be seen in ***Figure 1***.

4 ACOUSTIC AND THERMAL PERFORMANCE

The acoustic and thermal performance of the building have been, since the first stages of the design, one of the key issues of the design.
Particularly the acoustic behavior of each building component have been carefully studied, being the lightness of the structural material a weak point for timber structures in comparison to other heavier building materials like concrete or masonry. However the higher density, compared to other structural timber construction systems, of the cross-laminated walls and floors, coupled with an accurate layering strategy and an accurate detailing, e.g. the use of high density insulating materials, double walls with gaps in between filled with insulation and the use of rubber separating layers for floating floors, made possible the satisfaction of the code requirements both for the air sound transmission and for the impact noise for floors.

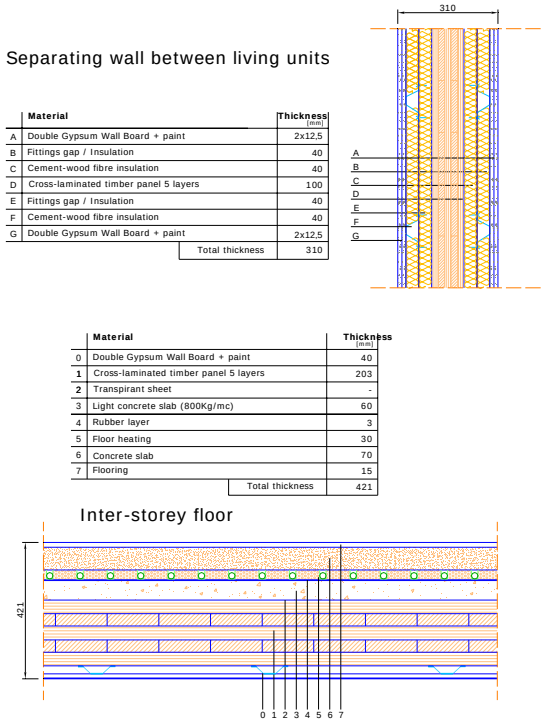

Figure 4: *Detail of the separating wall between living units and of the inter-storey floor.*

As for the thermal properties the code requirements were easily met far beyond the minimum values through the use of natural insulating materials like wood-fibre insulating panels and cement-wood fibre panels. As moisture is one of the most important agents leading to the deterioration of timber structures, the absence of condensation due to the vapor transmission was carefully checked by means of Glaser charts. Moreover the use of ventilated cladding for most of the exterior wall will assure, in case of moisture problems due to eventual leakages in the exterior cladding the possibility of drying through air flowing.

5 STRUCTURAL DESIGN AND SEISMIC SAFETY

The seismic safety of the building have been, since the first stages of the design, predominant above all the other aspects, far before the tragic occurrence of the earthquake in L'Aquila in 2009.
The challenge have been triple. Up to now there is no evidence to the authors of such a tall cross-laminated timber building built in seismic areas all over the world. Secondly, being the building originally conceived in reinforced concrete with complicate structural features (the 2nd to 5th storey core of the building overhang the 1st storey on two opposite sides), the design process have been really demanding.
Last but not least, the actual lack of design rules referred to the cross-laminated construction system both in Italian and European Standards, required a higher effort in the design stage in order to find and explain the design choices and the calculation methods adopted in order to fully meet the safety requirements foreseen by the current building laws.
The structural system chosen for the construction is a new system, which, in spite of his relatively new diffusion, is already nowadays the most used for the construction of multi-storey timber buildings in Europe (in 2008 a nine storey cross-laminated timber building have been constructed in Murray Grove, London, which is not a seismic area). As it is witnessed by the results of recent experimental researches on full scale multi-storey buildings made by Italian and Japanese researchers, to the natural features of lightness, strength and flexibility of other timber construction systems, the cross-laminated timber system join an excellent level of ductility, capacity of dissipation of energy and safety against seismic actions.

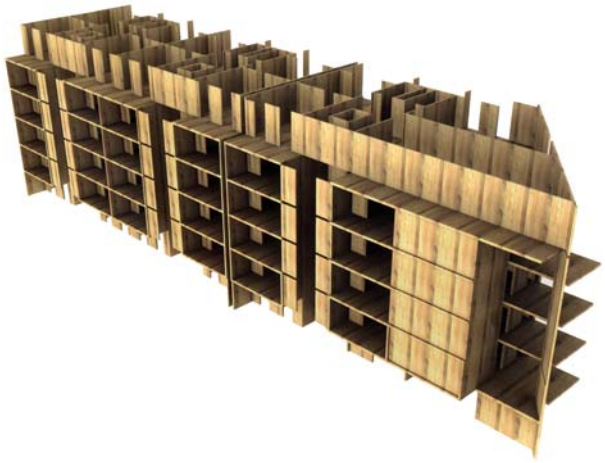

Figure 5: *Perspective rendering view of the timber cross-laminated structure of the six storey building*

Right in order to increase the global level of ductility of the whole building, it has been foreseen to build most of the bearing walls by means of short width panels connected together with vertical joints made with multi-layer timber stripes and mechanical connections like screws or nails. This solution, differently from the construction of the wall as a unique element already produced with holes for windows and doors, enable a

better seismic behaviour of the building and a greater ease and speed during the transportations and construction of the building.

The features of non regularity of the building made necessary for the structural design a linear dynamic analysis with a finite element program. The building have been first pre-designed by means of a linear static analysis, assuming, as a first hypothesis and in lack of the results of a modal analysis in order to evaluate the natural period, the maximum ordinate of the design spectrum defined by the Italian Building Code (Norme Tecniche per le Costructioni, 2008) for the reference seismic area. The preliminary linear static design made possible a first dimensioning of the structural elements and of the mechanical connections. In the lack of references in the code for this structural system, the value of the behavior factor q has been taken from the results of experimental researches recently carried out in Italy published in several reports.

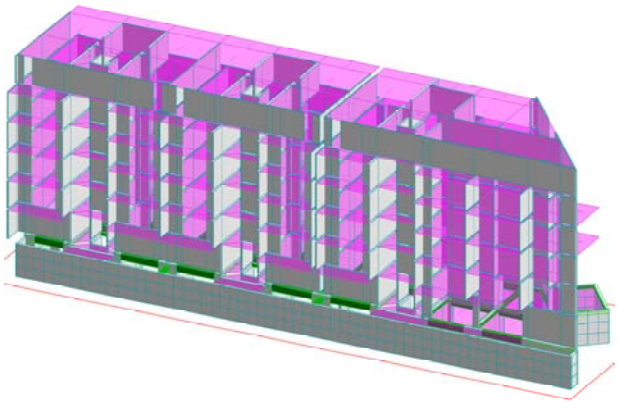

Figure 6: *Dynamic model of the building*

The results of the pre-design have been used to build the finite element model of the building for the dynamic analysis. Taking into account the importance of such a construction, three different models have been created and analyzed with three different finite element programs. The buildings have been modeled including all the walls schematized as shell elements and all the connections with their strength and stiffness properties schematized through link elements. The seismic loading have been calculated considering the building as a Class IV building (having probabilities of exceedance 10%, in 100 years which represents earthquakes with a 949 years return period) according to Italian DM 14/01/2008, i.e. buildings with relevant strategic functions instead of the Class II (having probabilities of exceedance 10%, in 50 years which represents earthquakes with a 475 years return period) which is the Class used for dwelling houses, therefore choosing a more severe design condition.

6 SUSTAINIBILITY AND USE OF LOCAL RESOURCES

The sustainability of wood as a building material it's very easy to demonstrate: it's a renewable and recyclable material, with low energy consumption during the production and construction stages and with the total absence of unhealthy substances or emissions. Each cubic meter of wood used in the construction of a building save the emission in the atmosphere of 2 tons of CO_2. The sustainability levels reached with the construction of the three buildings in terms of CO_2 and other greenhouse gasses and of energy savings will be assessed through a Life Cycle Analysis made with a software developed with funded partly by the Tuscany Region.
Within the frame of a research activity aimed at the development of the local forest-timber chain, a pilot plant is being assembled to produce the structural components of this building, using timber from Tuscan forests. The species used will be locally-grown douglas fir, white fir and pine. Using local timber will reduce the energy consumption and emissions of the whole construction phase, increase the skill of local workmanship and foster collaboration between Tuscan enterprises which had good competences in carpentry in the past decades, now largely lost. The pilot plant includes tailor-made pressing and CNC machinery, gluing equipment and software tools. The structural panels will have CE marking and a high degree of prefabrication, including some pre-assembled fasteners, thermo-acoustic insulation and parts of the installations.

7 CONCLUSIONS.

The project have been completed and the construction will start in 2010. For the design the indications contained in the "Guidelines for sustainable construction" and the "Guidelines for timber buildings in Tuscany" recently published by the Regional Council of Tuscany ,which have also represented an useful support tool, have been fully met.
Being the construction, the first case of such a tall multi-storey timber building in Tuscany and in Italy, the construction process will be monitored and published as it is firm conviction of CasaSPA that the spread of knowledge and of technical information will increase the confidence of designers and common people towards timber structures, and therefore address the future development of the real estate market in the direction of the sustainability and of a fair use of the natural resources.

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