NEW TECHNOLOGY FOR THE PRESERVATION OF HISTORICAL BUILDINGS: CASE STUDY OF THE MAGNIFICA COMUNITÀ PALACE AT CAVALESE (TRENTINO – ITALY)

Rossano Albatici
University of Trento, Trento - Italy

UgoBraito
Engineer self-employee - Italy

Lorenzo Jurina
Politecnico di Milano, Milano - Italy

Marco Sontacchi
Engineer self-employee - Italy

ABSTRACT

It has always been an exacting work to plan an intervention regarding the restoration, the structural renovation and the new destination of use of a building having high historical and artistic values, whose realization involves many different designing and technical-scientific competencies.

In order to change the destination of use of a building, in fact, it is often necessary to deeply modify the distribution of the inner spaces and consequently to modify its functional organization. Besides, it is necessary to take into great account the building's historical and artistic values, and to plan a complex intervention in order to safeguard and at the same time to re-propose them in the renovated construction.

This paper deals with a case study: the restoration of the Palace of the Magnifica Comunità di Fiemme, an autonomous board collecting the inhabitants of the Fiemme Valley in the Trentino Region (Italy). The restoration plan regards the changing of the inner spaces organization and, in particular, the structural reinforcement of the wooden floors, whose intervention plan has been the most complex but in the meantime the most interesting and innovative. The floors of the Magnifica Comunità Palace, in fact, are made of wooden elements frames finished with planks (both adorned with beautiful paintings) whose bending and torsional strength is limited. In order to make the floor elements bearing the required heavier loads, the structural intervention of reinforcements has been planned so to assure also the safeguard of the historical-artistic values of the building. Different solutions have been adopted for each floor, using innovative technologies as the plugging of a new kind of connector inside the wooden elements without resins, the reinforcement of the beams by means of spatial steel structures, the strength of the ancient roofing trusses using special tens structures systems.

Introduction

The Palace of the “Magnifica Comunità di Fiemme” is placed in Cavalese, a little city in the eastern part of the Trentino Region (Italy) in the Fiemme Valley. It is the main seat of the Magnifica Comunità di Fiemme, an autonomous board collecting the inhabitants of the Valley, an institution that dates back to the twelfth century.

The restoration plan of the Palace, a building made of stone walls and wooden floors, most of which are entirely painted, concerned the changing of the inner spaces organization in order to place the Community administrative offices, the restoration of the ancient and precious paintings, the intervention on the existing system as required by the new national regulations, and the structural reinforcement which has been achieved through the reinforcement of the walls, of the foundation system and of the wooden floors.

The building is L shaped, and its main vertical structure is made of stone walls covered with plaster and mostly painted. The first problem to be faced is the pulverization of many parts of the mortar between the stones, so that the walls could not guarantee any more the vertical load capacity. Besides, since the walls are not perfectly perpendicular to the ground, the eccentricity of the floors loads and of other accidental horizontal load (like wind and earthquakes) produces a slow but continuous rotation around the foundation axes; this means that the walls are moving away one from the other and the wooden floors are not able to contrast this movement because they are not well connected to the walls themselves.

Besides, since the new planning of the inner spaces organization transforms some rooms of the building into archives, library, meeting and conference rooms, the values of both the permanent and the accidental loads are supposed to increase, so as the outer walls instability.

The planning of a large and complex structural intervention has become necessary, also because a restoration plan of an old structure requires the fulfilment of the new regulations based on new plant engineering, fire and structural safety, as well as the fulfilment of criteria about health and work safety (recently introduced also in the Italian law), and of the recommendations regarding human comfort in inner spaces that in the last years are becoming more and more important all over the world, especially in Europe and Italy. The building structure has consequently deeply changed in many ways, and there is the real risk that the needed structural interventions become too visible and invading, so to disturb if not even compromise the artistic value of the building (as important evidence of the past years, of the use of traditional materials and techniques, of the presence of frescos, paintings and so on).

As written above, the structural renovation regards:

- the sack stone foundations, whose consolidation will be made through the construction of auxiliary concrete girders connected to the existing foundation by means of steel tie-beams;
- the stone vaults of the basement, consolidated through the insertion of steel tie-beams;
- the walls, reinforced with high pressure injections of mortar and concrete in special holes till the complete rejection;
- the wooden horizontal structures.

In the following chapters the planned intervention will be described in detail, with particular reference to the wooden floors and to the realization of a proper connection with the walls in order to contrast the rotation movement.

The existing situation

The Palace of the Magnifica Comunità develops up to six floors (basement, ground floor, first, second and third floor, floor below the roof) and its building elements have maintained their original shape and structure during the time in spite of the few maintenance intervention realized. The floors are wooden frame structures. Wood was a material widely used in the past to realize this kind of structures, because of its good bending strength values also for great spans, and of its easy availability near the building site. Besides, the timber coming from the Fiemme Valley has always been of high quality, as certified through the Ecocertification F.S.C. from 1998, according to the Strasbourg and Helsinki international agreements.

All the horizontal structures are simple or double framed, covered with a simple or double plank floor and finished with a wooden, a cement or a Palladian floor. They are not well maintained, and in some parts they suffer for structural problems.

In particular, the first floor is mainly composed of a simple frame structure made of timber elements, often lower sized and reinforced (in order to prevent a structural collapse) by means of timber auxiliary joists. This level is, perhaps, the simpler to reinforce, because all the joists are rough elements, with no paintings or valuables historic-architectonic works and they are now covered with a double ceiling made of trellis work.

The elements of the second floor, instead, present a clearly visible state of decay, single collapse problems near the bearing of the walls and localized fungi's or biological attacks. Besides, some parts (in particular those of the south-east and north-west wings of the building) have visible beams painted and finely worked. The floor of the present Bishop's Room, instead, is a double frame floor made of wooden joists in various sizes laying on well preserved larch beams.
The third floor can be divided into two different parts. The first, corresponding to the Bishop's Room and to the adjacent rooms, is made of a secondary frame of visible painted wooden joists, and of a first frame of larch beams. The second has two timber beams, with no valuable works, covered with a double ceiling made of trellis work.

Finally, the floor below the roof is made of a first frame of wooden trusses with rafter, second rafter, chain, second chain and three king-posts, so to cover an average span of 12.5 metres and to realize a gable roof.

Methodology and description of the restoration plan

The main problems of the Palace of the Magnifica Comunità are the lack of a perfect perpendicularity of the walls to the ground, the eccentricity of the vertical loads (whose value will probably increase in the future after the intervention) and the subsequent rotation of the walls around the foundation axes towards the outside. To solve this problems, a solution in two step has been proposed:

1. reinforcement of the floors in order to realize an horizontal stiff membrane, able to bear the tensile stress due to the opening horizontal movement of the outer walls;
2. realization of a stiff joint between the floor and the wall, in order to guarantee an efficient connection of the two elements.

Generally, and where possible, the realization of a stiff membrane is made by laying a concrete slab 5 centimetres thick on the upper plank of the wooden floor, and connecting them by means of steel pins plunged into the joists with a hooked-shaped connection to the slab reinforcement. This methodology is not really new, but here an innovative variation has been applied. In fact, the steel pins are generally connected to the wooden elements by means of injections of epoxidic resins into the housing hole. In this case, since many joists of the Magnifica Palace are painted and finely worked, and in order to avoid, in the next future, that the resin could percolate outside ruining the paintings, an innovative technique has been applied, screwing the pins into the elements without using resins or auxiliary glues. An effective connection between the steel element and the wooden one is guarantee by the particular thread of the former (FIG.1).

Now, the concrete slab that stiffens the floor represents a simple overload. In order to make it working as part of the floor and so collaborating with the outer walls, it becomes necessary to connect it as stiffly as possible to the walls themselves. The connection has been achieved through three steps as follows:

a. reinforcement of the wall in correspondence of the external girders, by means of injection of mortar and concrete in special holes till the complete rejection, so to fill in any possible cavity between the stones, to substitute the damaged mortar and to guarantee an adequate connection of the stone elements;
b. connection between the concrete slab and the walls by means of steel bars (with a diameter of 20mm) positioned along the external girder with a constant step;
c. connection between the two walls positioned on the opposite sides of the same floor in order to contrast the opening movement, by means of double steel bars (with a diameter of 14mm) going from a wall to the other through the concrete slab, positioned along the perimeter of the floor and in the central parts of it, ending inside the wall with a unique inox steel bar (with a diameter of 20mm) positioned using epoxidic resins.

As already explained, this was the main method used where possible, i.e. where the outer parts of the floor have not valuable finishing that can be removed in order to lay the concrete slab, and where the joists have good strength values.

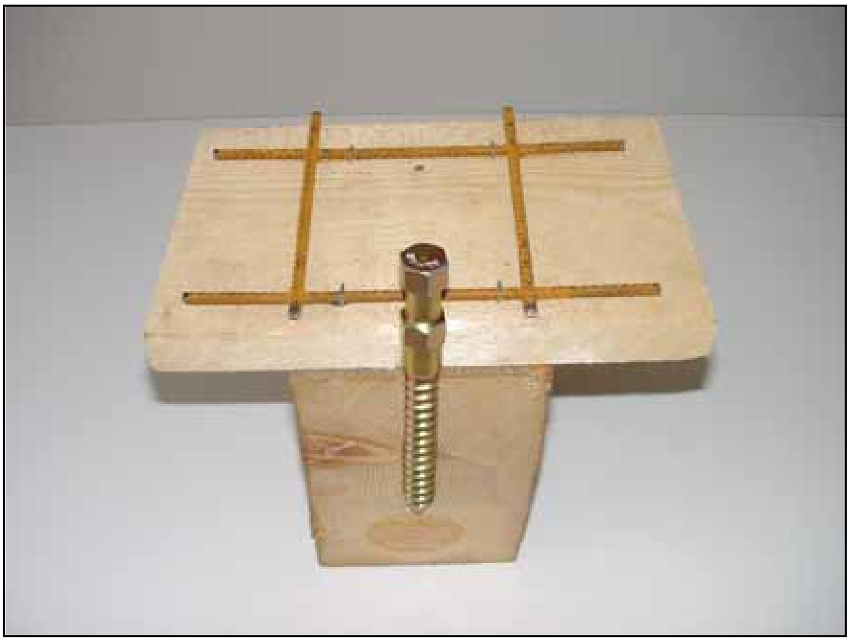

FIG.1: The particular steel pin screwed inside the wooden joists

In other parts, different methodologies have been planned from time to time, depending on the particular problems to be faced. In the following chapters, a general description is given floor by floor.

<u>First floor</u>

The finishing of part of the first level is a Palladian floor, i.e. the traditional floor made of concrete and marble in different sizes that can not be removed because of its historic value. So, since it is not possible to reinforce the floor from above with the usual method, it is necessary to plan an intervention from below. Besides, since the transversal section of the existing joists will not guarantee the structural safety with the new destination of use of the upper rooms, the intervention should be even sufficiently heavy (strong).

The engineers decided to realize a spatial steel structure under the floor, made of steel plates soldered together and connected to the outer walls (FIG.2). The plates have a constant step and a diagonal development comparing to the secondary frame, so that a lozenge-shaped plan is formed, whose vertexes are the intermediate bearings of the joists. In this way, the joists have no more one but two spans, and the middle bending moment value decreases.

The steel structure has been dimensioned in order to be sufficiently stiff, to connect the outer walls and to bear the horizontal forces due to the earthquake.

The intervention is clearly visible, it is not hidden, it shows its presence in a floor that now has a wooden frame laying on a stiff steel structure, collaborating together to guarantee the structural safety. In this way, the original structure and the ancient Palladian floor are preserved, and the floor maintains its former shape and function.

FIG.2: The spatial steel structure under the first floor

Second floor

Again, where possible, the structures will be reinforced by means of wood-concrete collaborating sections, i.e. in every part of the floor a concrete slab will be realized, connected to the joists by means of steel pins without resins. At this level, however, there are some particular situations that require a careful study and the proposal of alternative solutions.

1. Office of the Scario

The office of the Scario (the elected president of the Magnifica Comunità) has a double ceiling made of valuable wooden elements. For this reason the intervention can be done only from above. The joists are not well preserved, and the usual technique (the concrete slab) could not properly work because of the bad quality and of the low strength values of the wooden elements. So, the engineers decided to hang the joist up on steel cables perpendicular to the main frame direction; the top of the cables is connected to steel profiles L shaped jointed to the walls. The cables have an adjustable tightening screw in order to guarantee the structural capacity of the floor even in case of possible variation of the vertical loads.

2. Secretary Office

In this part of the building, the main beams are visible and painted on three sides, and the secondary frame still lays on them. To reinforce them, the engineers planned to put a reticulated steel beam (27 cm high) over the painted beams along their main longitudinal axis. The reticulated beam is connected:

- with the concrete slab by means of steel pins soldered to the top boom of the reticulated itself;
- with the lower wooden beam by means of screwed pins.

In this way, the original wooden beam still participate to the static safety of the floor, even if helped by a second hided steel beam.

3. Council Room

The ceiling of the Council room has two high valuable larch beams dating from the XIII century. The structural calculation considering the existing situation has been done, and a structural reinforcement seemed to be necessary. But each side of the beams is painted, they have a great span and they were born together with the building, since they are eight hundred years old; it could be a difficult and even dangerous work to substitute or to reinforce the original structures with invading techniques whose safety and length are not sure, in correspondence of a long life length of the original elements.

So, the engineers decided to do some load tests in May 2002, in order to determine the real state of preservation of the structural elements and to verify their loading capacity. The result of the tests was good, i.e. the elements had a good loading capacity, higher than the values required by the existing regulation.

At the end, no intervention has been planned for this floor.

4. Corridor

In this part of the building, the intervention regards two beams supporting the corridor floor (whose load capacity was compromised) by the realization of two particular tensile structures.

A beam borders with the wooden stair coming up from the lower level, and it lays in the middle of two wooden beams (with a traditional T joint) that are overloaded. In order to increase the loading capacity of the beam and to remove its weight from the side beams (that, in this way, are less loaded and so statically verified) a tensile structure has been designed. It is composed of two parallel vertical cables on which the beam is hanged up; the cables are connected to the external walls where the girder of the upper floor is. The tensile structure is visible, it deliberately shows its presence and its function.

The other beam is too bent, so it has been planned to reduce its span. The idea is to take advantage of the fact that, where the corresponding beam at the lower level is, there is a non-load-bearing stone wall with a door in the middle. Two structural steels have been planned to be put inside the door-posts so to function as supports for the corridor beam. The structural steels will lay on the corresponding beam at the lower level (FIG.3). In order not to overload it (because it entirely lays on a wall and it could suffer from crushing problems) the loads coming from the two structural steels are taken by two steel cables and sent to the upper level were the beams bearings are stiffly connected to the outer walls.

Fourth floor

The third floor will be entirely reinforced with the method of the concrete slab previously described, so we will describe directly the fourth level. Here, a part of the floor will be reinforced using again a concrete slab and in another part, with no valuable joists, some new timber elements will be positioned.

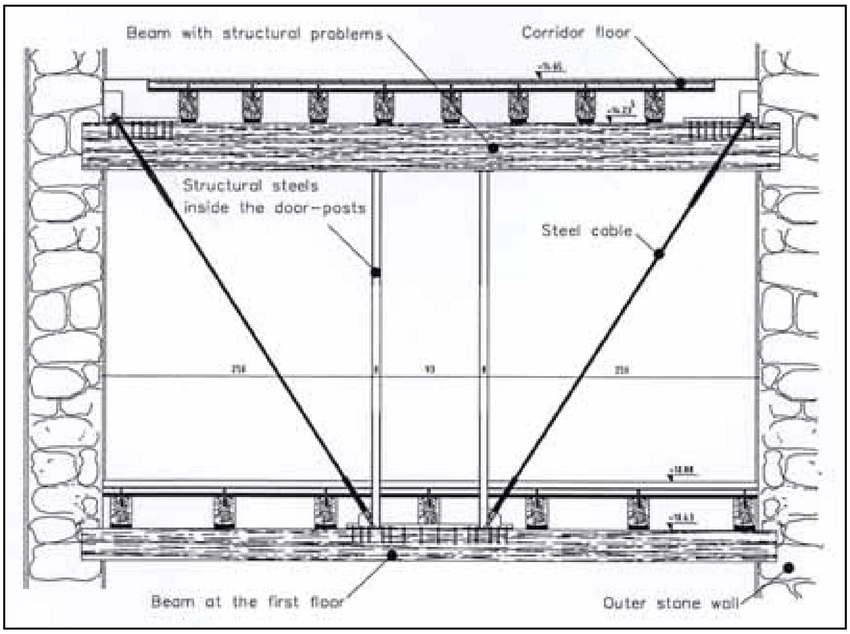

FIG.3: Intervention on the corridor’s beam

The most important and relevant intervention on this floor and probably on the whole building, concerns the reinforcement of the structures above the Bishop’s Room. Here, the second frame is made of timber joists with a low span and an adequate resistant section; but the main beams require a more problematic intervention. In fact, they are composite beams, i.e. they are made of two wooden elements positioned one over the other with serrated joints. They should work together as an unique element when a simplex compression on the vertical plan of the section is applied. Nevertheless, after a careful analysis of the existing situation, these structures seem to work at the limiting value of their capacity and, most of all, they suffer for secondary effects that generate orthogonal stresses to the fibres.

So, a reticulated spatial steel structure has been planned to be realized over the main beams, that will be hanged up on the structure in four points (FIG.4). The spatial structure will support the vertical loads and will help the beams to carry on the bending moment. Besides, it will act as a load dispatcher and it will stiffen the floor. Of course, the structure is connected to the outer walls in order to transfer the vertical reactions. The joint is realized by means of a particular damper material connected to a new concrete girder, so that quickly loading variation (earthquake and so on, for example) will be absorbed in time.

<u>The roof</u>

The level below the roof will be used as a storage. The chains of the wooden trusses covering the room are very near to the floor, and they block in some way the passage of persons and things. So, the engineers decided to remove the chains, the king-posts and the braces, and to replace them with steel cables crossed in the middle. In this way, the trusses still maintain a structural function and collect the vertical loads, but they guarantee at the same time a proper use of the space under the roof.

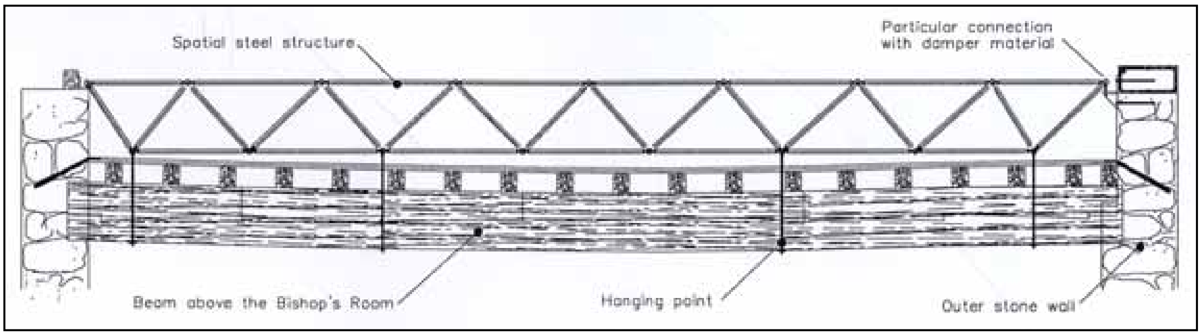

FIG.4: The reticulate spatial steel structure over the Bishop's Room

Conclusions

The intervention plan described in this paper is an example of how nowadays it is possible to restore old structures, realized with traditional materials and techniques (stone and wood) using new calculus codes, modern materials and innovative techniques (pins with no resins, steel spatial structures, particular tensile structures), when it's not possible to use the traditional workmanships. In order to apply this methodology , it is very important to know and to understand the building through a careful survey and a deep structural analysis, in order to respect it by a constructive and formal point of view, to plan sustainable modifications respectful of the pre-existing elements, and to introduce new structures that show their presence when it's necessary but that, at the same time, are compatible to the other part of the historical building.

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All the technical solutions regarding the structural reinforcement that have been mentioned in this paper, have been studied with the technical advice of Prof. Eng. Lorenzo Jurina, associate professor at the Faculty of Architecture of the "Politecnico di Milano" Technical University (Italy).

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