Advanced Materials Research Vols. 133-134 (2010) pp 473-477
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doi:10.4028/www.scientific.net/AMR.133-134.473

The Ancient Reinforced Beams as Model of Consolidation an Example in the Palazzo Pallavicino in Cremona (Italy)

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Abstract To verify the conditions and the possible use of the historical buildings, it is fundamental to individuate structural patterns really near to each particular configuration.
The calculation of a double warp ceiling usually supposes that the secondary warp structure simply leans upon the principal beams. Principal beams, on their turn, can lean or seldom be lodged into the walls. These conditions are usual in the most simple ceilings, but they cannot merely be transferred to the most riches and complex constructions. In the case of Palazzo Pallavicino in Cremona were inserted on some beams between the joists wooden blocks, forming a veritable reinforced beam.
Verification to calculation of these reinforced beams gave load values eligible for the new public destination. The old system has served as a model for consolidation, and allowed minimal intervention and avoided the introduction of incongruous materials

Keywords: Wooden floors, ancient beams, consolidation, sample of ancient wooden floor.

Figure 1: General wiew of the Palazzo Pallavicino, from the corner between Via Colletta and Via Manna

Palazzo Pallavicino in Cremona is now a complex of several buildings of medieval origin united and strongly reworked over the centuries and owes its name to Galeazzo Pallavicino Marquis of Busseto, who was the owner for only five years (1578 - 1583), during which was published the first printed map of the city, by Antonio Campi (1582) on which his name is written. It was really the formerly home of a wealthy patrician, Nicolino Roncadelli, built in the mid-fifteenth century (Spreafico 1989), of which today survive two wings at right angles, facing via Manna and via Colletta, and an internal courtyard. One contained a ground floor room – a very main hall - of over twenty meters long and seven wide, and north extremity the space of the entry from the public road to the court. The one upstairs, another room was superimposed on both rooms. Around the courtyard, a portico and a loggia acted as distribution. In the other wing, a portico of the same depth, just under seven meters wide and sixteen meters long, facing north, served as a opened summer room, and on the top floor corresponded to it a large hall. The walls of area in both buildings give down to delimit a large vaulted cellar that serves as solid foundation. A plan so essential is attested in other houses of Cremona in the same period (Jean 2000). To these spaces of representation and residence were added the wings of services, demolished between the late sixteenth and late seventeenth century, when two adjoining houses were included in the property to reach the extent sufficient to achieve the pattern of distribution and sequences of rooms typical of a residence of the aristocracy of the *Ancien Regime*. Impressive work and the construction of a large new building with its vaulted halls, were achieved the end of the seventeenth century, then the great room of the first floor was divided into tree rooms, perhaps by building two walls of brick masonry or maybe perhaps a wooden trellis, superimposed on the beams underneath. Become the Canossian school in 1837 and again in 1890 with the aggregation of two other medieval houses, alms-house, the building suffered heavy rearrangements, and more than half a century of neglect. Between 2002 and 2005 the complex was restored to house the National Center for Restoration of musical instruments. Recently however it was decided to house in it the Institute of lute making. In both cases, it pays tribute to a great town tradition, alive in the seventeenth and eighteenth centuries, rediscovered in the twenties, which led to Cremona in recent decades an international reputation. The assignment involved the verify of stability of the fifteenth century floors, of which some survives, compared to the load established by the legislation, 400 kg \ mq.

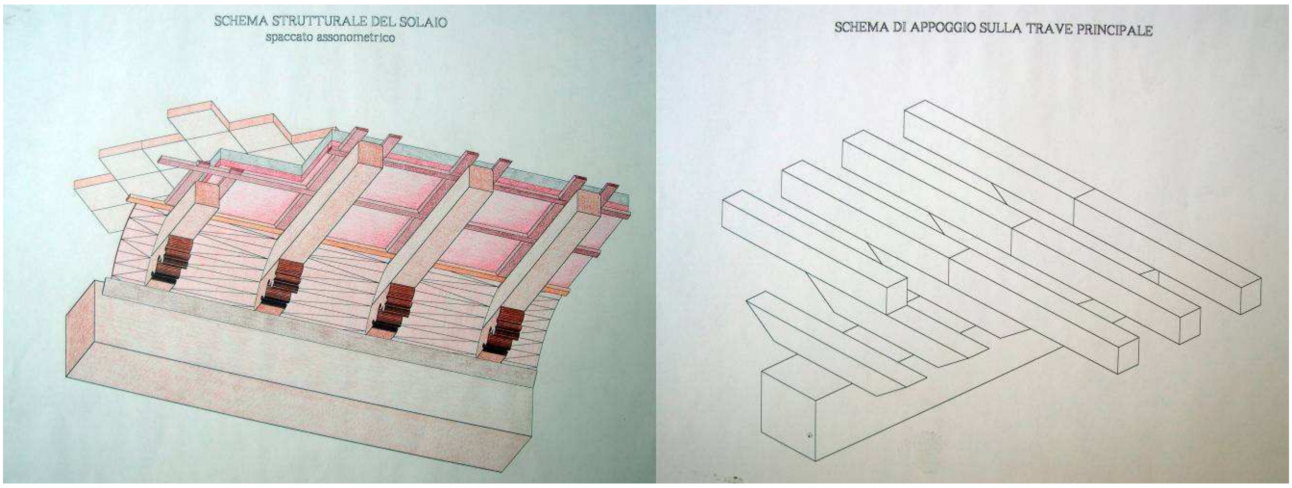

Figure 2: The details of the wooden floor of the main hall

Special effort required the wooden floor of the lower great room. It is divided into eight areas each between 2.30 and 2.40 m, from seven beams of which six of oak, with a span of some m. 6.80, averaging and a transversal section 35 x 30 cm. Edges, at least those of the lower face, hewed, are alive and quite regular. Some beams are curved upward, to fit without excessive wastage inclination of the trunk, in others the upper surface is irregular and are settled by wooden dowels. Perhaps the deficiencies were concealed by a coating of plates and frames at the corners, a solution proven in little later other floors, such as the roof of the provost of the Umiliati Sant'Abbondio, built by 1520(Bandera 1990). At the other beams, irregularities are hidden by a plank projecting on the face of beam, with the lower bottom shaped, just above the joists, which covers about one third of the high of the beam. But it could be a finishing inserted in the eighteenth or in the nineteenth century, when the floor was still visible.

The beams penetrate more than thirty centimeters in the two outer walls of brick. The one towards the road is about 65 cm thick, is equal to four ranges of bricks and the bricks facing towards the road, and the other about 50 cm., representing four ranges, on the porch inside. The walls are neatly woven with mortar of clay and lime, known locally as "Bazzana" (Carpani 2003, Fieni 1995). Obviously, behind the head of the beam was left a space of about twenty centimeters, to ensure that moisture does not stagnate in the heads of the beams. The cavity is closed by the external brick face very regularly arranged toward the road, and towards the wall of the porch, which was formerly designed to be plastered with a tile. There are no metal keys instead in axis of the beam. At the impost in the wall, the beams resting on corbels carved oak ever, a similar section, which penetrate into the wall for the same depth of the beam above it, to act as a sleeper. This solution in other contexts is a repair performed on a damaged head; in Cremona is very frequent in the monumental ceiling of the late Middle Ages and has spread throughout the Upper Italy.

Figure 3: The wooden floor before restauration

The minor warp structure is made of fifteen joists - two parallel and adjacent to opposite walls of room, separated by fourteen fields of about 35 cm. each. They too are oak with four edges, inscribed in a square of 12 x12 cm. Not rest directly above the beams, but double brackets of carved wood the same section of joists that protrude on both sides for about twenty-five centimeters, thus reducing to m. 1.80 on the effective free span. The joists are nailed on the brackets with their heads in complete contact with each other. From the upper edge of the beam to the wooden plank floor, closing the gaps were inserted boards curves, carved in wooden solid, planed and often also decorated with painted figures. The boards are inserted in the grooving etched in the joists themselves and in the underlying brackets. This stylish device, sometimes replaced by a simple board tilted, or two smaller boards with different angle, effectively impede the movement of each other's joists. The planking overlapped, again in oak, in planks 3-4 cm thick and about 45 cm. wide, is probably largely original. The trapezoidal shaped strips that cover the joints between the boards and continue alongside the joists to delimit fields have settled next to the square in shape and decoration that a technical execution could be traced back to the fifteenth century. On the planking and lay a foundation a few inches of sand and rubble, especially fragments of brick, on which lured a floor of brick. Although it is not earlier than 1890, and laid with care, with thin joints, then artifact poor, today it is very costly. The upper hall was parted in smaller rooms in the Seventeenth Century. Walls, probably made of bricks or wooden frames, were built upon some of the existent beams. In these circumstance, the little curved board were removed. Wooden blocks were fit between the consoles and the joists, and connected to the main beams with a dart-of -Jupiter groove. A very “trave armata” (reinforced beam) was built.

The useful section of the beam rises, as will be shown from 35 to 59 cm . A similar construction was also at first sight far from simple support. The dimensions of the wooden elements suggest, albeit with considerable differences also due to the irregularity of its rooms, the old measures of Cremona, particularly the fathom “braccio da fabbrica”(m.0.4358) and the "fathom of boards" (“braccio d’asse”) in use for wooden boards, an area equal to one for four “braccia da fabbrica” (Pederzani 1853, Carpani 2003).

Figure 4: after restauration and consolidation

The thickness of the planking, the size, the limited free span of joists ensure that the minor warp satisfied the required operating loads. The problem centered on the beams cross-section wooden scaffolding insufficient emphasis on ensuring a clear stiffness.

It was ruled out a priori any solution that would increase lift the beams with an “invisible” intervention "invisible" at the intrados, and then practiced at the extrados, which would require the extensive removal of the floor section and the increase in resistance by the addition of denture - even simple metal beams, however, connected with bars at the old warp. The drilling would produce an immediate but not well appreciable damage, and in perspective a further deterioration related to different properties of materials. The construction of a new cement slab was equally judged impracticable, overlapping the existing wooden ceiling, in the thickness of the floor tiles and of the floor rough. Continuous anchorages were to the perimeter walls were notuing and they would have stopped in the vertical continuity of the masonry, with severe damage in a masonry with mortar of clay and lime.

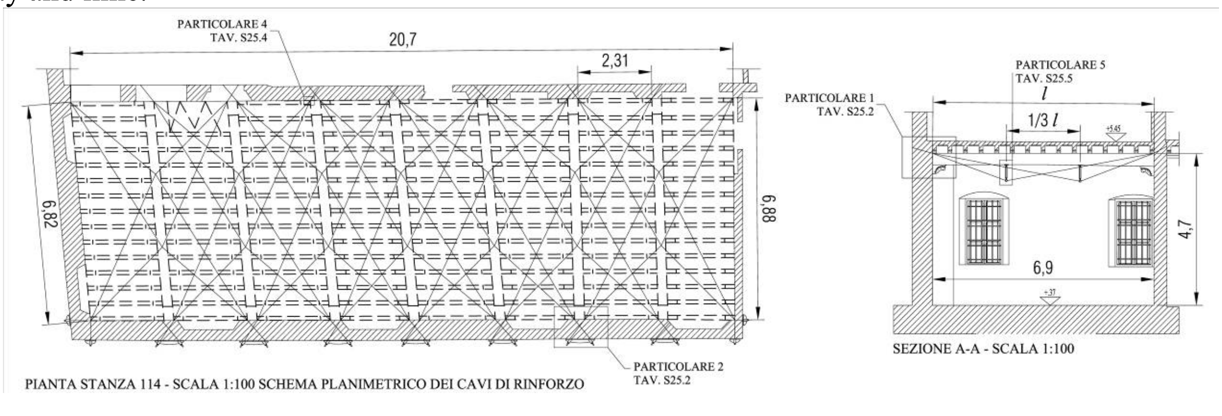

Figure 5: The first external solution of consolidation. Drawings

Must act, below the floor, with a visible and reversible structure. Was first examined, together with professor Lorenzo Jurina, a sophisticated solution that it proposed to tackle the downturn by putting two struts at regular intervals along each beam, which would be placed in tension by a complex web of metal cables cross each other. Divide the effort would have optimized the distribution of loads and avoid in future a simultaneous collapse. In turn, the tension of cables, transferred to large plates specially designed on the outside of the masonry would be transferred by them to the heads of beams, which would have been so subjected to strong compression. The scheme - in easiest kind was applied in the first half of the nineteenth century, and perfected, becomes reversed in some tensile structures of the sixties, designed to hold the fabric cover of temporary pavilions. The project, agreed reluctantly, because of its visual interference from the Superintendent of Architectural Heritage, was repeatedly published (Jurina 2003.1, 2003.2, 2003.3, Jurina 2004) but proved impractical for both the difficulty of managing the numerous irregularities, both fields between the beams, both the share of the beams themselves, despite efforts by the writer and by the architects Stefano and Carlo Dusi Corbari draw metal structural elements of steel support cables that fit the context and resolve the problems of implementation. To transfer the load on the heads of the beams would be necessary to fill the cavity behind the beams themselves, removing moisture can evaporate. Keys were studied also complex, making it possible to distribute the effort over a large portion of masonry. The load remained excessive for both beams, both for the wall with his malta resistant to compression alone, vertically. In search of a solution, loading tests were performed on individual beams. Two old beams, one of which had been reinforced to withstand the disappearance partition, and one without reinforcements, they were also subjected to the load of 1000 Nda, in a limited area in the center of the beam. The drop occurred was mm.1, 87 for the beam armed and mm.3.54 for the second beam. The difference is appreciable. The result was also confirmed on the remaining beams. The last beam to the West had been replaced recently, on old shelves. It was pine, not oak. By the close, a non-reinforced beam fifteenth, was subjected to a load of 2500 but Nda distributed over three square meters. The values were similar. The deformations could be explained just conceiving this structure in a different way. The joists had to be inserted in a higher beam conglobating the wooden blocks, the consoles and the heads of joists themselves. The calculation justify the hypothesis suggested by the carful survey of the wooden element. Along with the engineer responsible of the structural calculation, Mr. Gian Hermes Massetti, it is decided to replicate the seventeenth-century repairs on all beams, by inserting blocks of ancient oak tree on the beam between rafters and joists. The blocks were in turn secured with wedges, to get a real continuity in structural behavior. The solution allowed to adjust the floor to the requested loads, by the employment of any other materials than wood and without any action on the wooden planking and the floor above.

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