Preliminary Inspections of the Wooden Ceilings of The Al-Jami’ Al-Kabir Great Mosque in the Old City of Sana’a - Yemen

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Generality
The al-Jami’ al-Kabir Great Mosque, built approximately in 630 AD and placed just South of the old city, near the Door Bab al-Yemen, is characterized for its imposing quadrangular construction of approximately 100 x 80 m, that encloses a wide courtyard (as-sauh) in which, in an eccentric position, there’s the Kaaba, a solid construction with a cupola, where the more precious and ancient copies of the Corano are guarded (Ill.1, 2 and 3). The access is guaranteed by one entrance both North and South, by two entrances on West side and by four entrances on East side. The entrances normally used are placed on West side, through a tightened courtyard, and to the East side in correspondence of a front door like a classic “pronao”. The inner prospects are characterized from high pointed archs containing glass, the inner ones are characterized by a subdivision in naves with arches, columns and pillars. The number of naves differs by the wings according to the following reference: the North is constituted by five naves; the East and the West by three naves; the South by four naves. In order to identify the naves, a progressive numeration is used: from I to V beginning from the outer one. The extension of the East and West wings are reduced by a transversal wall in proximity of the South wing. At the margin of the South wing there are two cylindrical minarets (Saumaa): East and West. (Ill. 2 and 4, 5)
PRELIMINARY ANALYSIS OF THE STRUCTURES

General constructive characteristics of the wooden floors.
Nearly all the inner floors are constituted by coffered wooden ceilings (Ill. 6). Although constructively similar, they differ in the wood species employed, in the decorative

III.3 View of the Mosque and the great courtyard from the West minaret. The Kaaba in an eccentric position.

III.4 View of the West minaret from the cover

III.5 View of the East minaret from the courtyard

III.6 Inner view of the North fifth nave and ceiling system
characteristics, in the execution age and in the state of conservation.
The greater part of the beams and joists are very well worked: the load bearing structure
is mostly composed by elements squared with the axe, subsequently planed and
decorated.
The timber, constituting the frames, the battens and the boards, is sawed, planed and at
last decorated.
Almost all the floors (Ill. 15, 16, 17 and 18) are constituted by a system of orthogonal
reticular type of:
1) squared beams on the walls with carved and painted (and/or gilded) external face, 
bringing inscriptions, sometimes, in kufic language. (Ill.10). We observed that the union 
between two contiguous elements on the wall, and probably in the angle zones, is made 
of staple joints; (Ill.8 and 9)
2) main parallel beams, mostly squared, of about (b x h) 220 x 140 millimetres,
orthogonal to the walls, with wheelbase of about 700 millimetres, representing the load
bearing main structure of every floor. The beams are diffusely painted, gilded and
sometimes (East wing Ill.10 and 16) carved. Sometimes we also observed round painted
beams (Ill. 14). Frequent is the employment of lined beams, that means round beams
covered of painted tables;
3) parallels joists squared, of about (b x h) 115 x 65 millimetres, orthogonal to the
beams, with wheelbase of about 700 millimetres and half joined to the main beams
(Ill.11, 12 and 13). This system constitutes the secondary load bearing structure. Also
the joists are painted;
4) system composed by diagonal boards, battens with painted and sometimes carved
frames (East wing Ill.16), in a variable number of layers and dimensions (approximately
50 millimetres of medium thickness each one) according to the floor of reference, and
with superimposition of pyramidal cut type that constitutes the classic coffered ceilings
called “lacunare”; 
5) the last board (medium thickness of 30 millimetres) painted and closing the lacunare.
(Ill.11, 12, 13, 15, 16, 17 and 18). A portion of the floor, in the fifth nave of the South
wing, is of rustic type and composed by round and irregular beams and probably on
these, some branches in orthogonal direction. All covered by a mixture of clayey earth
and straw. At last all the surface is treated with chalk (Ill. 21). Portions of floor,
sometimes wide, were rebuilt probably as a result of deep degradation or for localized
fires. These floors are concentrated in the fifth nave of the South wing (Ill.20 and 21) but
there is also a limited portion of a substitution floor in the second nave of the North wing.
(Ill.19). In some cases (the West portion of the South wing and the floors of the North
wing) the structural systems are not of good execution from both a constructive and a
qualitative point of view of the interventions made in urgency or emergency conditions
(Ill.19 and 20). Consequently, in phase of restoration, we have to consider their redesign
with recognizable floors compatible with the context. The portion of floor towards West,
even if totally different from the historical system of the floor, is of good execution and
quality. Moreover it has been integrated up to now with the context and consequently its
conservation is suggested (Ill. 22). In this common system of structures, analogous to
the historic coffered ceilings, or lacunari, probably of Middle Eastern origin but also
present in the most ancient European tradition (Greek and Roman), some exceptions
represent the particular and complex cases concentrated in the North wing and of local
tradition (also typologically present in other ancient Mosques in the province of Sana’a):
a) on the West extremity of the floor there are four independent ceilings with similar
constructive characteristics but with different and more complex forms. On one of these
(in the fourth nave), a not optimal restoration is evident (Ill.26).
These floors are composed by a load bearing structure and a “covering” complex
decorated with geometric figures that are interlaced (Ill. 23, 24, 25 and 26). For this
constructive system it will be opportune to preview specific deepenings also in order to
establish the state of conservation.
b) in the first nave, in a central position, there is a system of wooden ceiling composed
by circular, much deep elements: a central one of greater amplitude and two lateral of
reduced dimensions, ending with a glass plate (today occluded) and definable as “cestili”
ceilings. (Ill. 27) Also for this complex constructive system it would be opportune to preview a specific deepening.

The floors constituted by a system of orthogonal reticular type

III.8 Staple joints of the beams on the wall

III.9 Particular of staple joints of the beams on the wall
**Ill.10** Squared beams on the walls with kufic language in the East wing

**Ill.11** "Lacunare" system in the North wing

**Ill.12** Lateral particular of the lacunare system.

**Ill.13** Systems of half joint between the various elements of the floor

**Ill.14** Round and red painted element of North wing

**Ill.15** Ceiling standard, North wing
Ill.16 Ceiling standard, East wing
Ill.17 Ceiling standard, South wing
Ill.18 Ceiling standard, West wing
Ill.19 Incompatible replacement floor, North wing
Ill.20 Incompatible replaced floor, South wing
Ill.21 “Rustic” floor covered with organic material and chalk, South wing
Ill.22 Replaced floor, South wing
Ill.23 Incompatible replaced floor, North wing
Ill.24 Second nave, North wing
Ill.25 Third nave, North wing
Ill.26 Fifth nave, North wing
Ill.27 Fourth nave, North wing
Ill.28 System of "cestile" ceilings in first nave, North wing
Stratigraphy of the floor from cover

In order to study the constructive techniques of the floors and to verify the conditions of conservation of the lumber, we carried out five stratigraphic diggings of the cover. Four areas of stratigraphic digging were chosen according to the various situations corresponding to the four wings of the Mosque and according to the state of degradation visible from the inside.

A fifth digging was executed in correspondence of the floor of the second nave of the North wing, on the West head, in order to detect photographically the constructive characteristics.

The inspection diggings was of approximately 1m² and always achieved with the exception of the digging E, the upper wing surface of the wooden members of the floors.

Generally the concrete “blinding”, that constitutes the flat floor of cover, is composed by layers of mortar with combines of different nature and dimension, underneath of which is noticeable one or more layers more than earth, sometimes rough and compact, sometimes fine ones and melted, sometimes with organic rests (animals bones) or inorganic (rests of ceramic fragments). Around to the wooden elements of the lacunari, on the top, a rich mortar of lime is present which aims to seal waterproof and adhere the wooden members, that normally have no nails but are only superimposition of elements for gravity and half wood joint.

In the spaces between a wooden element and the lacunare one, there is a layer of compact material constituted of little pomegranate branches disposed with insulating functions.

In a case it was found the presence, to directed contact with the structures, of a thick covering layer of ash with a probable hygroscopic equilibrium function for the lumber.

In two cases it was found the presence of vegetable mat which aims to prevent the wooden elements from the direct contact with the earth.

Now we refer the stratigraphic description of every single digging:

**First survey on A area executed on the second nave, in the central portion of the West wing corresponding to the span No. 12 to count from the South side.**

1. smoothed layer of conglomerate (quadad), thickness cm 2;
2. rougher layer of white conglomerate (quadad), thickness cm 2 (until 4 cm from the level of the cover);
3. layer of a cm6 thickness: parts of conglomerate with melted aggregate (until 10 cm from the level);
4. layer of a cm12 thickness composed of fine earth. Until 22 cm from the level;
5. filling layer of earth and organic parts (small pieces of branches and animals bones). Thickness of approximately 9 cm. Until 31 cm from the level;
6. layer of the wooden board. To 31 cm from the level of cover, the wooden board appears to occlude the underlying lacunare. The board is not nailed and does not bring signs of attack of xylophages bugs neither of other biotics organism. To the same level, in the other areas, some branches are placed. The board is cm. 5 and is composed by one base of a 2.5cm thickness and by a carved part of a cm.2.5 thickness. The board is cm 26.5 x 27.
7. layer of wooden battens that forms the base of lacunare. Every battens, in softwood (conifer) probably assaulted by woodworms, are sealed with fine compact and white mortar. The frames are fixed with nails of hardwood. The battens stand alone.

**Second survey on B area executed on the first nave of the North wing in correspondence of the lived span No.2 from East.**

1. smoothed layer of conglomerate (quadad), thickness cm 4.3 – 4.5. Harder than first layer of the first survey;
2. 2a. conglomerate layer, like the first one, thickness cm 4.3 – 4.5. Rougher with inserts of small pieces of black volcanic material larger than a grain of sand;
3. 2b. a volcanic stones of dark colour is dipped in the white conglomerate. The volcanic stones are until 10 cm³. This layer has a remarkable thickness but is irregular;  
4. layer constituted by melted material that include: earth, aggregate of small dimensions and ceramic fragments. Thickness approximately of 8-9 cm. The layer reaches 30 cm from the level of cover;  
5. mixed layer of bricks of irregular thickness, earth and melted material like on the third layer. Thickness from 4.5 to 5 cm. The bricks can be of 18x18 cm or 22x22 cm;  
6. wooden board. At 35 cm from the level of cover there is the wooden board, that occludes the lacunare. The board is not nailed. At this same level, in the area occupied by the board, there is woven straw or vegetables fibers (type mat) and little branches. The thickness is not precisely recorded but approximately of 5 cm.  
7. At level of wooden battens, that constitute the thickness of the lacunare, there is a second layer of bricks mixed with earth without (at the visual analysis) organic material like bones or little branches etc. The thickness of ceramic bricks varies from 4.5 to 5 cm. The bricks can be of 18x18 cm or 22 x 22 cm. The wooden battens of the coffered ceilings are made of mixed woods, partially hardwood (not assaulted by woodworms) and partially of other kind of wood.  
8. Under the bricks there is an other layer interlaced of vegetable fibres. Thickness not found.

**Third survey on C area executed on the North head of the East wing in correspondence of span No.1 of the second nave.**  
1. smoothed layer of conglomerate (*qudad*), thickness of cm 4.2 – 4.3;  
2. smoothed conglomerate layer (*qudad*), thickness cm 4.2 about. It approximately covers up to 6.8 cm from the level of surface. Probably it is a layer of ended cover of previous age respect to the first layer;  
3. layer that occupies up to 14 cm from the level of cover. Rough conglomerate with inserts of small black volcanic materials and a little bit bigger than a sand grain;  
4. layer of coherent material constituted by an aggregate of volcanic material of dimension of approximately 1 cm³ dipped in a lean mortar. The layer has a thickness of approximately 5 cm. It reaches 19 cm from the level of cover;  
5. layer of heart of rosy-warmth colour. It reaches 36 cm from the level of cover and has a thickness of 17 cm.;  
6. layer of wood boards that close the lacunari of the ceiling in the upper surface. The boards are much degraded and are sealed by a large amount of mortar. The durability is insufficient. The upper surface (towards the cover) of the board is assaulted by brown rot and the lower part (towards the Mosque) by woodworms. The thickness of the sealing and the boards is of 9 cm. The degradation is so high that the boards nearly seem an imprint inside its sealing. This imprint has a thickness, inside of the sealing, from 1 to 3 cm. At the same level, around the boards, there is a woven of vegetables fibres (mat) that reaches 45 cm from the level of cover;  
7. 7a. layer of wooden battens that determine the thickness and the flanks of lacunare. The battens are probably of hardwood. Around the battens there is perhaps a layer of branches and pieces of ropes (maybe bundle of tied wings) of a thickness of 19 cm;  
8. 7b. layer of ash on the upper wing surface of the beams and the joists of a thickness of approximately 1 cm;  
9. 7c. layer: Healthy beam of hardwood.  

**Fourth survey on D area executed in the South wing in correspondence of first nave on the upper side of the span No.6 from the West**  
1. smoothed layer of conglomerate (*qudad*), thickness cm 4.5 cm;  
2. conglomerate layer much hard. Thickness of 4 cm, up to a depth of 8 cm from the level of cover;  
3. layer of dipped volcanic stones in the earth. The stones are smaller than those of the layer 2b of the B area and are also less porous and more compact. The dimension is
approximately 5 cm³. The stone layer is homogenous with extended material on a regular basis between the incoherent material. The thickness of this layer is approximately 11 cm and reaches 19 cm of depth from the level of cover;
4. layer of bricks between incoherent material composed by ruins and earth. Thickness of approximately 8 cm. Up to a depth of 27 cm from the level of cover;
5. layer of branches of a thickness of approximately 1.5 cm;
6. 6a. layer of the upper board that closes the lacunare. Lateral frames with battens of the lacunare sealed with mortar along the edges. All around there are the same little branches of the 5th layer. Thickness of approximately 16.5 cm. The layer reaches a depth of 48 cm from the level of cover. At 40 cm of depth from the cover there is a secondary rafter with small lateral boards. Its thickness is not recorded;
7. 6b. layer of wool coloured threads (oakum) in order to fill the slots around the frames, in the deeper part of the layer;
8. 6c. earth layer, under the branches, for approximately 1 cm before reaching the beam;
9. Beam. It is 48 cm of depth. It was attacked by woodworms but on the whole, the state of conservation is good.

Fifth survey on E area executed in correspondence of the West head of the North wing, on second nave, span No.1
1. smoothed layer of mortar in the upper side. The volcanic materials are present in fragments of about 0.5 x 0.3 cm. Thickness of approximately 3.5 cm;
2. layer of dipped volcanic stones in the earth. The layer is much thin, approximately 3.5 cm, up to a depth of 7 cm from the level of cover.
3. board of cover of the underlying lacunare, protected by lime. The survey is not continued to the beam.

Wooden species and durability
The determination of species of wooden elements was executed, where possible, on a macroscopic observation. In order to acquire more information about the employed wood species, a sample (10x10x10 mm) and a inlay of inspection (30x30x1 mm) were limitedly carried out, drawn both from the lower surface of beams (in the North wing) and the upper wing surface from the stratigraphic diggings (diggings E and D).
It was noticed the generalized use of hardwood which constitute the load bearing, primary and secondary structure of the floors. Nearly always the hardwood also constitutes part of the lacunari as the board of closing, battens and frames. In some cases, for these structurally secondary elements, it was noticed the presence of softwood (conifer wood).
The conifer wood seems to belong to an only species (native in the Yemen is the Juniperus procera that reaches 10 m of height) while more species, many of which deriving from the Acacias family, seem to belong to the hardwood. Here following the most common aboriginal species of hardwood: Acacia negrii, Acacia tortilis, Cordia abyssinica, Dobera glavra, Ficus vasta, Tamarix nilotica, and Zizyphus spina-christi.
However the imported timbers from East Africa and from near Asia are not excluded. Owing to the much complex taxonomic determination, their possible presence as material of work in the Mosque, cannot be limited to the single macroscopic observation.
Regarding the durability, a no resistance to the saprophytic biotic aggressions was noticed (infections and infestations) for the elements in conifer wood while in main cases the elements of exotic hardwood have a good or optimal durability to every kind of attacks.
**LEGENDA**

- Malta fine (Thin mortar)
- Malta grosolana (Coarsely mixed mortar)
- Malta magra (Lean mortar)
- Materiale scelto composto da terra fine e materiale organico (Lumbar material with thin earth and organic material -bonese-)
- Materiale scelto composto da terra e rametti (Lumbar material with earth and little branches)
- Terra compatta (Compact earth)
- Struola vegetale e rametti (Vegetal mat and little branches)
- Rametti (Little branches)
Ill.29 Inlay inspection executed on one beam of the North wing

Ill.30 Macro (30x) of the inlay in Ill.29: exotic hardwood

Ill.31 Inlay inspection of the upper board of ceiling in E digging

Ill.32 Macro (30x) of the inlay in Ill.31: exotic hardwood

Ill.33 Pick up of a sample from a edge of joist in the D digging

Ill.34 Conifer wood frame to low durability of upper ceiling board
Preliminary determination of the class of biological risk

As a result of the observation inside the mosque and, above all, of the inspections on the flat cover, it can be said, also for climatology of the region, that generally and tendentially the class of biological risk is 1: the wood normally is protected with humidity of the wood to the underneath of 18-20%. Different is probably history of the floors as the spots of infiltration on the wooden elements show. The concrete of the flat cover seems to be slightly permeable to the water and would not catch up the wooden elements.

In the “cover package”, there is probably an elevated thermal excursion between the external surface, exposed to the intense solar radiation, and the inside and also between the different thermal conditions between the day and the night. It causes remarkable differentiated movements between the materials that constitute the cover. The concrete of the cover, that turns out to be continuous, consequently creates joints of natural expansion of the blinding, as it is obvious in these conditions. From these cracks the rain water can penetrate and influence wide zones of floor causing, beyond a reduction of the mechanical resistance of the lumbers, also a risk of saprophytic biotic aggressions. Presently (we do not know in the past time) a recurrent maintenance was executed (it would seem of traditional type) by putties with more elastic and waterproof lime of mortar by adapting the fat of kneecaps. (Ill. 36)

However the durability of the traditional material employed for the putty has turned out to be low and quickly; it still cracks. (Ill. 37 and 38)

Moreover, during the inspections, it has been noticed a deficiency in the drain of rain water systems, above all in the East and West wings. Deflections of floor or insufficient slopes cause localized (in proximity of the external perimetrical masonries of the North wing and of the North head of the East wing) and diffused stagnations (in the East wing from the half in South direction; in the central portion of the South wing). The stagnations, with presence of fissures on the cover, aggravate the dangers of infiltrations and degradation of the structures and in these cases the risk class can reach 4 with serious risks of infections for the not durable elements and for elements into the masonry or at direct contact with the top earth layer.

A more deepened survey of the way of the water would have to be carried out in the period of rains.
Defects, alterations, pathologies and damages in existence or in the past.

It is specified that the great part of the observations was carried out from the pavement of the Mosque at about 6 m of distance from the structures. In phase of restorations, it will be therefore indispensable to observe in details the wooden elements in order to gather precise information beyond that on the wooden species also on the defective state, pathologies and damages, important information for a corrected intervention of conservation.

**Defects**

The observation, as possible, showed the presence of material generally of optimal quality. However some elements have failures by a slope of grain (Ill. 39 and 41, 42, 43, 46) or waved grain (Ill. 40), lengthen knots and spike knots. (Ill. 47)

These main defects reduce the typical mechanical resistances and consequently they will have to be taken in consideration during the consolidation interventions. In many cases, and of particular gravity, such defects show lesions and collapses (Ill. 41 and 44, 45).

In the extreme situations, it has been partially already intervened by inserting efficient subbeams from the structural point of view and compatible from the material point of view but aesthetically unacceptable (Ill.60, 61, 62, 63, 64, 65, 66, 67, 68 and 69).
LEGENDA

- ristagno d’acqua (water stagnation)
- pozzetti di ispezione (inspection pits)
- fotografie scarichi dell’acqua (water drainages picture)
- fotografie copertura (roof picture)
- fotografie pozzetti d’ispezione (inspection pits picture)
- percorso acqua piovana (rain water way)
Ill.40 Slope of grain with lesion beginning, North wing

Ill.41 Fissure of waved grain with lesion beginning on round element, North wing

Ill.42 Slope grain lesion, North wing

Ill.43 Slope grain fissure, North wing

Ill.44 Slope grain fissure, West wing

Ill.45 Lesion on beam, North wing
Alterations and pathologies
All the wooden surfaces are interested by coherent and incoherent dust. In many cases the coherent material is constituted by thick smoke stratification (Ill. 48). In the areas near the windows and in the area more exposed to the natural light, even indirect light of the sun, the decorations turn out to be fade (Ill. 49). Spots of various nature created, above all, by the rain water infiltrations, characterize almost all the surfaces. (Ill.50, 51, 52, and 53).
Rough and big putties diffusely spoil the wooden members.
Where it was possible to directly observe the wooden elements, it was observed an intense and diffused entomatic wooden attack of the less durable species (essentially the coniferous wood) (Ill. 54).
The macroscopic examination of the emergence holes appearing on the surface and the microscopic observation of the bore dust from the galleries produced from bugs lead to assume that there are feature of Coleopters of the Anobium Family (*Oligomerus ptilinoides*). (Ill. 55 and 56)
The advanced degradation by the bugs has probably determined the substitution of conifer wood overlay (sometimes in plywood) of some beams. (Ill. 57 and 58)
The covering board of the lacunari were frequently assaulted from brown rot. (Ill.59)
The aggressions generally seem to be extinguished, with the exception of the risks of infections, potentially in act as some still active in the infiltration areas.
Ill.49 Thick superficial coherent dust, South wing

Ill.50 Chromatic alteration of the finishing, East wing

Ill.51 Spot by localized infiltration, North wing

Ill.52 Spot by localized infiltration, West wing

Ill.53 Spot by localized infiltration, South wing

Ill.54 Spots by diffused infiltrations, East wing
Ill.55 Serious entomatic attack of the elements of conifer wood. Notice the healthy nail in durable hardwood

Ill.56 Emergence hole (30x) on conifer wood

Ill.57 Anobium boredust (60x)

Ill.58 New overlay

Ill.59 Incompatible overlay with plywood, West wing

Ill.60 Brown rot on the upper board, digging C
Damages
The great part of the damages found on the structures of the floors is imputable to the defective state of some elements, defective state which has already been reported about. Many of these situations expect opportune and urgent safety interventions.
For other elements, a further irregular beam in round timber has already been inserted to the underneath of the cracks and normally is of not good quality. (Ill. 60 to 69)
In some sporadic cases the cracks, deriving by slope grain, was repaired by introducing metallic wraps nailed to the wood. (Ill.70)
Anyway, beyond the aesthetic judgment, where interventions were made, the situation is safe. However the intervention has also to put in safety the secondary elements (battens, frames and boards) that turned out to be assaulted by xylophagous.
Moreover we have observed high bending of floors (with slopes not necessarily compatible with the drain of rain waters), obvious arrows of bending deflection, a yield of the beams on the wall of East Minaret, big out vertical of all the West wing in West direction,; horizontal lesions on the pillars and columns of the nave and cracks in arch key.
Ill.65 Particular of zone of collapses, West wing
Ill.66 Zone of collapses, West wing
Ill.67 Particular of zone of collapses, West wing
Ill.68 Type of reinforce in West wing
Ill.69 South wing
Ill.70 South wing
Ill.71 Repair with iron slab in North wing
CONCLUSION
Hypothesis of survey of second level and instrumental kind
The inspections were quickly and had a recognitive nature of the situation. Before the restorations, it will be necessary to deepen the situation for intervention phases. It become necessary, beginning from the reliefs made by the Social Fund, to add detailed surveys of every constructive typology. At the same time it will be possible to assess the true state of conservation by near observations and with the aid of specific testing equipments for the wood. With all these information it will be possible to carry out calculations and simulations at the limit states on the resistances of the structures. At the same time it will be possible to determine the wood species and, thanks to dendrochronology techniques, try to set the age of the lumbers. In order to determine the resistant residual sections, the use of penetration instruments is favourable for wood. Moreover, benefits could be obtained by the loadings test and by continuously monitoring for a period at least 365 days, the main physical factors that can determine the degradation of the wood: Relative Humidity, Temperature and Ultra Violet radiations and the monitoring of the referring movements of the structures. Other specific diagnostic techniques for the wood could be taken into consideration in works according to the problems to be faced and interpreted scientifically.

First hypothesis of repair and consolidation interventions
Beyond the directed interventions on wood and on the precious decorations, the main structural interventions concern, following a more deepened diagnosis of the situation, the putting in safety of the defective structures, or near collapses, or already collapsed one. The structure of the floors appears, thanks to the basic sizes of the wooden members, of the species employed and thanks to the wheelbase draws near between the elements, extremely resistant. Where there are not defects or damages caused by the infiltrations, the situation appears sufficient to resist also to abundant load of the blinding of cover. Many doubts are remained on the situation in some points (for example, the conditions of the beams inside are not known for the linings elements). Moreover, for the characteristics of the site, it will be necessary to supply with camouflage interventions of consolidation system. Consequently, given the over mentioned conditions and technically in order to give again continuity to the grain, it will be necessary “sew” the failed or fissured beams with insertion of steel connectors or carbon fibres opportunely calculated and proportioned. In order to avoid the removal of the old concrete of cover, whose typological and historical value cannot accept modifications or sacrifices, it will be necessary to operate from the bottom of the beams. This choice will cause a limited sacrifice of decorated intradosal surface (probably already compromised from the insertion of the reinforced beams), but it will allow a greater rapidity and economization of the interventions.

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