Reconstruction of Jupiter’s temple baptistery of St. John in Split, Croatia

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ABSTRACT: Jupiter’s Temple in Diokletian’s Palace in Split is neglected, in an inappropriate and rather bad condition today, especially its semblance. This is mostly related to its west gable and horizontal cornices of the longitudinal walls. It never had a roof, so it was always exposed to the bad environmental influences that forced its deterioration. Significant damages of ashlars, visible as shiftings and fractures at particular portions, as well as the corrosion and braking of the iron ties, demand an adequate reconstruction, and its preservation can be accomplished by final covering.

1 BRIEF HISTORY

The small temple in Diocletian’s Palace, near the Emperor’s mausoleum, is one of the most valuable and very well preserved antique buildings in Split. It was probably dedicated to the highest Roman god and Diocletian’s divine father, Jupiter, though the experts still argue about the titular.

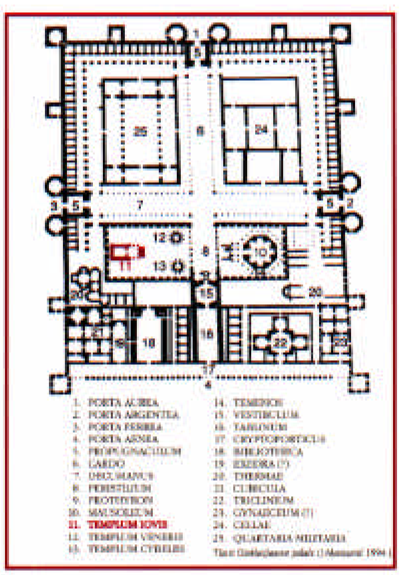

Figure 1: Ground plan of the Diocletian’s palace with a mark of Jupiter’s temple position

In Middle Ages, or even in late period of Roman Empire, the temple was transformed into Cathedral baptistery, while the crypt was consecrated to St Thomas. In 13th century the font basin was raised in the sanctuary. Two Mediaeval stone-coffins, in which Split archbishops John and Luca were buried, are preserved inside the temple. The bronze sculpture of Saint John by Ivan Meštrovic was also placed here.

Figure 2: Temple interior with the sculpture by I. Meštrovic

Figure 3: Reconstruction of eastern tower

At the eastern side of the vault that never had a roof, an early Romanesque tower had been built in 11^{th} century. It was removed in the year 1840. At the beginning of 20^{th} century a few houses at the eastern and western sides were removed, and Jupiter's Temple is free from interpolations, except one house that is still leaning to its north-western quoin.

2 DESCRIPTION OF THE BUILDING

The building has polygonal ground plan, according to Roman traditional way of building temples. The walls are constructed of large ashlars straight cut in a technique of the highest type - *opus quadratum*. The high base of the temple is hiding the crypt whose vault sustains the sanctuary floor - *celle*. The sanctuary could be accessed across wide stairway through the tetrastyle portico whose pillars, roof and decorated gable disappeared long ago. The only light has been coming to the sanctuary through the big stone portal decorated with relief of high quality. The sanctuary interior is ascetically simple, except the richly decorated vault that rises above the hollow cornice. There is similar simplicity on the outer side where all decorations concentrate on the cornices and gables.

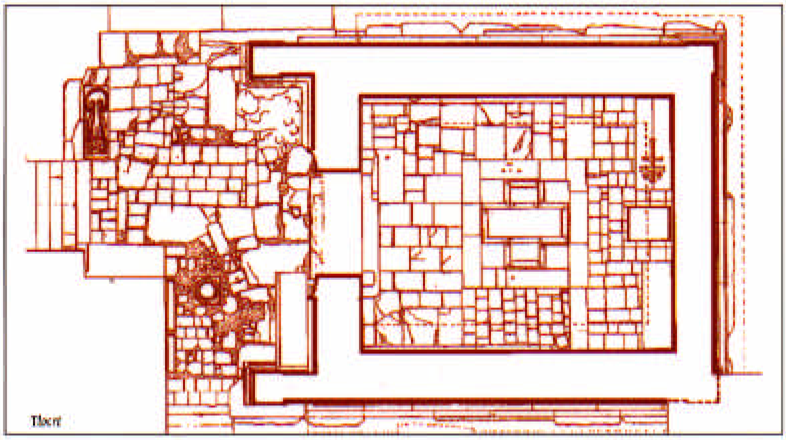

Figure 4 : Ground plan of the Temple

3 THE BEARING STRUCTURE

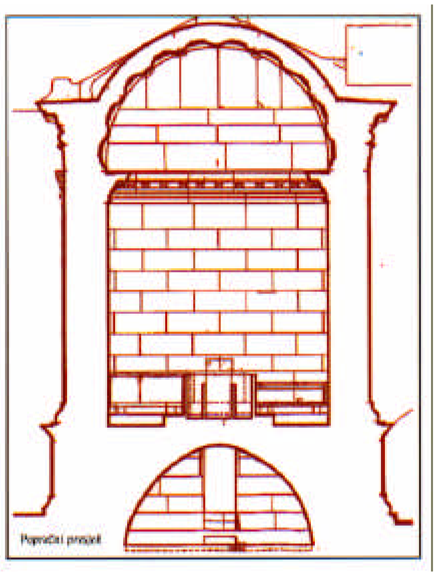

Figure 5 : Cross section plan

The stone bearing system of Jupiter's Temple consists of four walls that end with gables at the eastern and western sides; while the stone vault leans to the southern and northern walls that end with emphasised stone cornices on the top.

The baptistery vault is built of forty ashlars, placed in eight rows lengthways, with five ashlars each, across the longitudinal axis.

Figure 6 : Soffit of the vault

On the outer side the ashlars were hewn round shaped with quite a lot of rough areas, but they were profiled very richly on the internal side.

The high position of longitudinal cornices, concerning the beginnings of the vault and the first joints of the vault ashlars, suggests the interaction of bearing and designing aspects in body composition. The very composition of the cross section plan allows stating a question about the reason for placing the horizontal cornice at this particular height, concerning the geometry in cross section of the vault. An argument for placing the cornice here is, undoubtedly, the sloping roof plane (that had been planned, but never made) that determines the geometry of the west gable as well. The bearing's and design's contribution could be discussed about on this issue, however, the fact is there are certainly more than one criteria in question here.

Concerning the behaviour of the vault; in comparison to the length of *intrados*, the way of construction, the ashlar sizes and the length of the *extrados*; it is very interesting that the joint between the first and the second ashlar is placed exactly on the section line of the interior wall surface and the line of *extrados*. It corresponds the bearing, rather than the design geometry of the vault built between two walls that continue vertically to the upper floors across vertical line above the vault.

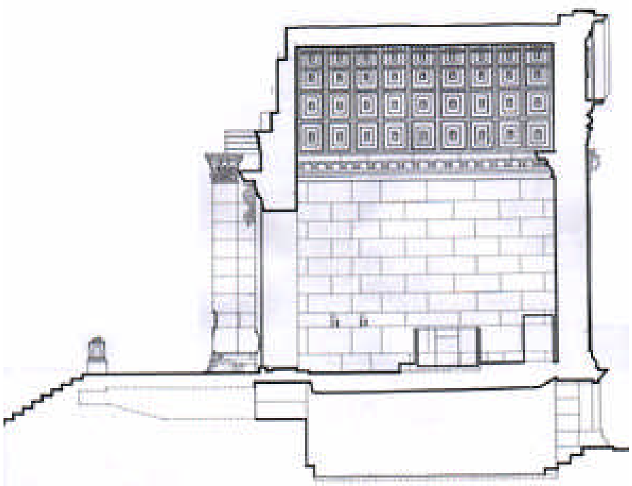

Figure 7 : Longitudinal section plan

The cornices of the longitudinal walls, both the ones at the top on the outer side and those cornices the vault leans on inside, must be mentioned in the context of the bearing system. The outer top cornices are made of ashlars of about 150 cm ground cross dimension, that, considering the method of joining them together with metal ties and the distance between cross walls of the baptistery of about 7,00 m, gives the cornice potential ability of taking and transmitting the horizontal pressing of the vault. The cornice below the beginnings of the vault is probably also able to take such pressing.

Figure 8 : Vault and cornices - the exterior

The crypt vault is constructed of limestone and leans to the shared foundation of the longitudinal walls of the temple.

In spite of numerous hard circumstances, like deterioration of temple's upper parts of the bearing structure mostly exposed to bad weather impacts, the corrosion and braking of iron ties, shifting of the ashlars on the western gable and on longitudinal cornices; the antique temple is still standing, witnessing that the bearing structure is active enough and still possesses sufficient capacity to sustain the actual weights.

The damages of the bearing structure are most obvious at the western gable where significant shifting of the ashlars turned up. The shifting of the uppermost ashlars arose along the slope of the upper gable plane, (ashlars sliding up to 10 cm) and around their longitudinal axis as well. That led to the fractures of profiles at the lower ashlars because of concentrated tension. Vertical ashlars on the wall surface shifted from the vertical plane in a horizontal line.

The ashlars of the longitudinal cornices are moved from each other; at some areas place more – e. g. at the eastern side that could be an effect of the additional weight of the tower; at some areas less. At northern side the most outstanding part of an ashlar has fractured across the whole its length. At eastern end of southern cornice a whole ashlar is missing, while there are extraordinary large joints between the ashlars at eastern gable.

At southern side of the vault *extrados* the longitudinal joint between the first two ashlars, placed a little above the joining line of horizontal cornice ashlars and vault ones, has a fracture that is the proof of its opening.

At *intrados*, the longitudinal fractures arose in longitudinal joints between the central ashlar and the two adjacent ones.

Binding mortar between joining surfaces of the ashlars at horizontal cornice and the vault has disappeared; the water that flows down the vault and penetrates into longitudinal walls that way washed it out.

4 ANALYSIS OF THE BEARING STRUCTURE AND THE PROPOSED METHOD OF RECONSTRUCTIO

The model of bearing structure is made by placing the *gap-elements* at the vault, in the joints between ashlars, in the direction of the lines that are able to transmit the load and shear stress, but not the tensile stress. The vault is also, over the *gaps*, leaned to the longitudinal walls and connected with upper longitudinal cornice. This way the model is reflecting the actual condition much better. The weights of the gables of the eastern and western walls are simulated on the model as the vertical load stress.

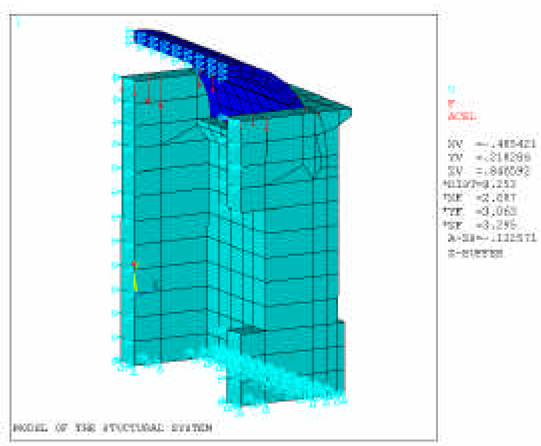

Figure 9: Three-dimensional model with gable loads

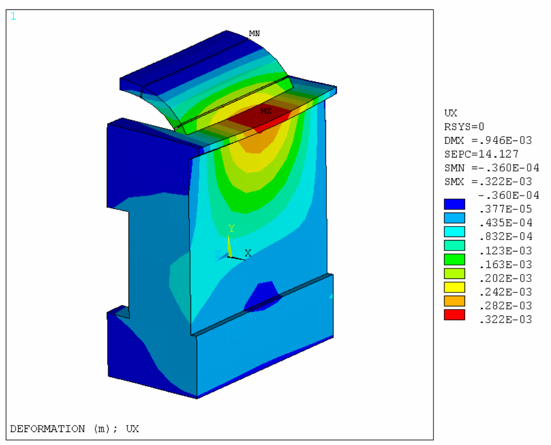

Figure 10 : Print of distortions

Analysing the behaviour of bearing structure has shown the expected qualitative condition, together with quantitative illustration of all relevant data (distortions and tension).

The three-dimensional model of the bearing structure has shown characteristic places of the greatest tensions and shears.

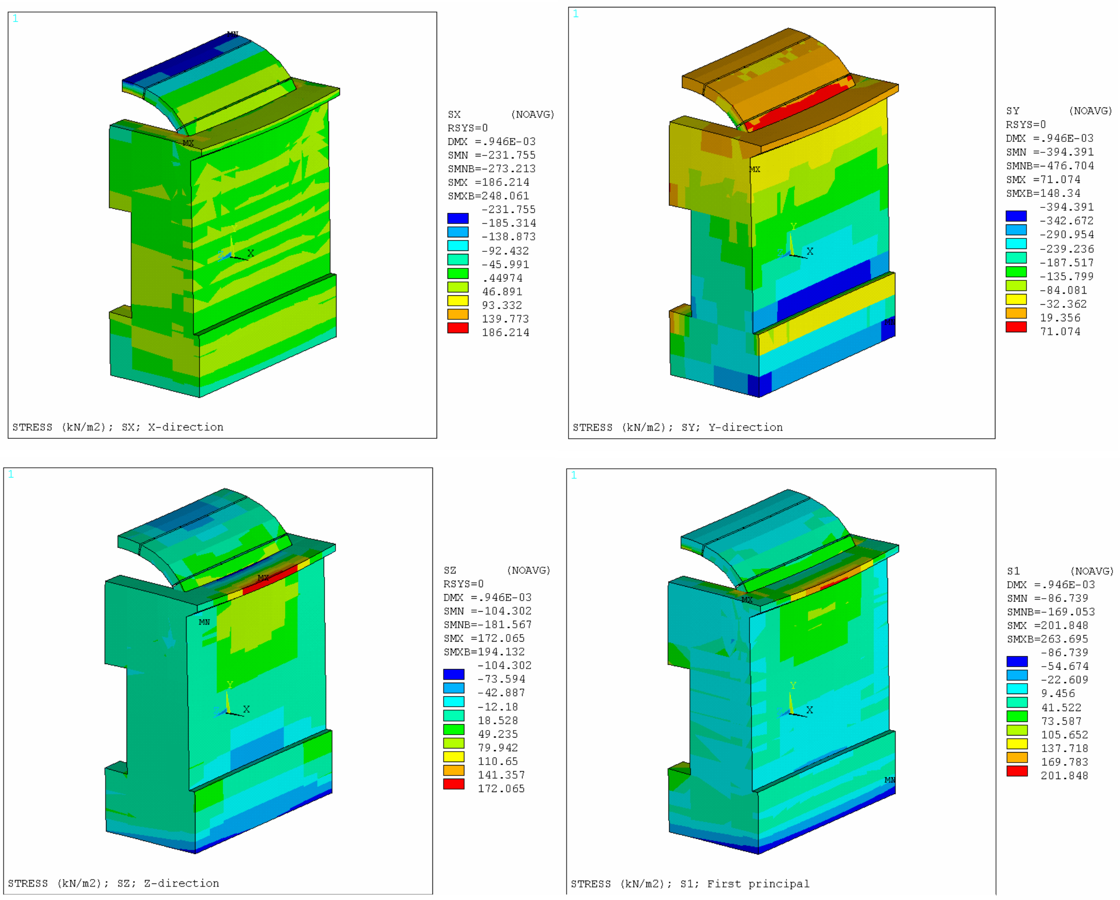

Figure 11 : Prints of tension

The bearing power of longitudinal walls against the impact of vertical and horizontal load of the vault and wall was tested according to Derand's (1643), Rodrigo Gil's (1550) and Simon Garcia's (1680) "geometrical formulae" to compare the results. The resulting wall thickness needed was approximately 20% bigger than the actual one, which is understandable concerning the fact that longitudinal walls are not free-standing, but laterally supported by the eastern cross walls

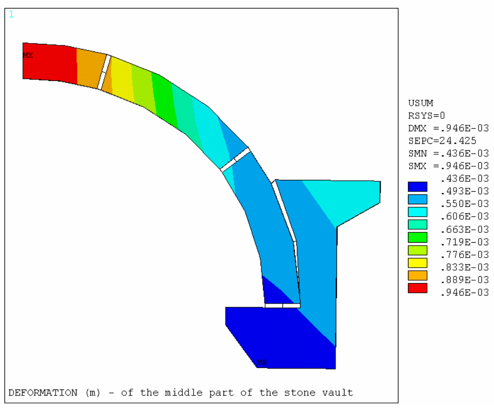

Figure 12 : Print of magnified vault distortions

However, the resulting values are not large, neither for tension nor for shear, but they illustrate the behaviour of the entire temple construction very well.

Opening the *gaps* (load and tense in elements) corresponds the fractures at the vault, which are typical in the case of horizontal shifting of supports.

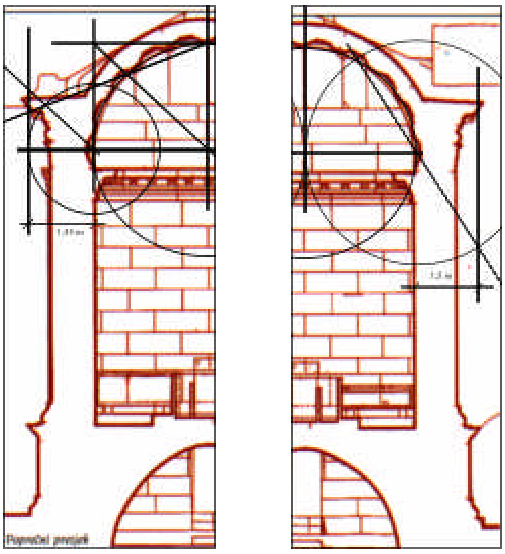

Figure 13 : “geometrical formulae”

Longitudinal walls are therefore lent to three sides, while the load stress impacts at the fourth side, but together with strengthening the wall dimension by horizontal cornices, so the transmitting of load must be interpreted by means of the three-dimensional, rather than two-dimensional model.

The shifted and damaged ashlars of western gable are the most threatened parts of bearing construction. The only reconstruction intervention option is disassembling all the ashlars from beginning of the vault level to the gable top. The ashlars have to be restored after that, old iron ties replaced with new ones made of stainless steel, all touching surfaces should be treated and the ashlars returned to their places.

It seems that ashlars on longitudinal cornices suffer damages at the places where iron ties were built in, the reason for their deterioration is the activity of ties together with corrosion that arose after their permanent exposure to environmental bad impacts.

With braking of iron ties on the ashlars, the cornice’s share in total load transmitting goes down to the lower layers of the wall, which uses both the load and the condition of rubbing to activate bearing potential. With active iron ties one more share of cornice, together with the one described earlier, gets additional part in transmitting load stress establishing potential support for horizontal weight from the pressing of vault, and at the convenient place concerning the vault cross section.

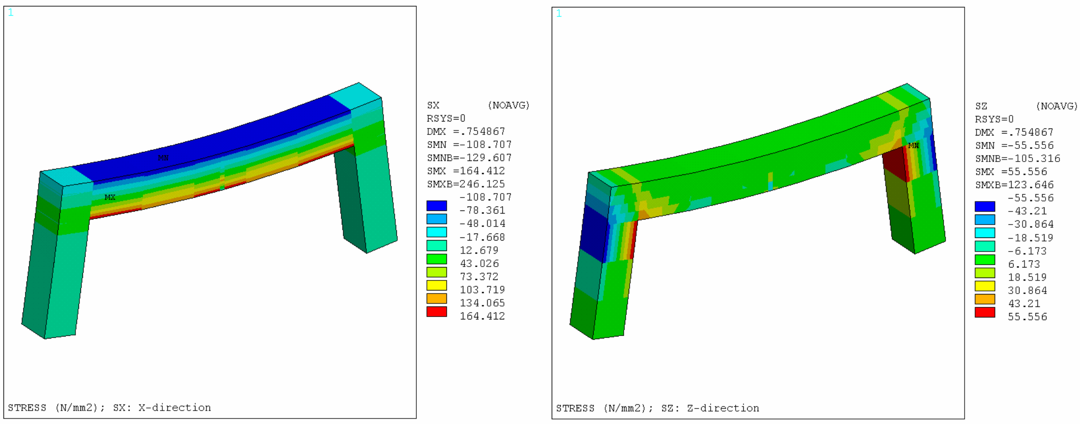

Figure 14 : Print of tension of the tie

Comparing the behaviour of the whole model of bearing structure with the model in which longitudinal horizontal cornices are removed has shown their share in shears and tenses in the vault and in lower parts of walls as well.

Dimensioning new ties was done by means of partial model using the tensile stress extent that appears in cornice under affection of horizontal load of the vault.

Because of all mentioned, the recommendation for reconstruction that seems reasonable is mutual joining the ashlars of horizontal cornices, as well as building in a new ashlar that is missing at southern wall, using the same method a the original one, except the new ties that are planned to be of stainless steel. This is the way to establish a lost part of total bearing potential of horizontal cornices again, resulting in getting a useful closed belt over the cross walls, that could take an important part in the case of earthquake as well.

"It is opportune to recall the insistence with which Alberti recommended the continuity of the cornices which form a "belt" half-way up and at the top of the building." in : "Protection of the Architectural Heritage Against Earthquakes", 1996. : A. Giuffre : 2A Mechanical Model for Statics and Dynamics of Historical Masonry Building, page 103.

5 SIMULATION OF BEARING STRUCTURE BEHAVIOUR

The simulations of bearing structure behaviour were made without horizontal cornices as well; then with the load of the old bell tower, and finally the combination with the vault and longitudinal walls only, without their cross walls supportings.

Results of these model tests are interesting since they show that, even in cases when certain parts of the bearing structure are weakened, the stability of the whole still is not vitally threatened, and that the temple's actual condition with all existing damages, spending its reserves of bearing ability endures successfully after all.

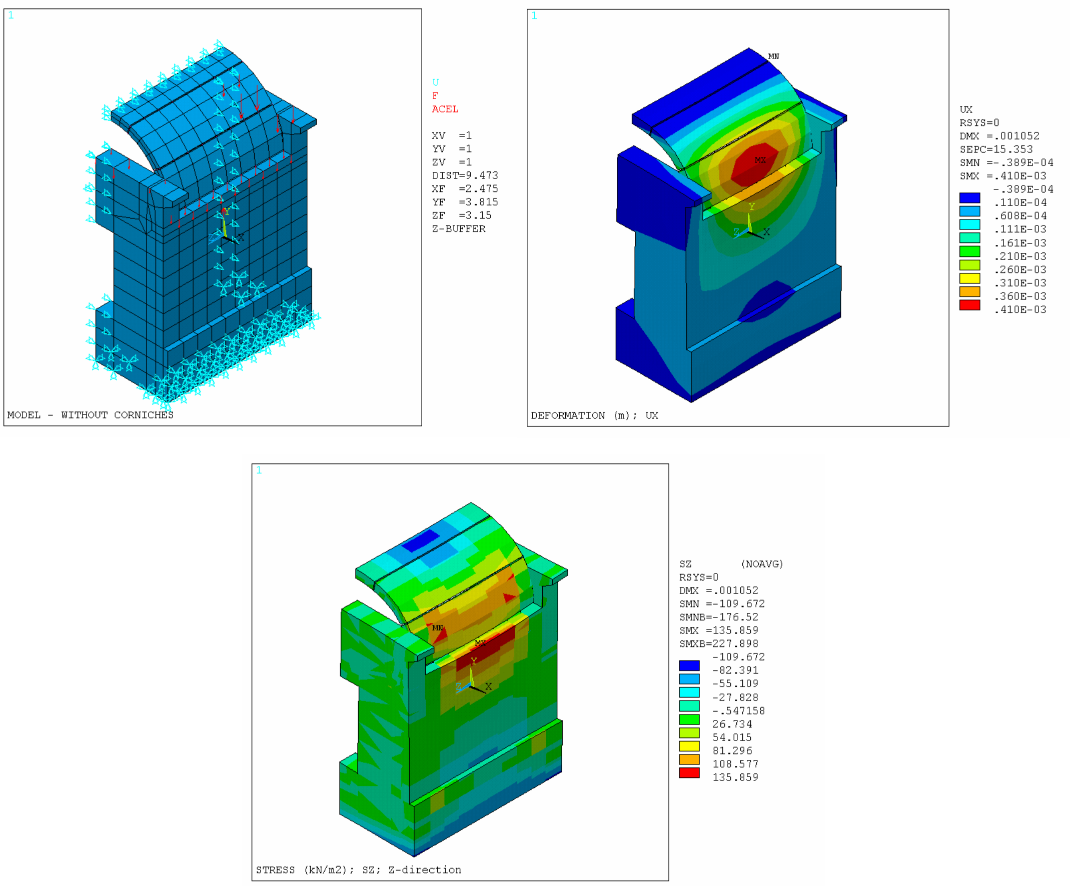

Figure 15 : Model of bearing construction without horizontal corniches

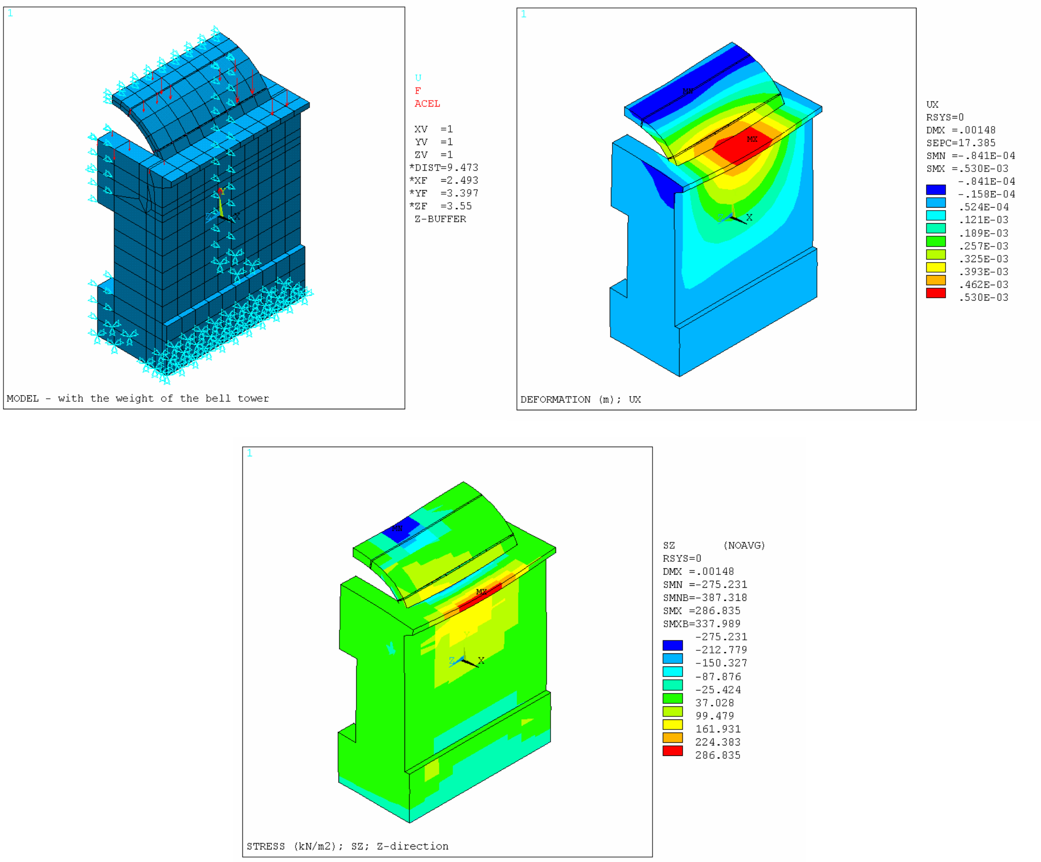

Figure 16 : Model of bearing construction with the load of the old bell tower

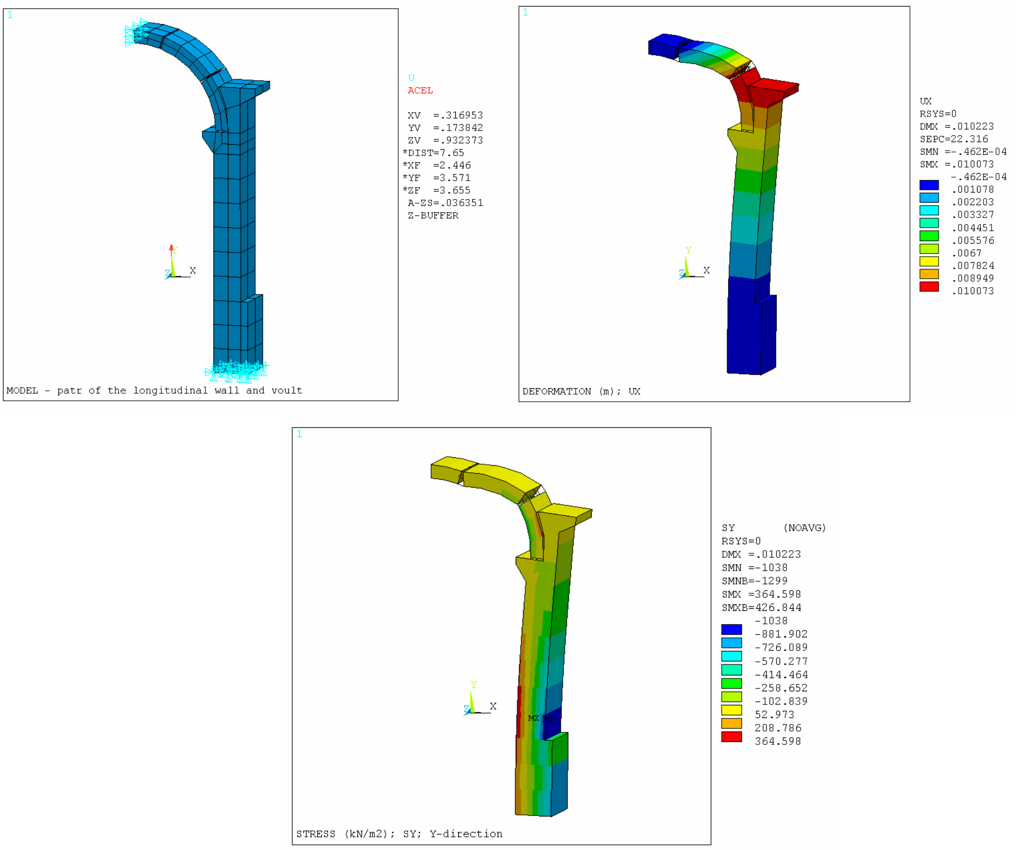

Figure 17 : Model of the part of bearing construction of the vault and longitudinal walls only

6 PROTECTING

7 THE TEMPLE FROM BAD ENVIRONMENTAL INFLUENCES

Together with reconstruction of the bearing construction parts, the temple has to be finally protected from rainfall and other bad environmental impacts. A lead covering on the bearing under-construction of steel “T” profiles is planned for protection. The board shuttering and a layer of hydro-insulation are laid over the profiles as a support for lead covering. The covering is set in a way that allows ventilation space between lead covering and stone vault to prevent any kind of inconvenient physical condition.

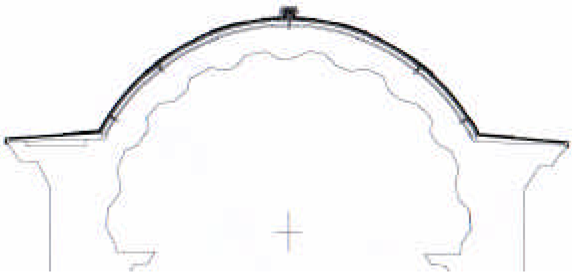

Figure 18 : Part of the cross section plan with the new lead covering

7 CONCLUSION

Actual damages of bearing structure of Jupiter's temple, and all its parts are the bearing structure have reached the degree that calls for reconstruction. Respecting its value as the cultural property, the condition of material every part of bearing structure is made of and the type and the number of damages, the proposed reconstruction method has to respect the original condition completely. The temple’s condition is fortunately not essentially changed, so the proposition is just to return the missing parts to the bearing structure. This way the model of transmitting load is completely preserved, the damaged parts are restored and missing parts replaced, the same in shape and material, completely protecting and renewing the original material substance of the building. The only new thing is the protection from environmental bad impacts, which is indispensable in making certain the long life of the temple.

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