ICOMOS Technical Review

Property	**Bagrati Cathedral and Gelati Monastery**
State Party	**Georgia**
Property ID	**710**
Date inscription	**1994**
Criteria	**(iv)**
Project	**Proposal for reinforcing the base of the drum of the dome of Gelati monastery**

ICOMOS received a report on the *Project of the Arrangement of the Metal Belt on the Bottom Point of the Drum at the Church of the Virgin of Gelati Monastery*, submitted to the World Heritage Centre by the State Party on 20 July 2015.
The documentation included with the report contains the following files:

- The proposal for strengthening the base of the dome;
- Test certificates for the stainless-steel flat bar (Animation, versions I-II-III);
- The table of results from the seismic modeling;
- Certificates for the material proposed to be used.

The **Report on the joint ICOMOS / World Bank advisory mission, 21-25 January 2015** (hereafter **– Report**), raises the question whether the drum of the dome could withstand potential strong horizontal seismic pressure, given the following facts: the great height of the drum, the large number of openings (windows) that perforate the body of the drum, and the narrow trunk of the intermediate walls-piers (see Report: pages 32 and 41-par.5.3.2 and compare figs. 67-C, 68 and 18).

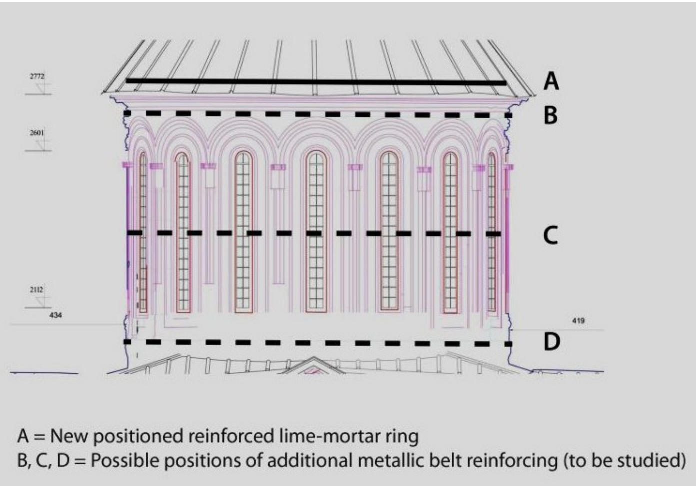


Figure 67. The cupola : position of the established ring and additional reinforcing

Fig. 18. The cupola : condition before hypothetical starting the architectural rehabilitation works

<u>ICOMOS agrees with the proposal for the reinforcement of the lower part of the drum with a metallic belt which will be attached onto the drum structure and to the pendentives with anchors.</u> From a structural point of view, the metallic ring appears to be efficient. The tension stresses are absorbed by the resistance of the metallic ring. This circumstance gives an important role to the structural behavior of cupola-drum system.

Figure 68. The S-W windows of the drum, closed
with masonry of bricks / stones in mortar

In this regard, ICOMOS would like to propose the following comments for consideration:

A. In order to ensure better adhesion between the metallic ring and the stone construction of the dome, it is proposed to introduce a filling in the space between the two mating surfaces. On the issue of this kind of collaboration between the two materials, in the **Report** it was recommended that *"… if necessary, the ring-beam's contribution can be improved by inserting, between the ring-beam and the base of the dome, a system of jacks able to produce supplementary horizontal radial inward forces (fig.79, fig.80, fig.81), pre-stressing, by this way, the dome ..."* (Report page 41, par. 5.3.1). The system of jacks can ensure satisfactory adhesion between the ring-beam and the cupola construction, and therefore a constant and controlled cooperation between them in a more "flexible" way, which additionally could "undertake" future tensions resulting negatively to further opening of the cracks.

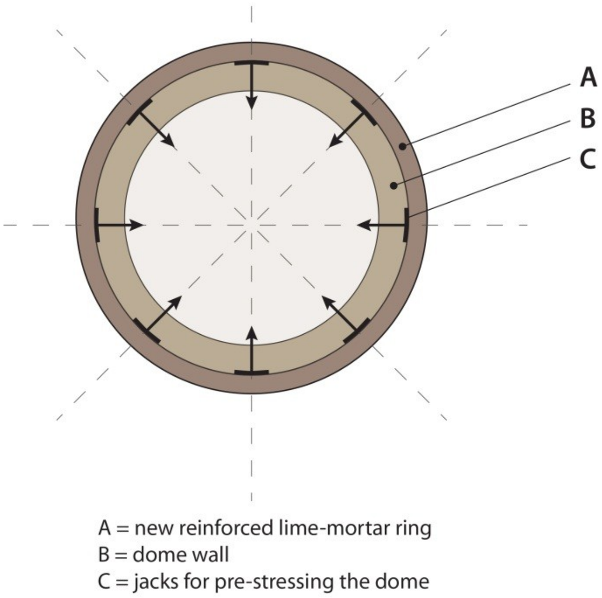


Figure 79. Proposed jacks for pre-stressing the dome

B. Furthermore, the **Report** points out that *"The historical research has shown that the Cathedral has resisted well to earthquakes even if more precise information should be necessary*" (page 40) and that *"some specific research on the characteristics of this action (magnitude, intensity, epicentrum and frequency) should be done in the development of the project"* (page 19). On this matter it should be underlined that a micro-zoning analysis of the historical seismic behavior of the Gelati Monastery wider region is an integral necessity of the structural analysis of the monument - and this was noted in No.8 of the **Conclusions and Recommendations** of the **Report** (page 54). This data should have been taken into consideration for the analysis of the seismic forces on the monument.

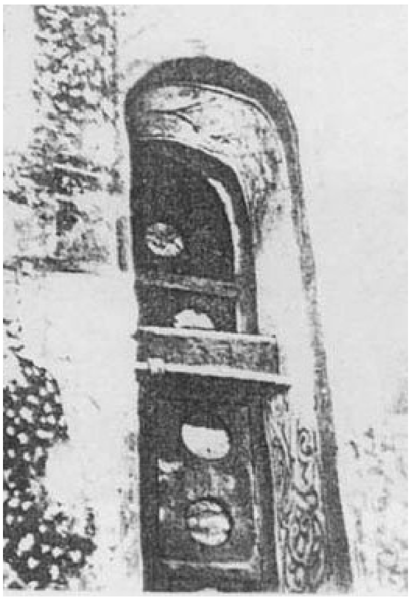
C. The already installed reinforced ring-beam at the base of the hemisphere (place A of Figure 67) and the additional proposed metallic belt at the base of the drum (place D of Figure 67) will undoubtedly enhance the static stiffness of the drum at its upper and lower ends.
Regardless of these interventions, the behavior of the body of the drum (place C of Figure 67) remains problematic in the case of a future strong seismic act. After this, the most weakened parts of the drum remain the elongated "free-standing" masonry piers. This is proved by the "Structural Analysis" of the "**Proposal for reinforcing the base of the drum of the dome":** displacement along the axes X and Y (plans F1X and F1Y in all three versions I-II-III), where the cupola is more vulnerable to the directions E → W and S → N instead of W → E and N → S because of the already walled windows of the drum.
In this connection, the issue of strengthening the drum window piers and openings appears crucial. As it is not possible to establish an anchorage truss system for the drum (which would be visible), it is of particular interest that the Georgian experts are considering the possible effects of the introduction of horizontal wooden joints for strengthening the window openings. The idea is studied in the "Table of results, Scenario III", but the results do not seem to improve the behavior of the dome construction and this is at least strange. On this matter, more details regarding the size and location of the considered timber tie-beams in the window openings should be provided.

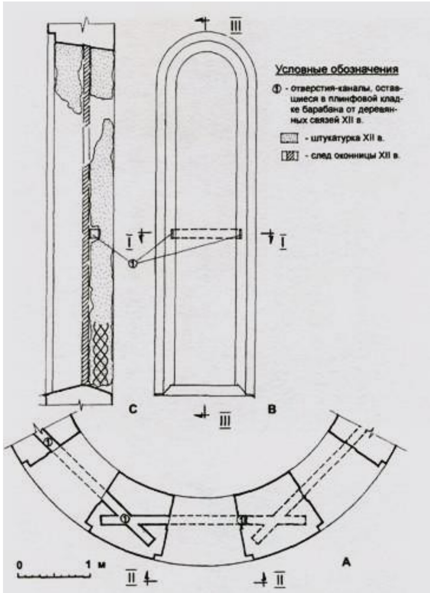
In this regard, and in order to encourage the research on strengthening the stability of the cupola of the monument to this direction, it should be noted that the use of similar wood tie-beams during the construction of the drum window openings is well known in Byzantine architecture (e.g. Mother of God Kosmosoteira Church near Evros River, Greece, built by Isaakios Komnenos, 1152 – Figure 1).

Figure 1. Wood tie-beams on the windows of
Mother of God Kosmosoteira Church, Greece

The use of oak jumpers in early Russian monuments and especially in architecture of the pre-Mongolian period is also well known. These wood tie-beams in some cases served additionally for fixing the window sills (full length) made of a hewn oak or pine boards with holes on them (e.g.

Novgorod, Mother of God *katholikon* (1119) in St. Anthony monastery: window with preserved medieval (and restored) wooden window-sill, Figures 2, 3; Smolensk - Church of Archangel Michael (1180-97), Figure 4).





Figures 2, 3. Novgorod - Mother of God *katholikon* in St. Anthony monastery: window with preserved medieval and restored timber window-sill

Figure 4. Smolensk - Church of Archangel Michael: wood tie-beams for fixing the window sills

The wood tie-beams were used in some cases, additionally, as lintels on the limitation of window openings, while strengthening the construction with partial walling (e.g. Kiev- Church of the Saviour in Berestovo (1113–1125), Figure 5; Novgorod, Mother of God *katholikon* (1119) in St. Anthony monastery, Figure 6).

Figure 5. Kiev - Church of the Saviour in Berestovo: northern wall windows
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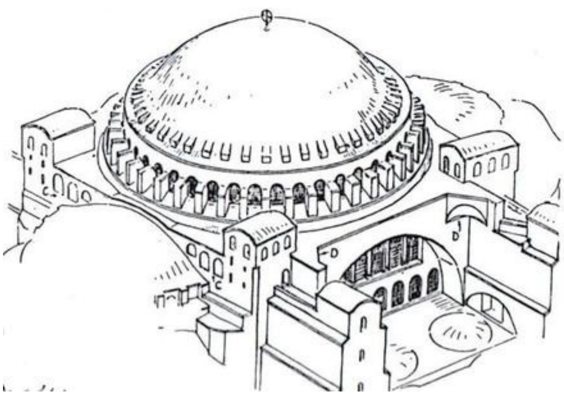
Figure 6. Novgorod - Mother of God *katholikon* in St. Anthony monastery: walling of window opening s

In the Gelati Monastery *katholikon*, wood tie-beams are still preserved in some of the drum's window openings. There is no information provided as to whether they are original. Furthermore, it is unknown whether timber tie-beams were used as horizontal lintels in the already walled window openings of the drum. It would be worth investigating when these openings were walled, which in any case should have been before the existing wall-painting of the dome (Figures 7, 8).

Figure 7. Wood tie-beams still preserved on drum window openings

Figure 8. Walled drum window openings

Let us remember (from a historical point of view) the strengthening works which were carried out similarly on the piers of the drum of St. Sophia in Constantinople, after the collapse of the original dome and during its reconstruction with a more normal hemispherical shape with a 6 m. raising up (559 AD - Figures 9, 10).



Figures 9, 10. St Sophia in Constantinople – reinforcement of the piers between the windows, after the collapse of the original dome in 559

The Daphni Monastery (with its famous mosaics, inscribed on the World Heritage List in 1990) is situated on a Neocene tectonic graben, on the western side of the Athens basin. The church was built in 11th century AD. Large-scale damages were reported in the 13th and 14th centuries. In 1889 and 1897, after the damage caused by earthquakes (estimated magnitudes of 6,7 and 7,0 on the Richter scale), restoration was carried out on the church. The heavily damaged dome and its drum were removed and reconstructed. Three concentric iron rings (I – beams) were inserted at the base of the dome's drum. The mosaics were cleaned and consolidated. These interventions helped the monument to survive until the end of the 20th century. Unfortunately, extensive damage occurred during the latest Athens earthquake (September 7th, 1999 – 5,9 g) especially to the drum and particularly to the masonry piers of the drum (which are lower and wider than those in the Gelati monastery *katholikon*). As emergency interventions, specially-designed steel elements were constructed to brace the windows and confine the masonry piers on two levels, with special care taken to assure the in situ assemblage of all these structures without harming the mural mosaics (Figures 11, 12, 13).

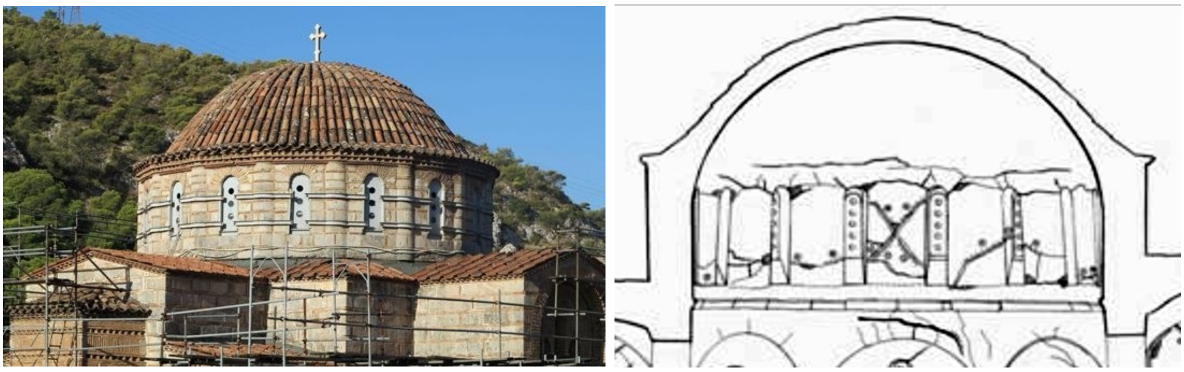


Figure 11. Daphni monastery, Greece: Specially designed steel elements to brace the windows and confine the heavily damaged masonry piers

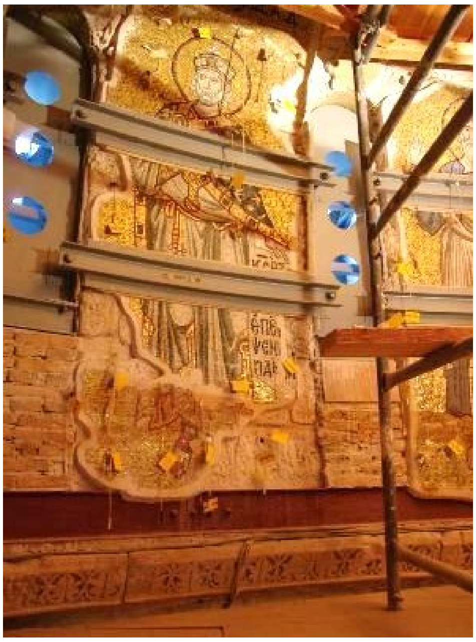
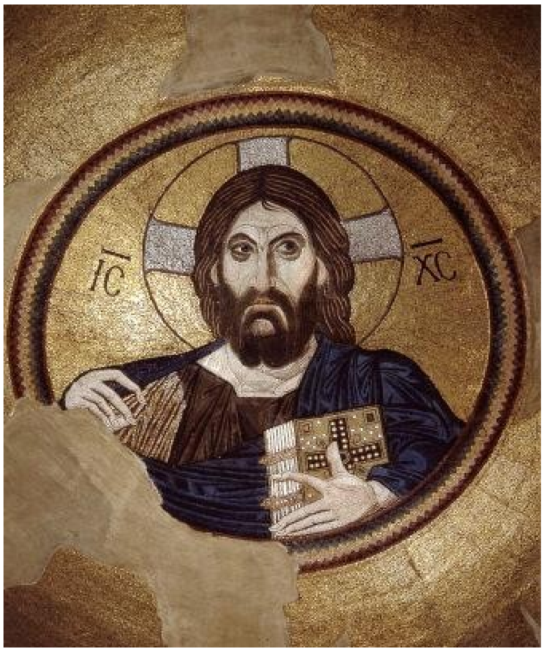


Figure 12. Steel elements to confine on two levels the masonry piers. Note the old I – beam on the lower part.



Fiure 13. The famous Pantocrator on the cupola's Daphni monastery *katholikon*

It is worth mentioning that during 1962 restoration works, extensive local re-pointing was carried out using mainly cement-based mortars. Fortunately the non-deteriorated old mortars were not removed. Thus, they survive today in better condition than those used by the restorers in ‘60s, which showed extensive decay and during the recent restoration works were removed (the mosaic conservation works are still in progress after so many years).

D. The electronic monitoring gauge which is currently being installed on the cupola of the Gelati monastery *katholikon* will allow the possibility of systematic checking of any movement taking place and for the problem to be addressed in time. In case of further monitored movement, in order to increase our understanding of the seismic structural response of Gelati monastery *katholikon* and to decrease the uncertainty of the seismic action, it would be advisable to install a seismic monitoring system which can evaluate the overall behavior of the construction and not only that of the cupola.

In such a case, for further improvement of the stability of the drum, it would be advisable to consider the idea of setting up specially-designed steel elements in the form of full length metallic windows, with strong steel frames, connected between them, in order to “close” the window openings, leaving small round intermediate openings for lighting the dome: this would be in practice an imitation of medieval full-length wooden windows. Such a construction requires additional calculations, taking into account the possible thickness of the metallic windows and the dimensions of the steel frames.

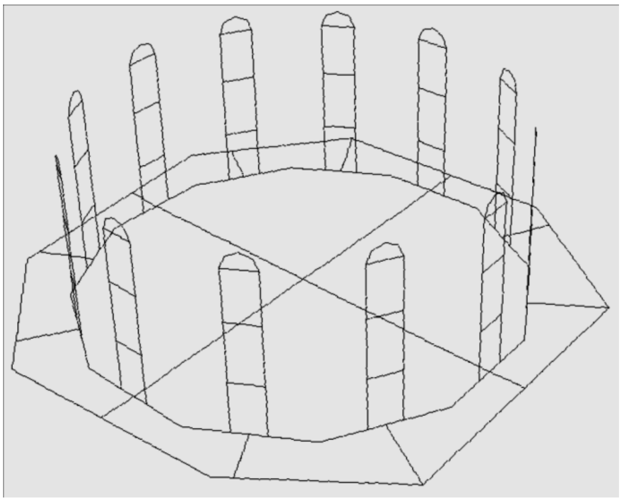


Figure 14. Schematic proposal for supporting the drum of the dome, consisting of metal rings and metal frames on the windows, while covered by full length metal sills

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