# Safeguarding and conservation of Gelati Monastery World Heritage Property, Georgia

*Agreement between LEPL "National Agency for Cultural Heritage Preservation of Georgia" and "ReStruere ltd, Florence University spin-off"*

## PHASE 2
## Analysis and development of the acquired documentation

## Deliverable 2
## Findings of the analysis: keynotes based on the results of the studies conducted by RS and GET

*Preparatory material for the remote meeting (organised on a PowerPoint presentation) with all teams, foreseen for the end of August-beginning of September 2022*

**July 29th, 2022**


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## How to approach the identification of the Guidelines

The current report summarises and finalises the entire content of Phase 2, “Analysis and development of the acquired documentation”.

ReStruere proposes Deliverable 2 as a preliminary synthesis of what was analysed, investigated and evaluated, together with the Georgian Expert Team and Microclimate Consultancy Team, during the last year of studies. The content of this document is preparatory for the meeting with all teams, foreseen for the end of August/beginning of September 2022. The meeting is crucial for the decision-making process that aims for the conservation of the Monastery. This report, the contents of which will be presented and discussed during the mentioned meeting, is aimed at initiating a roadmap that will allow a shared final landing on the Guidelines.

ReStruere thinks it useful to introduce now this document on which to discuss and evaluate the effects on the implementation, effectiveness, conservation and management of the Monument. Many and different can still be the technical solutions to be adopted and it is important to understand and share which are more compatible and feasible from a Georgian point of view. It is indispensable to activate, after about a month of reflection, a discussion table with Georgian Experts in order to better understand the main choices to be carried out (not yet a design). Here, the discussion will be facilitated by a PowerPoint presentation prepared by ReStruere.

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## Definition of the Terms

GET: “Georgian Expert Team”. It is the team in charge of carrying out the activities in Georgia related to the safeguard project of Gelati Monastery, World Heritage Property. The Team is composed of Tariel Kiparoidze and Lasha Shartava.

MCT: “Microclimate Consultancy Team”. It is the team in charge of carrying out the activities relating to microclimatic issues. The Team is constituted by Studio Massari.

RET: “Restoration Expert Team”. It is the Italian Restorers Team. The Team in charge of carrying out the restoration of frescoes and paintings, joined with Georgian Restorers. The Team in constituted by Marco Pulieri and Vincenzo Centanni.

RS: “ReStruere Team”. The Team is composed of Ugo Tonietti, Sara Stefanini and Arash Boostani.

## 1 - Results of the diagnostic process and key principles to be respected in the intervention strategy

### 1.1 - Results of the diagnostic process

On the basis of the collection of documents and reports drawn up during Phase 1, a reliable idea of the causes that determined the current unbearable situation, which puts at risk the conservation of the Monastery and the survival of the frescoes, can be exposed.

The precipitate of the harmful events after the integral changing of the roofing system during 2008-'19 allows reconstructing of the chain of crisis factors. These factors can be summarized as follows.

**A) *Defective materials***
Glazed tiles (both white and red type). In addition to the obvious damage suffered by the material in a very short time (Figure 1), the tests carried out at CNR-ISPC showed how the used tiles could not guarantee effective protection from water infiltration because of their composition and inadequate cooking (see "*Test on material samples taken on-site. Scientific report explaining the results of the tests*", December 2021).

Figure 1 - Damaged glazed tiles

**B) *Incorrect installation technique***

b1. The whole tiled surface of the pitches has been placed directly on an uniform thick layer of lime mortar (Figure 2). This layer was made by a porous mortar (as lime is), capable of absorbing a lot of water. The entire tiled surface was conceived as a stiff body, unable to allow the necessary small relative movements useful under thermic exposition. In addition, the ridges follow such a technique too (Figure 3).

b2. In some pitches, no insulation layer, able to protect the under-roof from the infiltration, is installed (Figure 2). However, even where some kind of insulation is present, both the material (quantity and thickness) and the installation are defective, in particular as concerns the connection line between the top of the pitches and the vertical surface of the stone-made walls on which the pitches rest (Figure 4). Furthermore, the nails, with which the tiles are anchored to the mortar layer, penetrate the isolation layer making it ineffective (Figure 5).

b3. Since the tiles covering layer does not exhibit autonomous support, it is forced to lean against the filling of the under-roof making ventilation solutions essentially impractical. Furthermore, the large quantity of the (variable) filling material of the under roofs, absorbing the water transferred from the tiles layer, constituted a reservoir of humidity, with devastating consequences for the life of the frescoes below (Figures 6 and 7).


Figure 2 - Thick layer of mortar insert during the last intervention. It is possible to see that in this pitch (belonging to the West Arm) there is no insulation layer;
Figure 3 - Particular of the ridge: also here there is a thick layer of mortar under the glazed tiles.


Figure 4 - Connection between the insulation layer and the vertical wall: the insulation is tucked up by just a few centimetres, insufficient for effective insulation.
Figure 5 - Nail that pierces the mortar layer. In this pitch (West Arm) there is no insulating layer; if there had been, as happens in other pitches, it would have been perforated.


Figure 6 - Roof stratigraphy: it is possible to see the wet filling under the mortar layer.
Figure 7 - Sondage carried out during autumn 2021: here also it is possible to see the wet filling.

**C)** ***Un-functional design solution***

c1. The roofing of the pitches does not have sufficient overhangs to guarantee the protection of the cornices and other parts of the stonewalls (Figures 8 and 9);

c2. There are no specific protection devices on the intersection surfaces between the pitches and the vertical walls or in coincidence with the valley where the risk of infiltration is greater (such as flashings) (Figure 10);

c3. The absence of devices useful for the collection and channelling of rainwater (gutter and downpipes) is assessable as a cause of the damage and deterioration to the masonry walls of the monastery (Figure 11). This item includes the broader one of the transmission system of the rain from the roof to the ground and the subsequent removal from the foot of the building. Consequences of this deficiency concern the phenomenon of rising water by capillarity at the floor level too.


Figure 8 - Insufficient overhang of the roof in the West Arm facade.
Figure 9 - Particular of the pitches at the base of the drum: here the cornice protrudes more than the pitch.

Figure 10 - Absence of flashing at the intersection between the pitch and the vertical wall;
Figure 11 - Absence of gutter and downpipes in the Monastery.

## 1.2 - Key principles to be respected in the intervention strategy

The cultural-technical issues on which the coverage functioning model is based are set out below. It is worth pointing out that it is important to consider these key principles as integrated with each other in order to achieve an efficient and effective project.

**Key principles**

1. **Historical-aesthetic compatibility** of the new roofing, connected to the construction and architectural reality of the monument. For this reason, it is significant to adopt a material for the final roof covering layer which is coherent with the usual materials already present in similar Churches and accepted by people and recognised by international institutions.

2. **Control of the persistence or formation of humidity by means of ventilation**. The new roofing system must permit the evaporation of the humidity to the outside through the ventilation, capable of aerating the under-roof/vault-extrados. This space will be partially emptied to facilitate transpiration and ventilation.

3. **Compatibility and interaction between all elements of the new coverage** in pursuing the target performance of the project with respect to specific **safety and security needs**. To achieve this it is suggested to adopt a support structure for the new roof which will be structurally autonomous, light and not-thrusting on the perimeter walls.

4. **Control of the water impermeability** by means of a sealing element (water insulation layer), **control of the formation of interstitial condensation** by means of a control layer to the diffusion of steam (vapour barrier), **control of the thermal changes** through the presence of an insulating layer. To obtain such a kind of performance it is important to provide the new roofing with a performing technological package.

5. **Control of the rainwater** in order to protect the Monastery from the harmful effects of atmospheric agents. It is necessary to create a robust water runoff system on the roof able to remove the water and collect it, by transferring devices, to the ground, where the integration with a drainage system will allow the water to drain away from the buildings.

6. **Carved stone cornices protection** through a correct design of the new covering.

7. **Protection of all the tricky and discontinuity points** of the roof geometry by means of any properly designed suitable device. Junctions, such as the intersection between covering and vertical walls, valleys and ridges, are critical points that must be correctly designed in order to protect the building from rain infiltration.

8. **Compatibility in terms of the useful life-time of each single element** with respect to the **duration** of the entire system with particular attention to the **ease of maintenance**. It is preferable to use resistant and durable materials arranged in a way that will be maintained easily, allowing the possible dismantling of little parts for substitution in case of necessity.

9. **Physical, mechanical and chemical compatibility** of the elements that guarantee the functionality of the roof. The use of tools and materials as sustainable as possible is indicated.

## 2 - Identification and study of the qualifying elements of the drainage and waterproofing project.

Once the main crisis factors have been identified (see § 1.1), it is possible to identify the principles to be followed in the radical renovation of the roof. In particular, we are interested in the activities and solutions that derive from these principles; since we need to identify the design steps needed to secure the Monastery (see Figure 12).

### 2.1 - Removal of ineffective current components

2.1.1 Removal of the current covering in all the pitches. The removal concerns the external layer of glazed tiles and the below lime mortar layer installed during the last intervention (2008-2019).

2.1.2 Removal of the incoherent materials present as filling in the under roofs and cleaning of the extrados of the vaulted system. It is important to distinguish between the different filling materials. The aim of this activity is to create a space in the under-roof useful for making possible ventilation. Therefore, inconsistent materials can be removed while the old conglomerate made by lime mortar and gravels, when still well connected to the barrel vault and of solid consistency, has to be maintained on-site.

### 2.2 - Qualifying components of the safeguard design

2.2.1 Creation of space in the under-roof useful for ventilation. As explained in item 2.1.2, it is necessary to set up a volume capable of permitting a constant air exchange (if possible by a chimney effect). For this purpose, we have to clean the extrados of the vaults from the incoherent filling, trying to achieve some channels for the passage of air (where the space was limited). At the base of the pitch (approximately at the level of the vault haunches) the space will be wider while, approaching the top, only a protected air outlet will be needed near the ridge. Most likely, we have to expect different situations in so many pitches, preparing ourselves to carry out targeted interventions.

2.2.2 What is suggested in 2.2.1 requires that the external covering and the layers of insulation and protection can rely on an autonomous support structure. This structure must be light and sustainable.

2.2.3 The design of a new structure supporting the coverage package will have to allow a new shape of the terminal part of the pitches, more protruding and protective for the moulded stones of the cornices.

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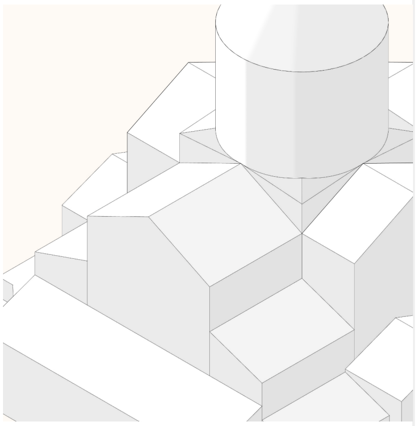
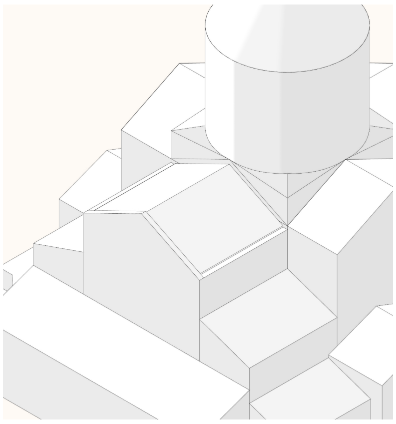
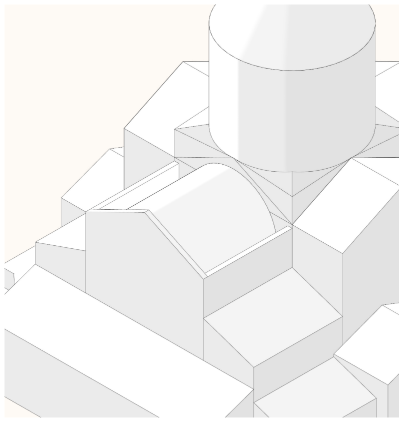
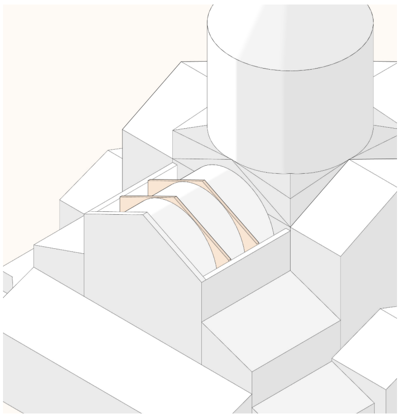
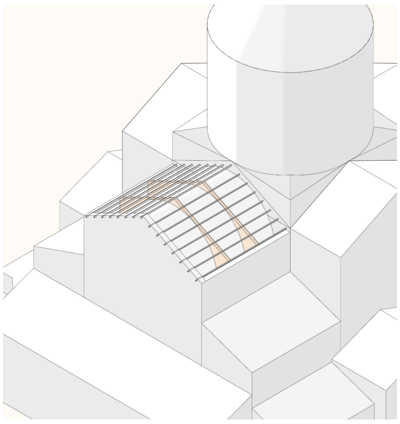
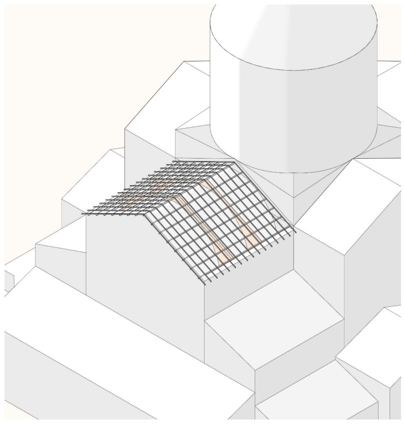
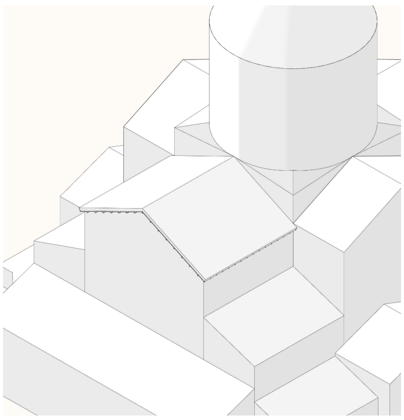
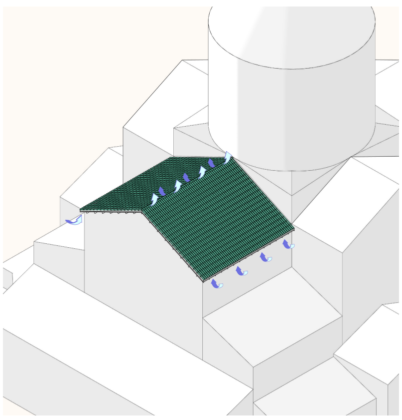
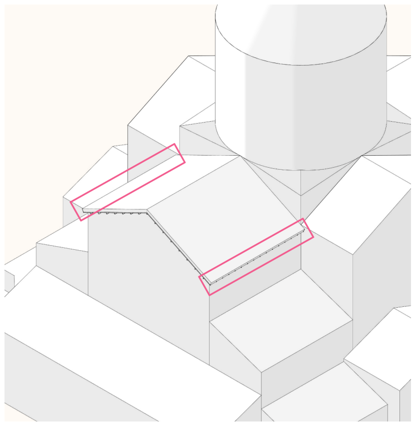
|  |  |  |
| *Existing situation* | *2.1.1 Removal of the current covering* | *2.1.2 Removal of the under-roof filling and 2.2.1 Creation of space useful for ventilation* |
|  |  |  |
| *2.2.2 Creation of the new structure for the roof used in old times: sort of spurs or buttresses (in Italian “frenelli”). The picture shows the proposal with only two “frenelli” (see also § 4 below).* | *2.2.2 Creation of the new structure for the roof: purlins (see also § 4 below)* | *2.2.3 Creation of the structure supporting the coverage package* |
|  |  |  |
| *2.2.4 Creation of the new package* | *Functioning of the new ventilation system* | *2.2.5 Attention must be paid to the creation of the water runoff system (gutters and downpipes)* |

Figure 12 - Scheme of the steps to be followed in the renovation of the roof. The scheme is purely indicative and only shows the West Arm as we currently have the documentation relating to this Arm. We have to expect different situations in the pitches, preparing ourselves to carry out targeted interventions.

2.2.4 The completely new organisation of the roof will have to guarantee - by the creation of a thin, stiff (and light) surface – the protection from water and insulation from thermal excursions. The current technology exhibits many different solutions (devices and tools); we have to choose the most suitable and sustainable for the Monastery life.

2.2.5 In the creation of a new shape for the lower parts of the pitches, a system must be provided for the collection of rainwater and disposal on the ground (in special channels). This type of intervention is considered necessary, even if it differs from the most traditional solutions for similar churches. In fact, the water percolation over the past centuries has determined a serious weakening of the masonries and a high exposure to the humidity of the frescoed parts. Today we can no longer expose the building to this threat if we wish to safeguard it.

**2.3 - Choice of roof covering material**

This issue is crucial in the Monastery Safeguarding project. Given the importance of the monument for the Georgian people and its inclusion in the WHC list, a serious study of possible solutions is necessary (in this regard, see the reference to the documentation on historical reconstruction of coeval roofs in the area, at item 1.2.2 in Deliverable 1.5).
A revival of glazed tiles roofing could be possible but this choice certainly has two contraindications:

- the first one concerns the fact that, if we prefer a light and easy-to-maintain support structure, we may find it more difficult to find a compatible technical solution;
- the second one, very serious, is that it needs a lot of time for the production of tested tiles even if it could be possible to import them from foreign countries.

Therefore, an easy alternative could be found on already tested roofing solutions with a metallic material (Figure 13). The copper represents a good, traditional, effective and pleasant material and the covering would certainly be light, sustainable and capable of ageing well. Furthermore, it is possible to pre-oxidize the copper in order to make it green in colour (green patinated copper) (Figure 14).
In any case, a careful discussion must support the choices to be made.
Furthermore, the presence of a pitch covered with stone slabs on the northern side of the Virgin Church opens up the discussion about the maintenance and/or reuse of this covering material.

The entire decision-making process and each design choice must include the prior consultation of the Georgian Authorities and of the research teams currently working on the Conservation project.

Figure 13 - Example of metal covering;
Figure 14 - Example of pre-oxidised copper.

## 3 - Investigation on the ancient water drainage system present on the site and evaluation of the possibility to put it back into operation

At present, the drainage system corresponds to the morphology of the land, which has a prevalent orientation from South-East to North-West. The choice to use only the grass covering as a drainage system dates back to the last interventions that interested the Monastery (2008-2019), as written in the report "*Gelaty Monastery, roofing of archaeological objects uncovered near the academy building and correction of general plan - Infrastructure and conservation project*" (2014):

"Within the project following works were done:
- Correction of the general plan which keeps principal positions of the general plan prepared earlier. However, changed is the format of the path for the tourists and pilgrims. Their parameters are slightly changed in order to increase area of a lawn. It was decided to deny preparation of the drainage systems around churches with stone because it was proved that water running from the roof of the church is getting reflected on the stone slabs and so wets and damages the base of the church wall. Instead of the drainage systems made with stone slabs, it was thought to use grass covering [...] which significantly decreases force of the water jet."

The report express also the need to "prepared a project in which it will be showed how the underground drainage system can be made with the idea to have underground drainage system or underground invisible drainage system", referring to the fact that "After the archeological study of the site it was established that historically there was a drainage system like that at the Gelati complex".

Actually, during archaeological excavations, ancient drainage channels have been found around the Churches of the Monastery (Figure 15). The ancient channels do not cover the entire site but are limited to portions of it. In particular, the ancient system consists only of portions located on the Northern side of S. George Church (Figure 16) and on the South-East of the Virgin Church (Figure 18). The ancient water drainage system is out of order for a long time and, moreover, it is not visible as it is covered by the ground (with the exception of a few stones on the north side of St. George, Figure 17). Its conformation and its state do not suggest the possibility of its rehabilitation.

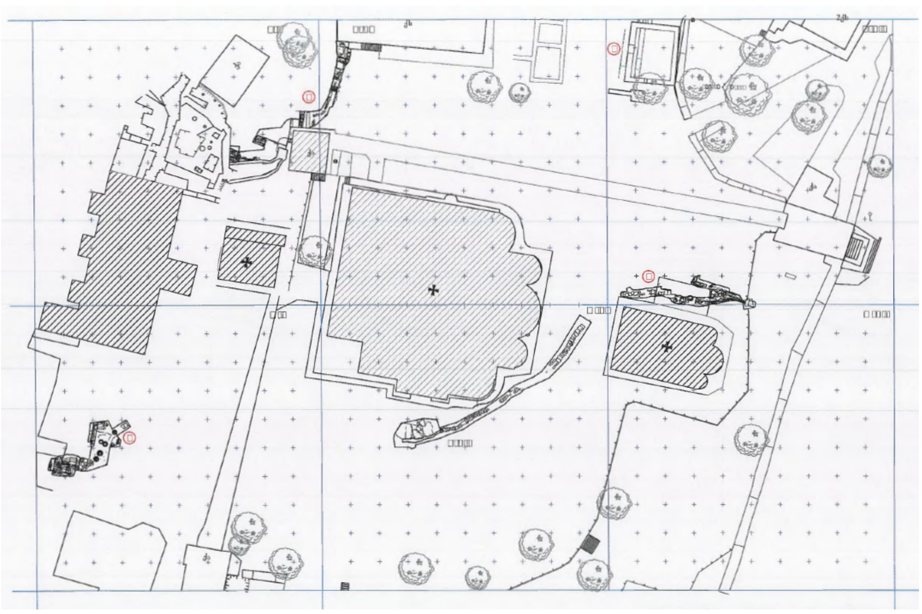


Figure 15 - Plan of the archaeological finds of the ancient water drainage system. From Photo Report on *Drainage Collector restoration-rehabilitation (2018-2019)* (DCR Ph Report) shared by GET



Figure 16 - The ancient water drainage system near Saint George (from DCR Ph Report);
Figure 17 - Partially visible drainage channel on the Northside of St. George (from MCT SG report);
Figure 18 - The ancient water drainage system near the Virgin Church apses (from DCR Ph Report).

For the collection and passage of water, there is a more recent system (2019-2020) consisting of downpipes, sewer manholes and a sewage network outwards pertaining to the Virgin Church (Figure 19). The scheme is described in detail in "*Investigations on the structural hygrometric and micro-environmental state aimed at safeguarding the internal wall paintings - Mission Arch. Alessandro Massari of 06-12 November 2021 (December 2021),* accompanied by Technical sheets regarding the *Current State* and the *Hygrometric Survey"* (MCT report).

Figure 19 - Detail view of downpipe d15 with manhole sm 9 (from MCT report).

Regarding the connection between the Virgin Church and the terrain, the building rests on a stepped stone plinth. Only a modest conglomerate sidewalk protects the base of the external walls. As explained in the MCT report, regrettably, for years large amounts of water have been let run freely on structures such as the plinth and the sidewalk from the above roofs. This led to infiltration and capillary rising damp phenomena considerably more severe than the current ones. Thus, it is evident that the sidewalk surrounding the church is inadequate in the instances of copious exterior water flow (Figure 19).

The situation appears more serious as regards St. George Church. Also here a stepped plinth connects the Church to the ground and there is a modest conglomerate sidewalk along the entire perimeter. However, here there is not a sewage network outwards with sewer manholes, but, as described in "*Church of St George - Preliminary investigations on the structural hygrometric - Missions Arch. Alessandro Massari of 06 – 12/11/2021 and 28/06 – 01/07/2022",* June 2022 (MCT SG report), "the water is discharged, with temporary pipes, immediately beyond the conglomerate pavement surrounding the small building where, due to the slope of the surrounding ground, it accumulates, flooding the pavement itself". The water stagnations along the outer perimeter of St. George are particularly abundant along the South and East sides (Figures 20 and 21) due to water coming in from the roofs and from higher elevations - in fact, there is terracing supported by a low stone wall along the East and South sides, but the space between the Church and the terracing has irregular slopes that are not suitable for regular water drainage. The serious situation on the ground outside affects the internal conditions. In fact, the walls exhibit moisture from the ground up to 1.5 - 2 meters with consequent damage to the paintings (Figures 22 and 23). For a detailed description refer to MCT SG report, accompanied by *Technical sheets* regarding the *Hygrometric Survey*".

Figures 20 and 21 - Views of water stagnations along the outer perimeter of St. George, particularly abundant along the South and East sides due to water also coming in from the roofs (from MCT SG report).

Figures 22 and 23 - Views of the interior spaces of St. George with widespread damage to the paintings which are lost, for the most part, in the lower part (from MCT SG report).

### 3.1 - Assessment-for-design Actions

Based on the information collected so far, it is crucial to ensure that the water can flow away from the Churches to preserve the masonries. Works for the protection of the foundation walls are desirable and necessary but, to be sure about the feasibility of a foundation drainage system (such as drainage ditches, Figure 24), it is necessary to better understand the relationship between the Churches with the ground. To achieve this, we advocate the assessment actions proposed by MCT (MCT report), which are:

- to carry out a dimensioned survey of the floors (ground) outside the Churches to check the slopes of the land and identify the current surface water runoff lines;
- to undertake some ground borings to study the foundations (construction techniques, type of materials, depth) and to assess the presumable existence of a superficial rock bank and its planimetric layout. This survey should be performed along the North, East and South fronts;
- specify the water runoff system for the permanent roofs.

Regarding the last bullet point, indications regarding the final roof design are now under evaluation and drafting of the water runoff system is foreseen in the future Guidelines for the Intervention Strategy.

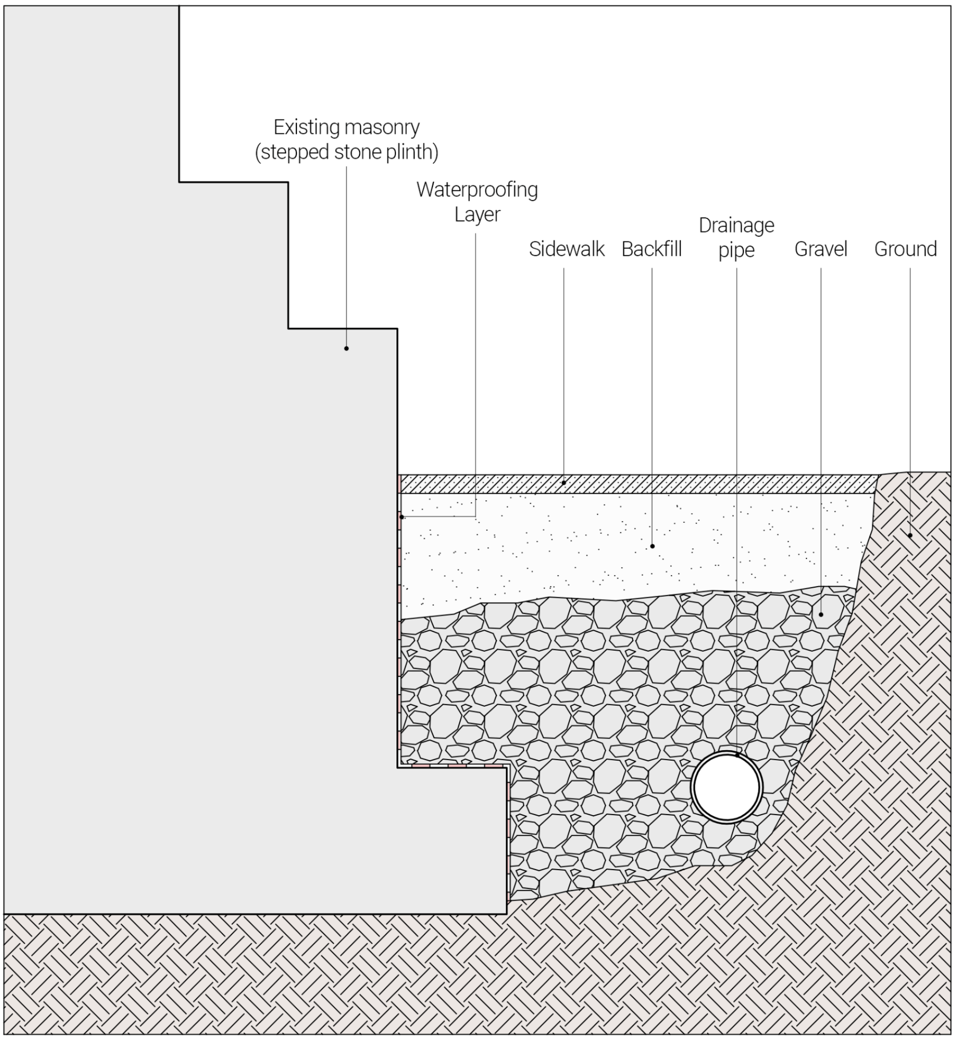



Figure 24 - Scheme of the drainage ditch.
It is important to note that the drawing shows a hypothesis of the Church's foundations.
Investigations are needed to identify with certainty the characteristics of the foundation system
(construction techniques, type of materials, depth…).

In addition, for St. George, as suggested in MCT SG report:

- realization of a specific campaign of investigations (completion of the instrumental hygrometric survey, sampling and laboratory analysis, small trenches on the outside of the building, etc.) that also takes into account the microclimatic aspects already monitored by the Georgian technicians but to be studied with particular regard.

**3.2 - Short-term Actions**

In St. George the treatment of the water carried to the ground by the downpipes is not correct as it leads to water stagnation at the base of the Church. While awaiting the construction of the new roof and the integrated water drainage system, interventions to protect the structure are considered necessary (MCT SG report), such as:

- to shaping of the ground slopes so as to divert the dispersed surface water away from the building with the creation of small terraces where the slope of the ground towards the building is too steep and collection of surface water with gutters;
- restoration of the exterior sidewalk or resurfacing of the same.

Moreover, it is necessary to install a water drainage system similar to that that was created for the Virgin Church consisting of sewer manholes and a sewage network outward.

**3.3 - Recommendations**

In addition to the actions to be taken in the short term and the actions aimed at the assessments necessary to design a drainage system for the entire site, as indicated in MCT report, it is an absolute priority to ensure constant maintenance of the building (e.g., of the joints between the stone blocks, with particular reference to those of the plinth) and of the technical equipment that protects it (fixtures, gutters, downpipes, manholes, etc.).

## 4 - Comparison of possible technical solutions to be adopted for the roof

**Design criteria determining the guidelines scenario. Identification of the most reliable solutions for Monastery safeguarding**

As a function of what has been clearly explained above, a list of technical interventions can be shown, organised by design areas. The aim of this section is to identify the fundamental design requirements (for each area) and connect them to different and possible technical solutions. At this phase, it is interesting to understand which solutions can be adopted and what repercussions they entail (in terms of conservation, sustainability, compatibility and feasibility). We think to make this discussion more accessible through the use of drawings and sketches. Some of them refer to the Gelati site (and to its real geometries) but others are taken from technical publications of the producers. In any case, the drawings are intended to illustrate only the requirements to be met. Only after a subsequent discussion with the authorities and the technicians and the institutions involved in the safeguarding of Gelati Monastery and the identification of a shared path to follow, it will be possible to identify the design choices that will be carried over into the Guidelines.

**4.1 - Ventilation**

The need to guarantee correct and efficient ventilation affects the entire coverage organisation. The ventilation is indispensable to prevent any other moisture problems in the future. A deep discussion with MCT put in evidence that to obtain an optimal roof ventilation system, it is advisable to create two separate circuits for the airflow (Figure 25):

1) External Package Ventilation (under-mantle ventilation). The first circuit will allow ventilating of the external package that will make up the roof pitch layers, in order to prevent the roof covering from overheating too much during the summer and from a great cooling down in winter. This ventilation has to be plentiful.
2) Under-roof Ventilation. The second circuit will allow ventilating of the under-roof and the extrados of the vaulted system (below which are the frescoes and paintings). This ventilation aims to prevent condensation phenomena and can be more moderate.

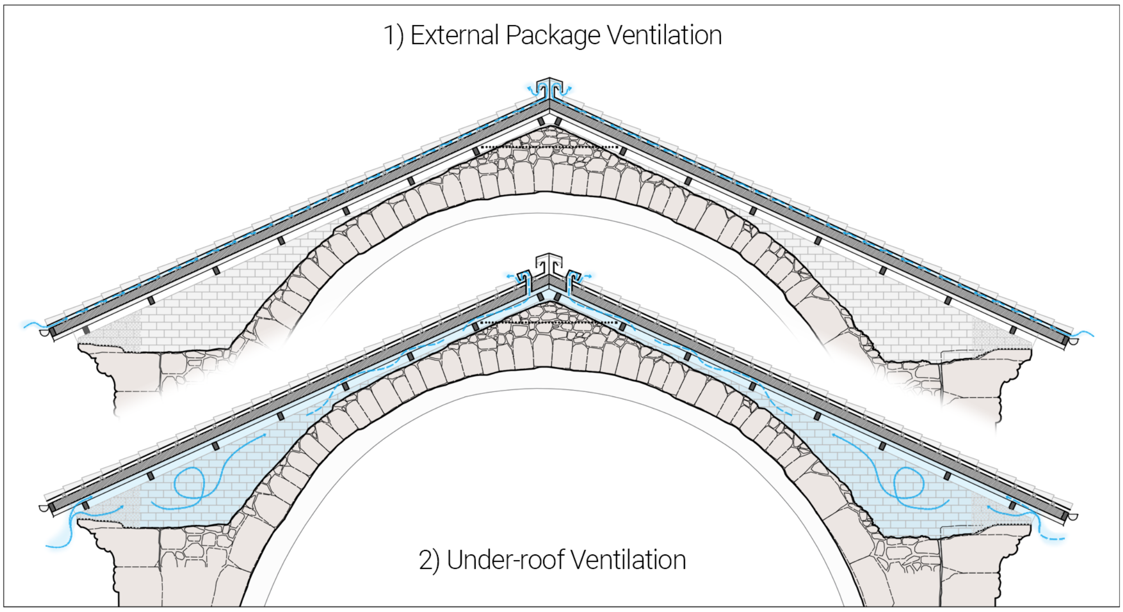



Figure 25 - Scheme of the double ventilation system. The external package ventilation system has to be plentiful, so the airflow outlet will be continuous along all, or almost all, of the ridge line. The under-roof ventilation system can be more moderate, so the airflow inlets and outlets will be punctual. In particular, the number of inlets and outlets requires careful technical evaluations in order to be defined.

The technical solutions to obtain such double ventilation are various. The important thing is to make sure that the airflows belonging to the two circuits must remain separated. Therefore, it will be necessary to pay attention to the definition of suitable technological details for the inlet and outlet of the air for the two circuits. Particular attention must be paid to the design of tricky nodes such as:

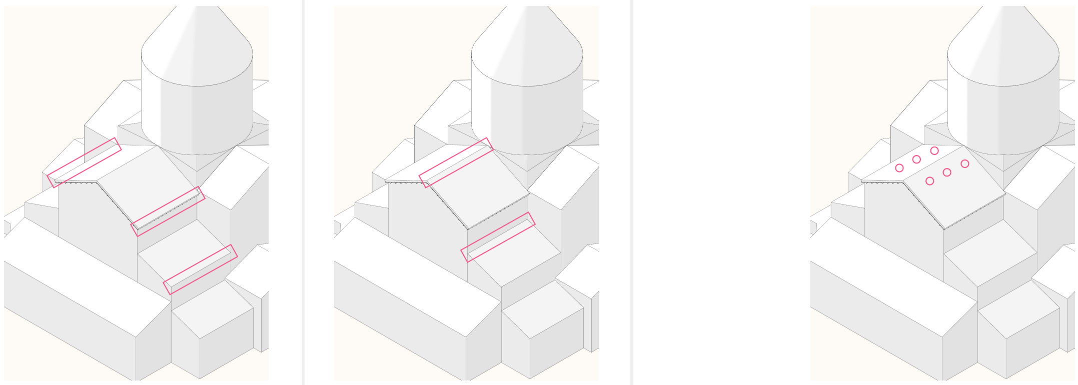
- Air inlet node, at the level of the gutters (Figure 26a);
- Air outlet node, at the ridge for the main arm's pitches and at the intersection with the vertical masonry for the minor arm's pitches (Figure 26b);
- Air outlet node of ventilation system 2, which, having to intersect system 1, must remain separate (Figure 26c).

Detailed drawings regarding the mentioned nodes are shown below (Figures 27, 28 and 29). It should be noted that these construction details are not intended to be representative of technical solutions to be used on Gelati, but they are intended to shed light on the technical problems to be addressed and to illustrate the requirements to be met. Some considerations regarding the drawings are the following:

- The drawings are based on the adoption of the spurs/buttresses (Italian "frenelli") as support for the purlins in order to avoid a thrust structure (see also § 4.3). These constructive elements represent an ancient technique to reinforce any type of vault through light masonry or to support the external roofing. This solution was also adopted effectively in the apses of Gelati Monastery. This is a possible solution to our problem, but alternatives can be studied.
- The connection between the system of buttresses ("frenelli") connected with the new roofing package and the stonework characterising the cornices and the West Arm load-bearing external

wall (see Figure 27) must be specifically designed taking into account the need to avoid thrusts on the cornices but also the crucial structural problems highlighted by the discovery of large longitudinal cracks ontop the perimetral wall. Such problems have to be addressed altogether within an anti-seismic consolidation design that requires in-depth dedicated studies (which we will work on afterwards).

- The drawings propose wood as a material for the roof support structure. However, the choice of the structural material is the subject of discussion as explained in § 4.3.
- The possibility to insert a chain to reduce the thrust of the covering is shown in Figure 28. This arrangement depends on the possibility of removing a little part of the old filling above the key of the vault. Regardless of the feasibility of inserting the chains, it remains important to reduce/cancel the thrust of the cover on the perimeter walls.
- An indicative proposal for the position and the shape of the air outlet for ventilation 2 is shown in Figure 26. This element must be carefully designed as it is a tricky node. Moreover, the ventilation 2 outlets could be integrated into the ridge (taking care not to make the two airflows intersect each other) if it is estimated that not the entire length of the ridge line has to be used for the outlet of the ventilation 1 airflow. Any technical possibility in this regard must be investigated in the light of considerations regarding the quantity of air that must flow to ensure proper ventilation.
- The gutters have been drawn according to a solution that makes them visible from the outside. If it is deemed appropriate to hide their presence for reasons of aesthetic compatibility, it will be necessary to design a solution with hidden gutters (see also § 4.5).



| *a) Air inlet node* | *b) Air outlet node* | *c) Air outlet points of ventilation system 2. The picture shows 3 outlets for each pitch, but the number and outlets require careful technical evaluations in order to be defined.* |
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Figure 26 - Position of the ventilation tricky nodes on which to pay attention. Every detail requires in-depth study.

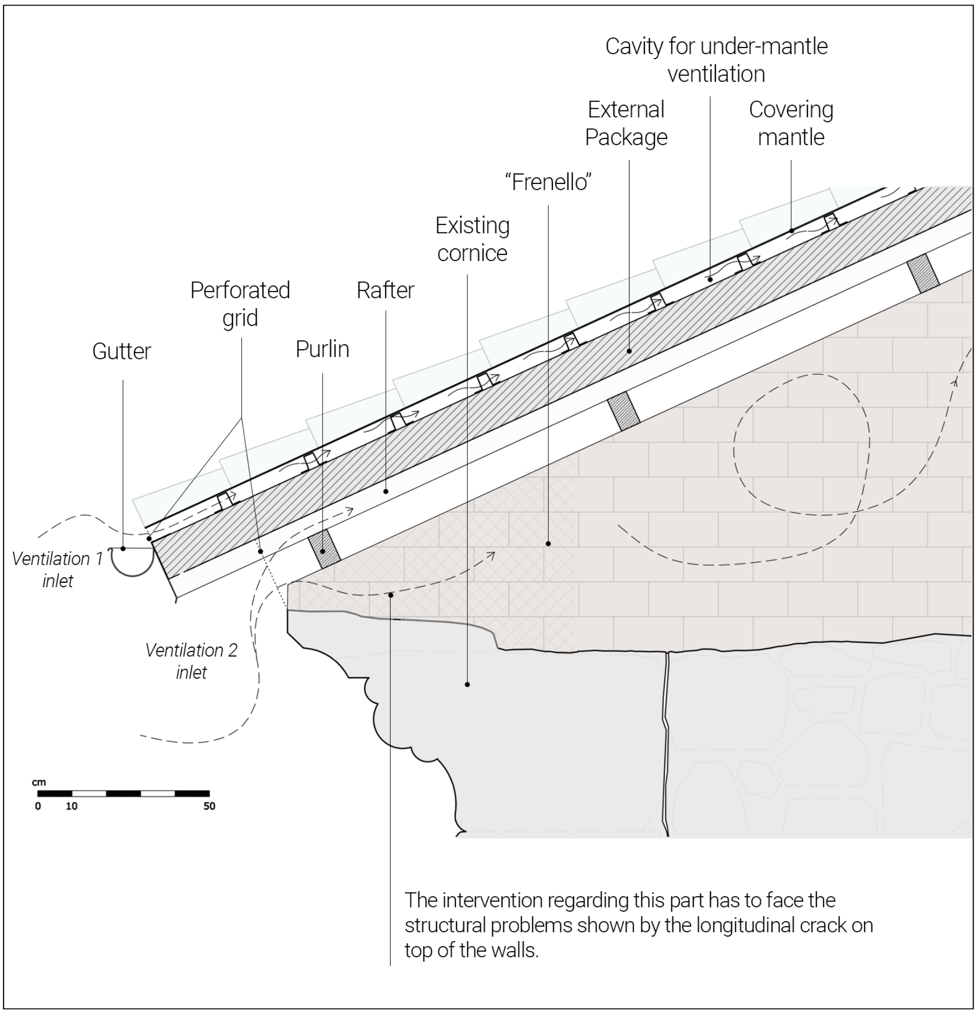



Figure 27 - Detail of the air inlet node.

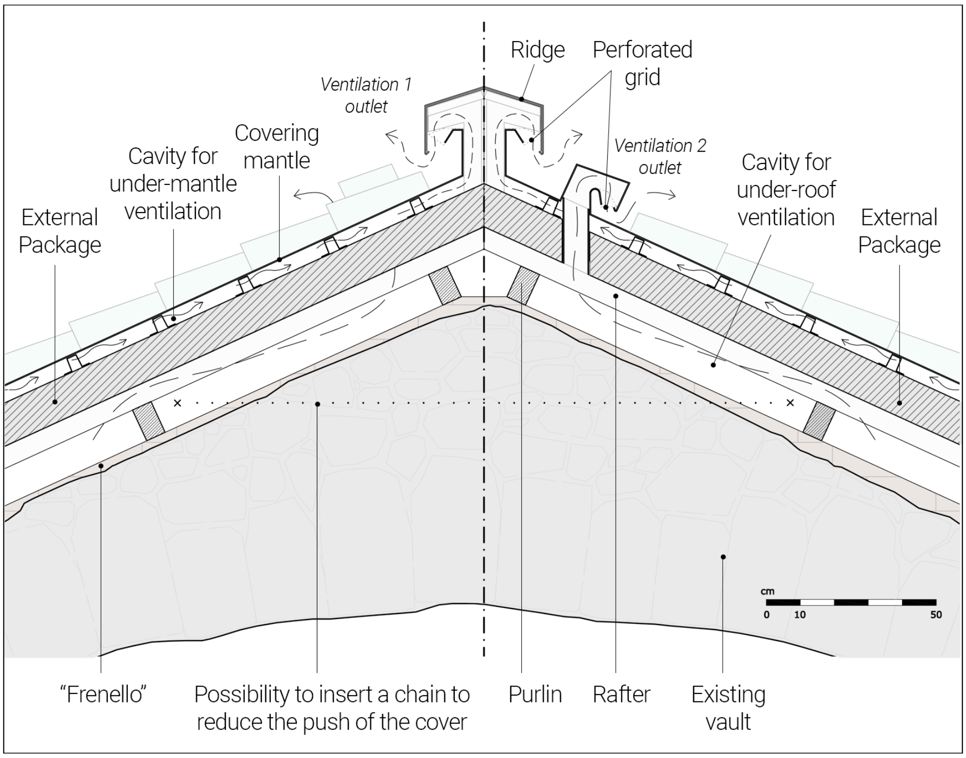



Figure 28 - Detail of the air outlet node at the ridge for ventilation system 1 (right) and for ventilation system 2 (left).

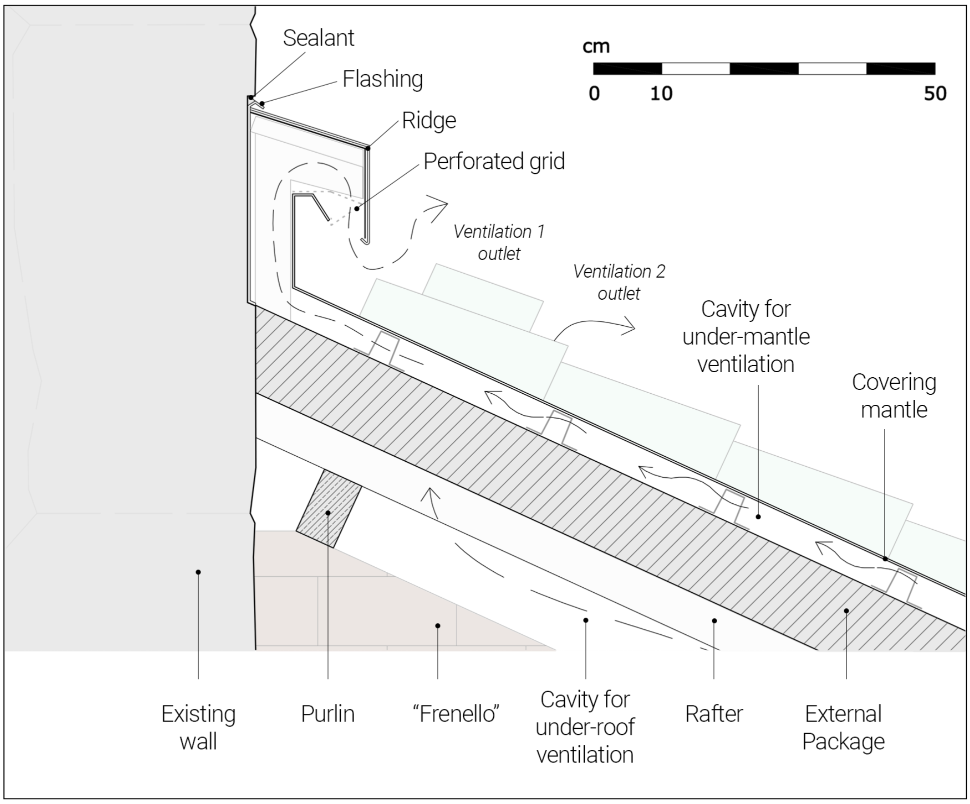



Figure 29 - Detail of the air outlet node at the intersection with the vertical masonry for the minor arm's pitches.

*Choices to make*: The surface of the air inlet and outlet section of the two ventilation systems is based on the amount of air needed for ventilation. Possibility of designing adjustable air inlet and outlet systems. The indications of the MCT will be essential for the definition of these parameters.

**4.2 - New roofing and external package**

The organisation of the outer part of the new covering system depends on the need to create a simple compact coat. The new package has to be comprehensive of (Figure 30):

- a thermal insulation layer to control the thermal changes;
- a vapour barrier to control the formation of interstitial condensation (this layer depends on the choices concerning the material of the thermal insulation);
- a new waterproofing layer to control the impermeability;
- autonomous ventilation aimed to prevent overheating and great cooling of the package (circuit of ventilation 1);
- a covering mantle.

The covering mantle can be made of tiles or "tiles-shaped" copper. In the second case, it is suggested to use green pre-oxidized copper. This choice has to be weighed in the light of the reflections on the historical-aesthetic and identity compatibility of the Monastery.

*Choices to make*: Material for the covering mantle (tiles or copper); materials for waterproofing layer. Material and thickness for a thermal insulation layer. This choice is reflected in the presentation and the type of vapour barrier.

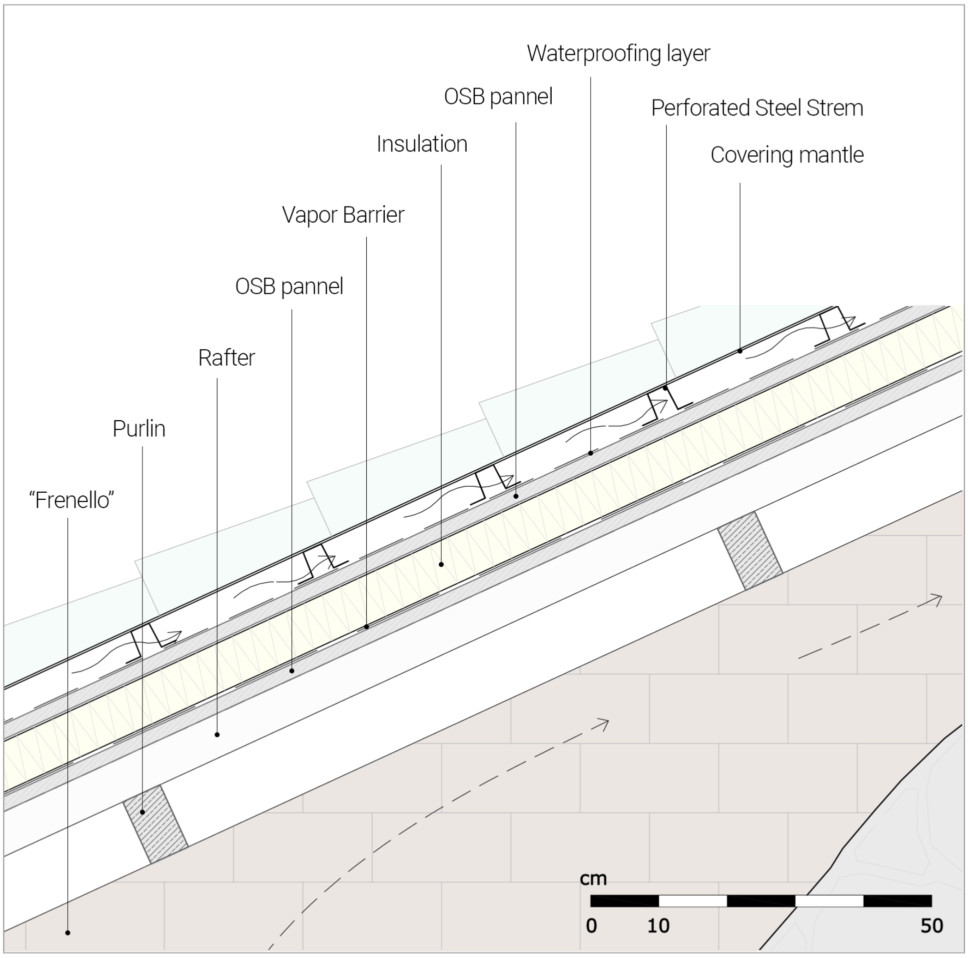


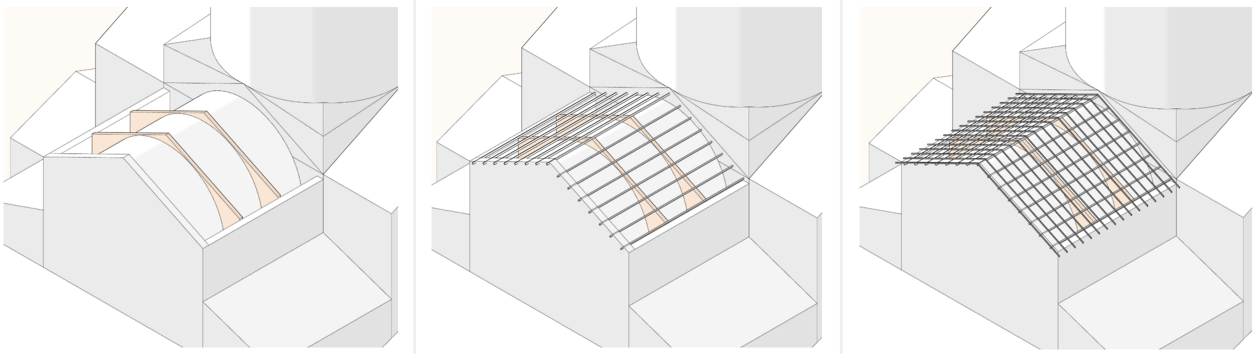

Figure 30 - Detail of the layers of the new external package. The drawing aims to make understandable the different layers needed within the package. The materials and thicknesses of each layer are the subjects of discussion.

Figure 31 - Example for the ventilation system 1. In this case, the covering mantle is made of tiles (from a technical publication).

**4.3 - A light simple structure able to support the external package**

The new roof should rely on an autonomous, light and sustainable support structure. Depending on the need to separate the external package from the under-roof space (and from the extrados of the vaults) a system of beams can solve the problem. Such a system has preferably to be designed able to not push on the perimeter walls (because of static and seismic reasons) and to be as thin and light as possible. Wooden or steel beams can allow achieving this. Some specific devices can be thought of in order to reduce the size of such a structure: a good solution may consist in building buttresses or spurs ("frenelli" in Italian constructive tradition) with bricks, connected to the extrados of the vault. This classic solution, of pre-modern origin, is light and also useful for consolidating vaults (Figures 32a and 32b). In our opinion, it is preferable to have a number of buttresses of at least 2 or 3 in the West Arm. In any case, alternatives can be investigated.
Moreover, the new structure must allow obtaining a sufficient overhang in order to protect the walls from water percolation (Figure 32b and 32c).
It is important to highlight that, at present, we can rely only on the clear cross-section of the West Arm so we can prepare solutions targeted to this Arm through what we can consider a pilot project. It is obvious how important the geometrical relationship between the extrados of the vaults (covered or uncovered by the old solid lime conglomerate layer) and the structure supporting the new roofing is. Of course, we have to expect different situations in so many pitches, preparing ourselves to carry out targeted interventions.

*Choices to make or to investigate*: concept of the structure, material of the new structure (wood or steel). Sizing of the new structure.



| *a) Creation of the new structure for the roof: "frenelli". The picture shows the insertion of only two buttresses.* | *b) Creation of the new structure for the roof (purlins), with overhanging to protect the facade* | *c) Creation of the structure supporting the coverage package, with overhanging to protect the cornices* |
|---|---|---|

Figure 32 - Schematic phases for the creation of the new structure supporting the new roof.

**4.4 - Under roof organisation**

In order to create a ventilated and insulated under-roof space we need, as stated above, to rely on a detailed survey after the cleaning of the extrados of the vault. In function of this, it could be clear how to allow ventilation from the lower and the upper parts of the space. If in some points the extrados of the vaults, protected by the old conglomerate layer, the empty space with the intrados of the new covering structure will be too scarce, it will be possible to create some small channels, operating through the conglomerate, able to guarantee the transversal ventilation.

**4.5 - Water runoff system and new design of the relationship between pitches and stone walls**

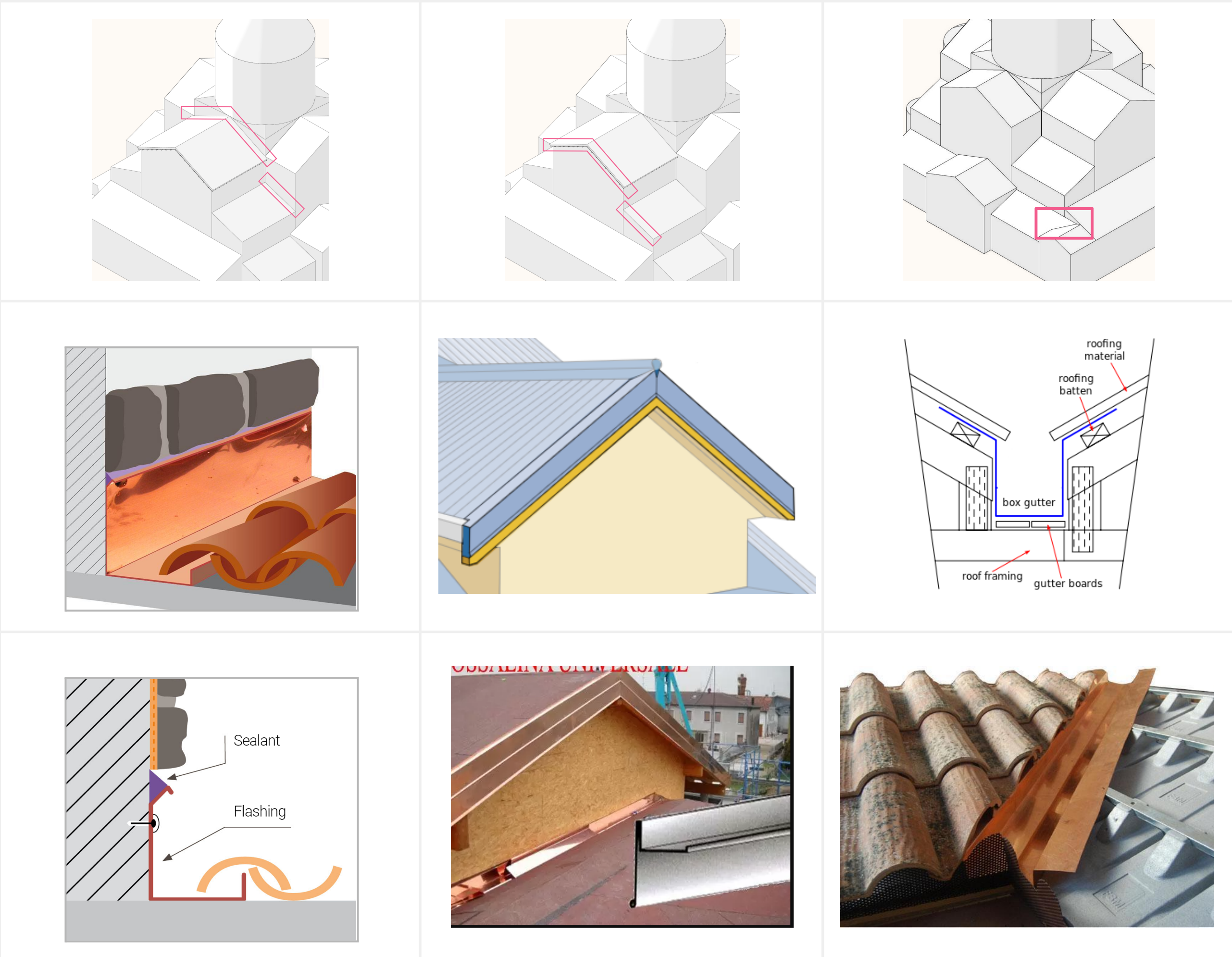
The installation of a system of gutters, flashing and downspouts is essential to prevent future infiltrations and protect the masonry from percolation phenomena. The runoff system has to be designed carefully,

paying particular attention to points of discontinuity (Figure 33), and it will be integrated with the water drainage system to be designed at the ground level in order to drain the water from the Monastery safely and efficiently.
The integration of the new water runoff system requires attention to be paid to the points of intersection of the pitches with the masonry as these points, if poorly designed and implemented, could be water infiltration points. Particular attention must be paid to defining the overhang of the pitches with respect to the moulded parts of the walls that have suffered greatly from exposure to atmospheric agents.

*Choices to make*: Position of downspouts. Downspouts and gutter materials. Gutter shape to better integrate them with the cornice of the walls. Possibility to design hidden or on-sight gutters.

### 4.6 - Maintenance

It will be necessary to take the utmost care in designing a system that allows localised (and safe) maintenance interventions with the possibility of inspections. The deepening of this point depends on the technical solutions that will be adopted




| | | |
|---|---|---|
| *a) Flashing at the intersection with the vertical masonry along the inclined side. The scheme shows a covering mantle made of tiles. The solution is similar if copper is chosen as the covering material.* | *b) Facade overhanging and flashing with drip trim.* | *c) Valley gutter. Position of the valley in Gelati's roof; scheme of the gutter; an example of the implementation with the covering mantle made of tiles.* |

Figure 33 - Scheme of the point of discontinuity regarding the water runoff system.
The solutions shown are indicative. Every detail requires in-depth study.

**In conclusion**, it is evident how all the design areas examined above interact with each other. In particular, the structure, the ventilation, and the water runoff system highlight how the design of the detail concerning the lower part of the pitches is both extremely important and delicate. In fact, this part must ensure sufficient overhang of the roof, must allow air to enter the two ventilation circuits, must accommodate the gutter necessary for the removal of rainwater from the roofs, and must appear aesthetically consistent with the Monument to not negatively impact its appearance. The design will therefore have to be attentive, integrated and sustainable. Finally, last but not least, nothing that we are now analysing in detail, and evaluating in terms of efficiency and compatibility, will prove useful if the implementation phase will not be taken care of to the maximum degree. In these types of works, a careful execution is the decisive part of the design. It is important to involve skilled workers and masons, accompanied by the constant presence of expert technicians on site (every day).