# The technical subsystems of the Church of the Holy Sepulchre

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## Introduction

At first glance, the presence of intricate technical subsystems under the floor of a church may seem strange, but the uniqueness and complexity of the Church of the Holy Sepulchre in Jerusalem justifies the existence of different apparatuses to serve the usage needs of this monumental ensemble and the three Communities present there.

In 2019 the Communities, namely the Orthodox Patriarchate, the Custody of the Holy Land and the Armenian Patriarchate launched an initiative of great importance and impact: the restoration of the stone pavement of the Rotunda, the aisles and the Ambulacrum. The floor had in fact undergone numerous alterations over time due to interventions, mostly related to installations (pipes of various kinds and electrical cables), with resetting and patches many times inappropriate. Added to this was the natural wear and tear causing the breaking and disconnection of numerous paving stones.

This initiative presented itself as a unique opportunity to carry out appropriate archaeological excavations, in continuation of the previous ones, especially those carried out by Franciscan Father Virgilio Corbo since 1960. The new excavations, conducted by the Department of Antiquities of Sapienza University of Rome, under the direction of prof. F. R. Stasolla, would then also allow an exhaustive survey of the foundations of the church and possible consolidation works.

When the project for the restoration of the floor began, it immediately seemed appropriate to take the opportunity to work on the facilities subsystem whose condition, in many places and in many respects, had degraded over time. It is to be remembered that the poor state of preservation of the floor was often due, in addition to prolonged usage, to subsequent installation or modification of pipes and cables, which had been followed by clumsy restoration of the floor surface, frequently by simple filling with concrete.

The primary purpose of the plant subsystems renovation project was to ensure the safety and functionality of existing systems, but at the same time the need arose to allow for future developments, especially regarding electrical, information and multimedia systems, without the need for tampering with the restored floor.

In this context, the design had to consider some important constraints. First, the plant works must be limited to the areas subject to the floor restoration, and therefore connections to existing utilities, which are substantially outside the church, must be made within those areas. Second, the works must not include the construction of the possible new facilities, but only the preparation, that is the laying of conduits with adequate access and inspection points.

## The ante operam situation

The subsystems existing at the beginning of the restoration work can be described as follows.

- Graywater drainage lines (no sewage), coming from rooms adjacent to the Rotunda and the aisles. They serve some fixtures (wash basins, lavatories and the like) in the rooms belonging to the three Communities, arranged around the Rotunda and the aisles. They also have to dispose part of the rainwater from a small courtyard adjacent


Fig. 1. A junction of a free-flowing drainage conduits inside a manhole.

Fig. 2. Electrical switchboards and meters near the main entrance of the church.

to the north aisle. Many of these lines are free-flowing conduits that in corrispondence of the inspection manholes practically put the interior of the church in direct communication with the flowing greywater (Fig. 1). Consequently, due to the insufficient slope available and the frequent inappropriate presence of solids, in the past there have been numerous malodorous overflows and flooding of the floor.

- Potable water supply lines serving the same premises: some of the pipes are metal, really old, others are plastic, installed several decades ago.
- Fire-fighting water supply: some hydrants are located on the interior walls of the church. They are currently connected to the public water network as there is no tank with an autonomous fire-fighting unit.
- Electrical power lines feeding the large chandeliers at the entrance to the Aedicula and some other lines serving the above premises. Most of the power lines are installed exposed on the interior walls of the church and run to some old, obsolete and substandard switchboards (Fig. 2) located near the main entrance of the church. Other lines run under the floor and, during the inspection, at some manholes showed exposed and disrupted connections The replacement of the switchboards is not included in the current project, but has been nevertheless considered, as it is absolutely necessary, while the underfloor lines will have to be replaced. The question arises as to whether the succession of works will allow future new cable ducts (later described) to be used immediately or whether a temporary connection will have to be provided.

## The survey of existing facilities

As a first action, a survey of the existing situation was carried out, starting with a plan showing the locations of the manholes. During a thorough inspection, carried out by IG - Geotechnical Engineering (Turin, Italy), the presence of numerous other manholes was detected. A photographic reconnaissance and descriptive filing were carried out of all of them. Visual reconnaissance and other information made it possible to reconstruct the layouts of the plant systems, thus obtaining the actual, *ante operam*, status of the plants. Fig. 3 shows the layout of the *ante operam* manholes, while Fig. 4 illustrates the route of some drainage pipes.

## The design approach

Following the constraints mentioned above, the project developed by Manens (Padua, Italy) involves the construction of new drainage, potable water and fire water distribution networks. It also envisages the placement of a large network

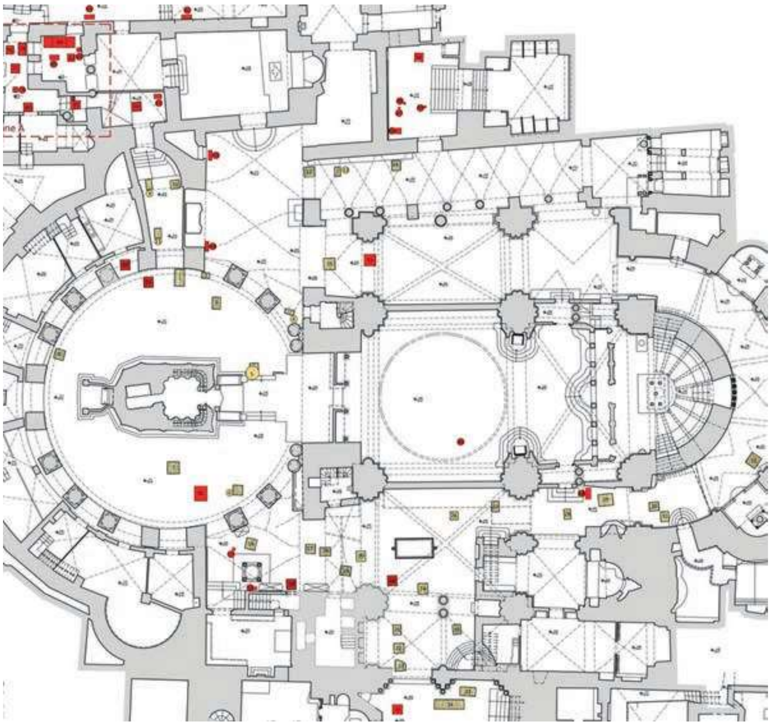

Fig. 3. The distribution of the manholes pertaining to the various facilities. Yellow: those known and present in the pre-existing plans; red: those found during the recognition work.

for cables conduits, with dense branches to existing electric utilities and branches for later implementations of power distribution systems, transmission of data, and signals.

These systems may be implemented by successive phases according to the needs of individual communities or agreed common needs, but already initially new cables may be inserted to replace the existing unsafe and substandard cables buried under the church floor.

Special attention has been paid to aesthetics, given the large number of necessary access points: all manhole covers will be of the type with inserted the same stones as the rest of the floor. A major challenge will be the correct positioning of the manholes in the texture of the renewed floor, where the old stones, scrupulously restored by the CCR of Venaria (Turin, Italy) will be repositioned in the places where they were, side by side with the new stones to replace those that are irrecoverable or missing. The general layout of the new plants is summarized in Fig. 5, where the differently coloured lines indicate

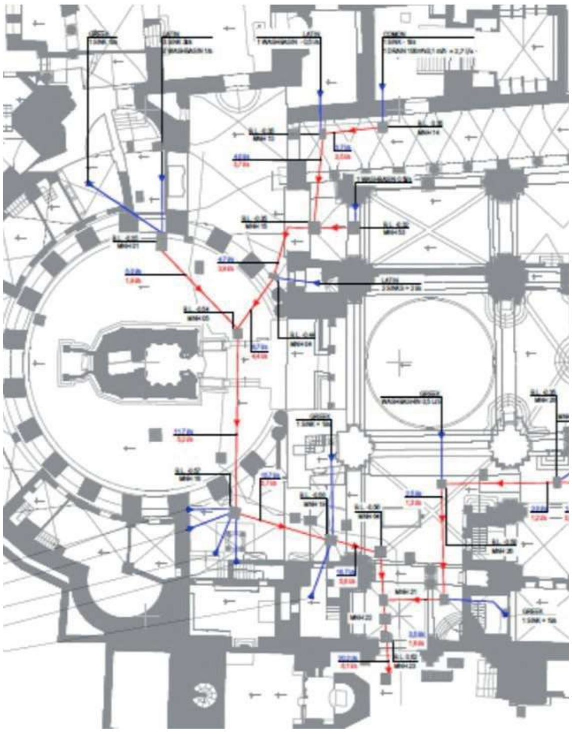

Fig. 4 . Detail of the ante operam greywater network inside the church.

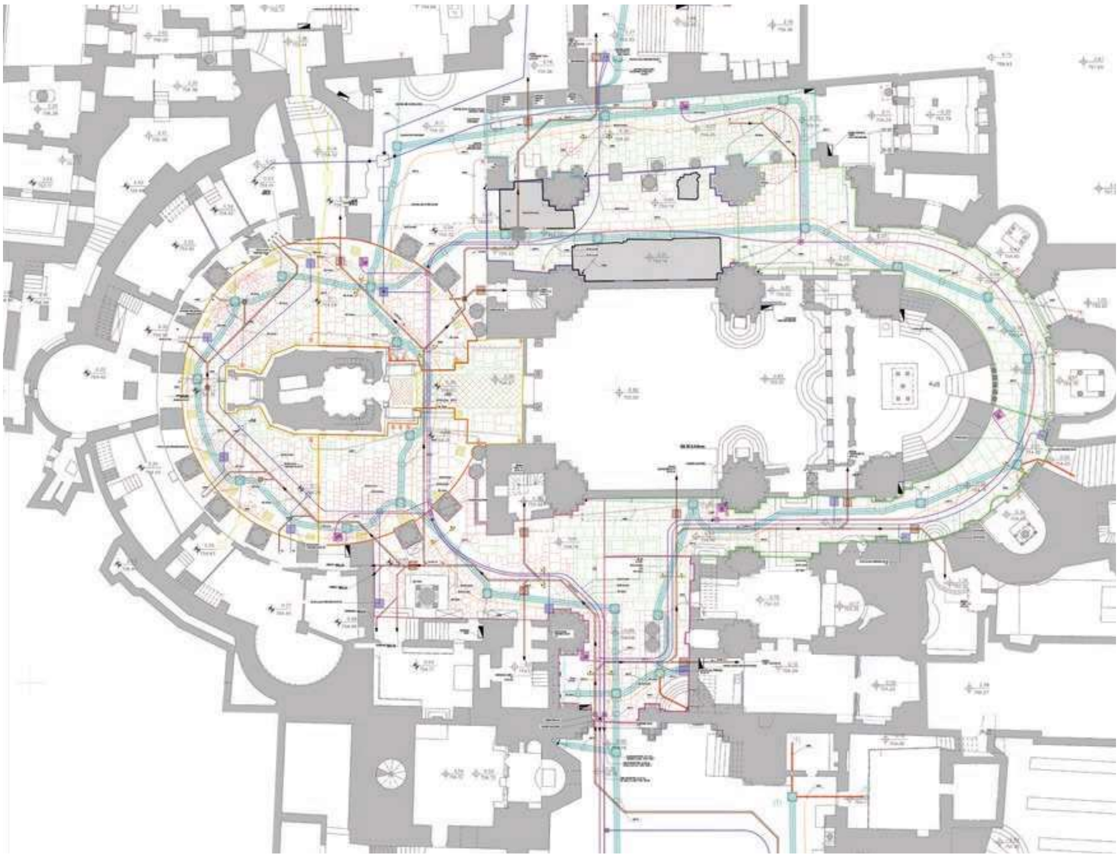

Fig. 5. The general layout of the new plants.

the paths of the new subsystem layout (Fig. 5). Particular attention is paid to the provision for future connections, which are generally placed underground just outside the area of intervention, in positions such that future connections can be made without affecting the pavement restored in this work. An example, relating to future connections in correspondence with the Rotunda, is illustrated in Fig. 6.

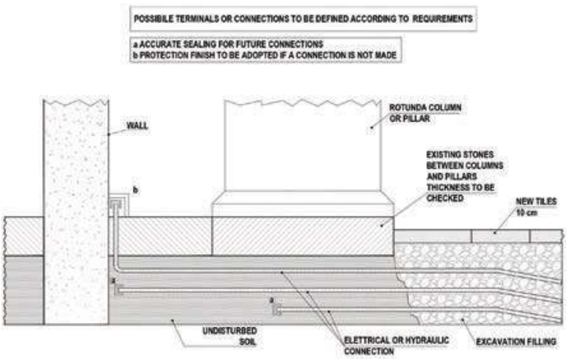


Fig. 6. Example of inserting terminations available for future connections.

## MAIN CHARACTERISTICS OF THE PLANTS

### The drainage networks

The drainage networks will be made of high-density polyethylene and along their entire route will be enclosed by a concrete shell sufficient to ensure adequate tightness even in the case of any minor defects or degradation of the material: it should be remembered that these are pipes with free-flowing outflow at atmospheric pressure, conveying modest quantities of water. The connection of the drainage network to the existing systems in the rooms will be made by means of hermetically sealed inspection and settling sumps, thus avoiding the inconveniences of overflows that were manifested due to the presence of sections operating

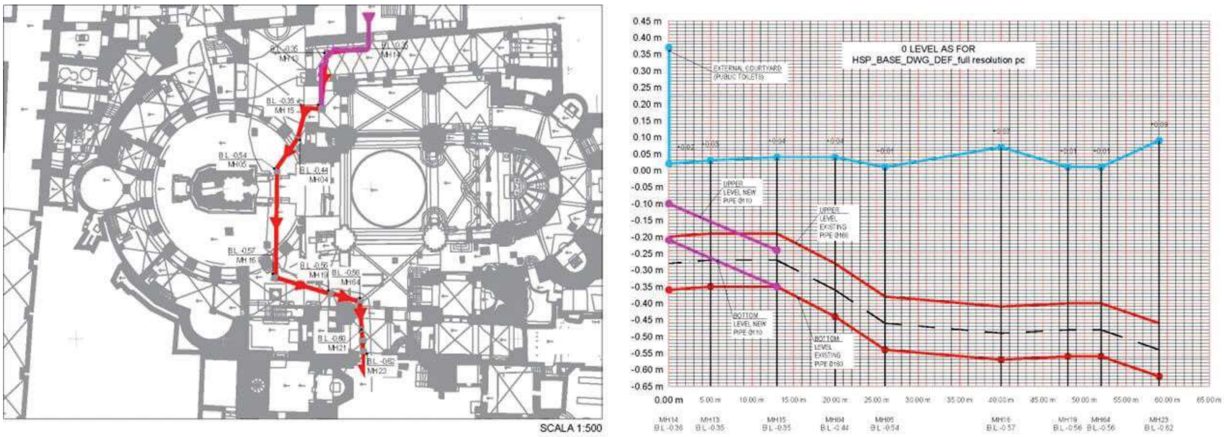


Fig. 7. Drainage pipeline path and elevation profile of a drainage path (blue: floor levels; red: existing pipe; magenta: new pipe, with enhanced slope in the first part (left).

at free surface. Special precautions have been taken, after cafreful analysis, in places where the lack of slope prevented the regular flow of water (Fig. 7). An appropriate number of siphoned drains will be placed on the floor to allow the discharge of wash water and any water seepage that sometimes occurs due to rain (Fig. 8).

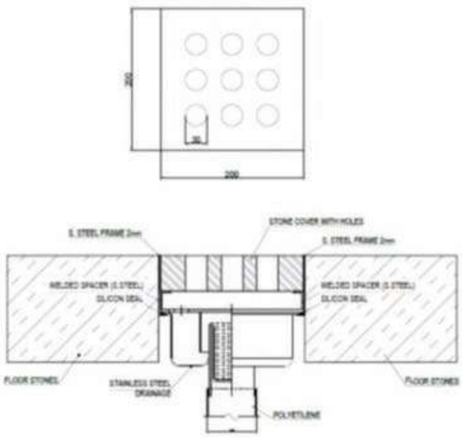

Fig. 8. Detail of the customised drain outlet for the floor of the Rotunda and adjacent areas.

### The clean water network

The potable and fire-fighting water distribution networks will be made of high-density polyethylene, for pressures up to 16 bar, laid in a pipe-in-pipe arrangement (Fig. 9), that is inserted inside plastic corrugated conduits connecting the different inspection wells. In this way any leaks can be detected through the manholes themselves and localized, for example, by probes equipped with webcam.

The fire-fighting system will have a new, more rational location of the hydrants, which, whenever possible, will be of the retractable type, i.e., placed inside manholes with the cover finished with paving stones and, due to the weight of this kind of cover, will have an air spring system that makes it easy for one person to open them by hand (Fig. 10).

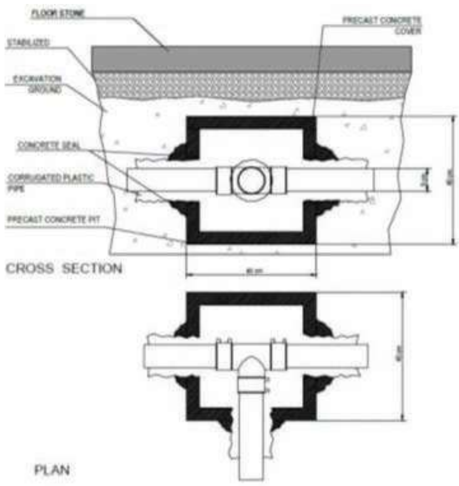


Fig. 9. Example of water pipes junction within a jacket.

### The electrical networks

The conduits for the power grids will be of the corrugated plastic type and will connect the various access manholes for branching and cable introduction. The conduits will be

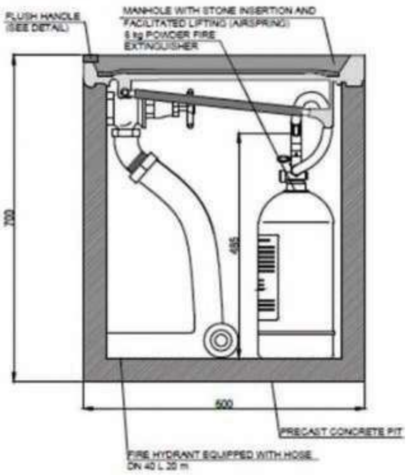


Fig. 10. Example of a fire hydrant inside a manhole with easy lift cover.

predominantly triple, parallel, in order to separate the power lines (typically 240 V) from the weak current lines (for internet connections and signal transmission). The third line will be a backup in case some installations are to be kept separate for special reasons.

In the Rotunda, the cable duct lines are developed around the perimeter to facilitate the connection of utilities in the surrounding areas as shown in Fig. 11. The development of the cable ducts constitutes, as a whole, a double connected ring, around the Rotunda, the aisles and the Ambulacrum, so as to optimize the cable layout of future lines. From the manholes provided for the connection of the various utilities outside the area of intervention, numerous smaller diameter (32 mm) conduits will also be branched off to create floor connection points for sockets, lighting and other services.

## The impact of archaeological excavations on plant design

The important archaeological excavations not only achieved the primary purpose of providing an exhaustive documentation of the various successive phases of the seventeen centuries of the monument's life, but also allowed for a perfect representation of the underground spaces available for the insertion of new installations without damaging the ancient structures. Fig. 12 shows a perspective view of the envelope surface of the excavations carried out, based on the photogrammetric reports of the works. Fig. 13 shows orthogonal photogrammetric projection, with isolevel contours and elevations of significant points: such a representation is extremely useful for verifying the routes of pipes and conduits in relation to the presence of underground structures. This documentation shows that in some parts, especially at the north-eastern limit of the Rotunda, the space available between the floor surface and the underlying rock is extremely small and requires an adaptation of the de-

Fig. 11. Approximate development (yellow line) of the new cable conduits in the Rotunda.

Fig. 12. A rendering from photogrammetric surveys of the archaeological excavations of the Rotunda.

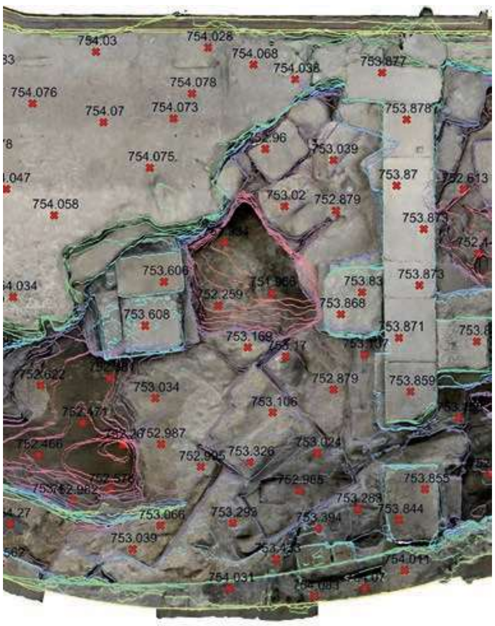

Fig. 13. Detail of orthogonal photogrammetric projection, with isolevel contours and elevations of significant points.

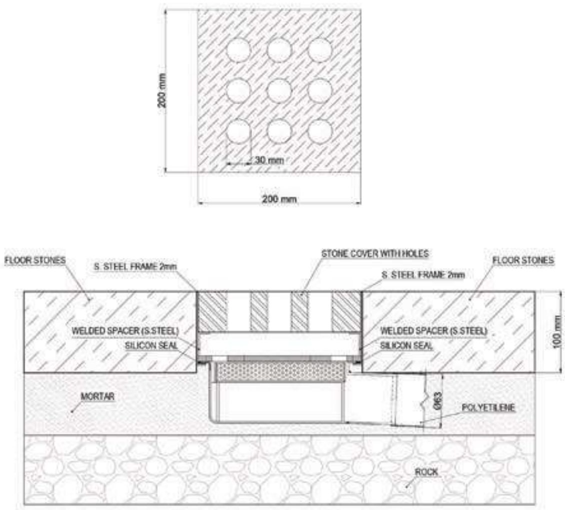


Fig. 14. A detail of a low thickness drainage: the grid and filter assembly, of commercial type, are placed in a custom-made casing closed by a perforated stone.

sign and the construction of some customised elements in order to make the best use of the limited space available: an example of a special patch for draining water in the Rotunda, is illustrated in Fig. 14.

## Acknowledgements

Elia Bettin, Michele Quaggia and Francesco Rigon took part in the development of the project. Special memory must be dedicated to Prof. Arch. Osama Hamdam for the many fruitful discussions during the development and study of the project.