

Introduction

Olive tree in the Garden of Gethsemane.



INTRODUCTION

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Jerusalem is situated in a highly seismic zone and, in the past, it has been the theatre of disastrous earthquakes. The 1927 earthquake was one of the worst ever recorded in that part of the world, and, as well as claiming hundreds of lives, it caused large-scale damage to various parts of the civic and religious buildings. The *Basilica* of the Holy Sepulchre was also heavily hit, and, following the damage caused by that quake, it saw major consolidation and reconstruction work. A study of the city of Jerusalem has revealed a cyclical pattern, in the repetition of seismic events, of every 100 years. The desire to avert a danger foretold was perhaps at the origin of the project described in this volume. In 2006 the three Major Communities of the Holy Sepulchre, concerned about the Church's stability in the event of a major earthquake, requested a technical evaluation of the structure of the Church, in order to determine its ability to withstand a major earthquake, and to carry out retrofitting of the *Basilica* according to the results of the analysis.

The late Fr. Michele Piccirillo, the archeologist and professor at the Studium Biblicum Franciscanum, suggested inviting a research team from the University of Florence to Jerusalem in order to carry out the seismic study, and, in September of the same year, he turned to the Director of the Centro di Ateneo per i Beni Culturali (CABEC), the late prof. Piergiorgio Malesani. With his usual calm determination, prof. Malesani identified all the skilled professionals needed to conduct the investigations: architects, surveyors, geologists and structural engineers, and he put together three groups, that have always conducted the investigations in a collaborative and highly interdisciplinary way.

The first group was tasked with geotechnical and geophysical aspects. Composed of Emma Cantisani, Andrea Fiaschi, Carlo Alberto Garzonio, Luca Matassoni and Giovanni Pratesi, it was coordinated directly by prof. Malesani. The second group, responsible for the three-dimensional surveys, comprised Valentina Bonora, Michela Pavan, Michele Russo, Stefano Nicolodi, Francesco Vezzosi, Alessia Nobile and Luca Carosso. They took turns in the survey campaigns, and I myself coordinated the group. Added to this group was Roberto Sabelli who, thanks to his previous visits to the places, and his good knowledge of the city and the people in it helped us to solve logistical problems. The drawings were mostly conducted by Valentina Bonora, assisted, in the production of the 3D model, by Francesco Algostino. Finally, the structural assessment of seismic vulnerability was carried out by Francesco Pugi, with the collaboration of Stefano Giannarelli for the modelling and analysis phases, and of Giuseppe Basile for 3D renderings.

All the individuals concerned responded very energetically to this challenge, which was to take us to one of the most fascinating sites in the world, whose historical stratification, aside from the more distinctly spiritual questions, makes it hard to read and interpret the rich, complex architectural palimpsest (destroyed and rebuilt several times over), as well as the important relationship to the bedrock which it stands on.

The initiative was also an important statement of a joint desire on the part of the Religious Communities (Greek Orthodox, Franciscan and Armenian) to subscribe to a common project aimed at finding out more about, and protecting, a unique part of the world's heritage. This aspect is far from negligible, if one considers the recurrent disagreements that have often been documented between these same communities.

The first campaign was conducted between 16 and 30 April 2007, without any preliminary on-site inspection, and thus it was necessary to address this very special context without the necessary "preparation". Only later on, in studying the accounts of previous surveys, was I able to fully comprehend the comments of the various authors who complained of the difficulties they encountered in undertaking such a task. Starting with the somewhat complex layout of the different parts of the building, such that Wilson was ultimately not satisfied with his own results, as he would say in a letter to Hayter Lewis,

and including the logistical difficulties in transporting instrumentation – the Holy Sepulchre is wedged within an urban structure, at varying heights, that does not make it possible to reach it with conventional vehicles – and in relations with the differing Communities. One need only mention the natural diffidence of those who, in the various Communities, took turns to supervise and guard that holy place. Not having been informed of our activities, it was necessary to explain to them the reasons for so many “unusual activities” in parts of the building that were usually not open to pilgrims and tourists. In this, I must note here that Father Piccirillo had provided very summary information, only showing us the main doorway, before leaving us to decide, by ourselves, after entering, the steps we should take with a view to the objectives assigned to us. At the time, we were not aware that merely leaving our measuring instruments on a plinth that belonged to one Community, rather than another, could give rise to stiffer reactions, and suspicions! We did not know the difficulties that could derive from the *Status Quo*, that was still in force. During the survey campaigns, the green laser beam, which back then was still visible as it travelled over (i.e. scanned) all the surfaces, and the immediate view on the screen of our data input (3D models of points) helped us a lot in “astounding”, and thus striking up friendly conversations with, members of the Communities of the Sepulchre, as well as interested pilgrims who would often come up to us in the hope of finding some interpretive key among those intricate lines and patterns that had nothing to do with what they imagined they would find in that Holy Place. For that matter, in the first campaign of data collection, owing to the waiting times required by the instrumentation back then – around 3 hours for each scan, which was cut to just a few minutes in later campaigns, thanks to the rapid evolution of electronics – the period we spent, day and night, inside the *Basilica*, was particularly long, allowing us to delight in some unforgettable moments, and have one of the most extraordinary experiences that a surveyor could ever wish for. What a surprise it was to see snow in Jerusalem on the night of 31 January 2008, on opening the doors of the Holy Sepulchre! So as not to interfere with visiting pilgrims, we stayed inside the *Basilica* for our work, and we had no idea of what was going on outside. At 5 o'clock in the morning, when we emerged, we were greeted by a city that lay beneath a blanket of white! Before going to bed, we couldn't resist the urge to walk through the whole city, and climb all the rooves we could find, enchanted by the beauty of the surrounding scenery. And what a pleasure to recall the loving attention of all the Communities who took turns to look after us: they would all bring us breakfast, and coffee and tea, and give us reassuring smiles, as they helped us to discover the most unexpected nooks and crannies.

Father Piccirillo had advised us to start from the *Rotunda*, and only later did we realize why: the *Rotunda* “belongs” to everyone! It was from the *Rotunda* that we set out, to construct a project that would take us to the same place on other occasions, up until 2009, and that would also make it possible to build a relationship of trust and cordiality with our hosts, who came and went every day, in accordance with a mechanism that constantly repeats the same movements, in a circularity of space and time. Just getting to know the rules would allow us to become, albeit only temporarily, part of that same mechanism, and to not interfere with the natural progress of life inside a meta-temporal world.

In the subsequent campaigns (the second from 24 January to 8 February 2008, and the third from 19 November to 12 December 2008) we would encounter new difficulties also in the transportation of the instrumentation; a common fate that is met by all those who have to transport heavy and expensive field research equipment. This is also described in Martin Biddle's book, where he recounts that British Airways, via its Charities Department, generously transported heavy equipment for free. What's more, going through the airport security checks would not simplify things: a never-ending wait, and hours of questions, without ever being certain one was going the right way about it.

As regards access within the *Basilica*, Father Corbo had already complained of the difficulties he came up against in surveying and studying the private areas of each Community. Despite the fact that he was regarded as the archaeological expert by all the faiths, it was not always possible for him to work in the areas under the authority of the Greeks and Armenians.

Finally, we are now able to testify to a completely different experience, in confirming that all the Communities fully cooperated in facilitating the work of the research teams, as we had to extend the investigation to all parts of the structure. They opened the private areas of each Community, and, in what was a completely unexpected development, they allowed us to view and digitally scan each part of the interior. Father Michele Piccirillo, who left us prematurely and unexpectedly on 26 October 2008, denying him the chance to witness the completion of the work that he had started, and who supported us so much, was far-sighted in leaving us with the task of identifying the best way to communicate with the Communities, to dispel any lingering doubts and diffidence, in order to achieve the best result for the good of all, in acquiring a knowledge of the parts of the building for research purposes! A crucial role in simplifying our measuring campaigns, and in supporting the success of the whole work, was undoubtedly played by Father Athanasius of the Franciscan Community, by Father Samuel Aghoyan

of the Armenian Community, and by Theo Mitropoulos, the official architect for the *Basilica*, from the Greek Community, all of whom always assisted us with great interest and participation.

In October of 2009 a report prepared by CABEC was presented to the three Major Communities. The report was divided into three volumes (1 - *Geotechnical and geophysical characteristics*; 2 - *Three-dimensional survey*; and 3 - *Structural evaluation of seismic vulnerability*), and represents the result of the work carried out between 2007 and 2009.

Great was the satisfaction not only over the work in itself, but also for the unusual fact that it managed to meet the deadline. Father Bagatti claims that very often, in studies on the Basilica, the amount of time that elapses between the investigations, the surveys, and the transmission of the findings to those directly involved (the three Communities) is very long, to the point of rendering them ineffective for the scholars who conduct their own research, one after the other, and who could instead benefit from those surveys.

Indeed, the report and the survey charts presented in 2009 were immediately made available to all three Communities, but the desire to make the findings of these studies available to a larger public, so as to leave a trace in the scientific community, too, wishing to contribute to knowledge of the Holy Places, prompted us to embark on a new adventure, with the publication of the present volume.

In actual fact, almost 10 years have elapsed, and there have been many events that have prevented the continuation of the work. However, they have also allowed us to deliver today a more complete project than was initially anticipated.

Prof. Piergiorgio Malesani left us on Christmas Eve, 2013. He was the cornerstone of this project, and it was to him, he who lovingly followed every phase of the work, and who never liked to leave things unfinished, that I promised, during his illness, to complete this volume; a promise that I am happy to have kept, albeit some (too many) years later.

In the meantime, the availability of an impressive quantity of three-dimensional metric data that had never been compiled before, although initially designed for analysis of a structural nature, prompted a curiosity, in other words the idea of investigating, in an entirely new way, other aspects of the structure, starting with the walled parts, using the now consolidated method of the stratigraphic analysis of elevations, which Alessandra Angeloni writes about in Chapter 2 of the first part. The investigation is confined to the North Transept, and adopts a methodological approach. It also sets out to demonstrate an approach which, it is hoped, could also be extended to all the walled parts of the *Basilica*.

Accordingly, in 2011, Roberto Sabelli sponsored a study, carried out by Simonetta Fiamminghi, of the conformation of the original site of the Holy Sepulchre, and its subsequent transformation, up to and including the construction of the foundations of the Constantinian building. Moreover, a fortunate meeting with Osvaldo Garbarino, who had had the opportunity, in writing his thesis, to explore issues involving the three-dimensional representation of material data, as a special branch of philology, and a further phase of archaeological research, applied to none other than the Holy Sepulchre, gave rise to Chapter 3 of the book, accompanied by a "Comparative spreadsheet of the main written and iconographical sources from the 4th to 12th centuries".

Similarly, the analysis of the relationship of the architectural features with the underlying rock would not have been possible without the aid of the three-dimensional survey, that recorded, in minute detail, all the irregular features of the quarry which the basilica stands on. A number of exceptional representations of surfaces, processed by Lidia Fiorini, are interspersed in the whole text, by way of illustration.

The opening chapter, "The Archaeological and Historical Context of the *Basilica* of the Holy Sepulchre in Jerusalem", by Carmelo Pappalardo and Alessandra Angeloni, aims to provide an overall framework for all of the first part, starting with the countless modern and contemporary studies, and ending with a short but effective summary of the building's main construction phases.

Chapter 4, by Athanasius Macora, brings the first part of the book to a conceptual close, with a necessary clarification of the meaning of the *Status Quo* in the Holy Sepulchre Church, one of the three Christian shrines in the world that are shared by different Christian Communities.

Chapter 5 could indeed be seen almost as a prelude to the studies and surveys presented in the second part of the book. Planned right from the start of the survey work, together with Father Michele Piccirillo, it had the task of compiling a sort of historical compendium of the various surveys produced for a range of different purposes, starting from the second half of the 16th century, when measuring started to have a new validity in terms of accuracy. I found myself faced with an interminable bibliography which it was difficult to find one's way around, and from which, inevitably, I had to make a selection. It is a chapter that could justify having a volume all to itself, and I like to think that it may constitute the

start of a process also allowing a critical comparison between surveys of the past. When excavations and archaeological investigations, on the one hand, and restorations, on the other hand, made it possible to examine never-before-seen parts of the *Basilica*, surveys inevitably became partial and, before our own survey, once again “complete” (and three-dimensional, also thanks to the evolution of computer technology, and in the fascinating field of measuring technology), only the team of Dennis D. Balodimos and Andreas Georgopoulos of the NTUA of Athens had responded to this great challenge, embarking on an onerous photogrammetry survey, as of 1993, the admirable result of which constitutes the first chapter in the second part of the volume. It took seven years to compile 36 drawings (plates), including floor plans, elevations, sections and details. In fact, we became aware of the existence of this exceptional survey only at the end of our own field operations: It would have been very useful to have had access to it earlier, in order to plan the operations themselves, but of course, still today, in the digital era, archiving and sharing data constitutes a vexed question, with the result that efforts continue to be multiplied when they could be better directed if they were coordinated, also on the basis of previous findings.

But life can have some truly bizarre twists, and a few years later I was to meet Andreas Georgopoulos in Lovanio during a workshop, and, over a hearty breakfast, we shared our experiences of the Holy Sepulchre, amazed at the particular coincidence. This was to be the start of a wonderful, lasting friendship. Andreas would later carry on a new survey, and would eventually take part, with the team from NTUA, in the restoration of the *Aedicula*.

The second part of the book reflects more closely the investigative project, aimed at assessing the seismic risk, the main aim and the driving force for the entire study commissioned by the three Communities. It is in this part that the biggest effort was made, to make the scientific methods and the technological instruments used comprehensible to the reader. The iconographical apparatus was specifically expanded and enhanced, as an aid to interpretation. For that matter, although there exists a vast bibliography on the Holy Sepulchre, mainly of a historical nature, there are not many works that recount, in such detail, the results of scientific investigations. More frequently, as lamented by F. Vienna himself in the case of his surveys “of a scientific inclination”, these surveys do not find a way of “being brought to the attention of scholars”, and are published in texts that have differing purposes, and which are therefore not suited to allowing an understanding of the scale of the work carried out in terms of knowledge of the Monument.

Chapter 2 in the second part describes the survey methodology adopted. Ten years on, this might seem obsolete, and not particularly innovative. For that matter, surveying has always been linked to technological advances in measuring instrumentation. The survey is to be seen as a product of the time when it was conducted, not only since it is a document of the situation at that time, but also because it is testimony of the history of technology itself: This is the perspective from which the chapter is to be read and interpreted.

By contrast, there is nothing obsolete, or limited, about the numerous, diverse renderings that can be produced from these data also for other purposes, and that could be produced, even at the time, as described in Chapters 3 and 4, where the emphasis is on the potential for modelling. Such modelling is useful for the purposes of both interpretation and communication. It is also useful today, at a time when these same data pave the way for more modern management projects, such as Building Information Modelling for the maintenance and planning of conservation interventions.

From Chapter 5 on, we go into details of the vulnerability study begun with the analysis of seismic hazard in the city of Jerusalem, starting with the collation of Hazard Maps and Peak Acceleration studies, and moving on to seismic noise measurements. There are descriptions of the measurement campaigns, the noise study, and the evaluation of the soil amplification and fundamental frequencies, before coming to the modal analysis. Chapter 7 is devoted to an analysis of the subsoil, with the aim of contributing to understanding the state of the places. Even though the main purpose of the study was to identify the dynamic behaviour of the subsoil under seismic conditions, further elaborations, and interpretation of the information found by Father Corbo from his diggings, enable the spectra to be assessed in stratigraphic and structural terms, with the objective of identifying the depth of the bedrock at each point of measurement. This information can also make a fundamental contribution to creating the engineering model of the area on which the complex is situated.

Chapter 8 is dedicated to the geology and geomorphology of the places, while Chapter 9 reports the results of the geomechanical surveys performed, in order to give an indication of the data useful for characterizing the physical and mechanical behaviour of the rock mass. They also give data that can be used for its modelling in seismic conditions, in

order to carry out structural modelling to define the vulnerability of the Holy Sepulchre monumental complex. The group of geologists, Emma Cantisani, Andrea Fiaschi, Carlo Alberto Garzonio, Luca Matassoni and Giovanni Pratesi, are the authors, together with Piergiorgio Malesani, of the four chapters mentioned previously.

Chapter 10 concludes the second part of the volume, and is the real point of arrival of the research as initially commissioned. Francesco Pugi gives a detailed account of the work carried out, and he must take credit for having described, in a comprehensible way, issues that are fairly difficult for non-specialists. In this case, too, the accompanying iconographic material, which is well organised, makes the reader's task easier.

From the point of view of structural analysis, for understanding the stability and the strength of the construction, a modelling was produced of the structure, that is a physical mathematical representation, taking into account geometry, material, forces, and loads.

Seismic actions are inertial actions caused by the mass, which can be represented by horizontal forces; they are correctly defined through a study of the dynamic properties of the structure (vibration and oscillations), on the basis of the physical law of static equilibrium, and the mechanical behaviour of the materials.

The response of the structure under the acting loads was analysed in order to obtain an evaluation of the strength of the structure. In the event of unfavourable results, it is possible to pinpoint the weakest parts, for a possible subsequent retrofitting intervention.

At the end of the work, a scale of priorities for possible retrofitting interventions was produced.

The general situation was quite good. Only two structures seemed to be somewhat weaker: the bell-tower and the Aedicule. Meanwhile, however, both these features have been consolidated and restored.

The considerations expressed above also apply to this part. Every analysis, from the point of view of both methodology and technology, must be placed in the context of the period when it was conducted, and placed in relation to the amount of time available for completing it. In view of the complexity of the construction under investigation, the results obtained must be seen only as an initial step, and certainly not an exhaustive one. In the synthesis of the analysis, the main criteria are put forward by means of which it will be possible to further an understanding of the structural behaviour of the Basilica, with the aim of optimizing any consolidation measures designed to increase static and seismic security.

For that matter, the large amount of information acquired constitutes by itself an excellent point of departure for developing further research. The three-dimensional model corresponding to the current status can also, by itself, be regarded as a document to be made use of for keeping an up-to-date record of the condition of the places. Let us not forget that these places are in a state of continual change as regards their exact layout, and the way in which they are used, also owing to the needs deriving from their intense level of daily use. At the time of writing, many things have already changed: To cite a few, the renovation of the washrooms, and the radical restoration of the *Aedicula*, while other changes are at the planning stage, such as the restoration of the floor of the *Rotunda*.

I would like to conclude with a circular image that might unite the past and the future. It would be pleasing to think that technology, both existing technology and technology not invented as yet, as well as virtual reality, augmented reality, and systems for managing geo-referential data, will lead to connections being made between the world's most famous *Basilica*, the Holy Sepulchre of Jerusalem, and the many other buildings that are inspired by it, and for which it was the architectural model. A database could be set up, one that is open and shared, and always open to being implemented, for use by all the scientific world and also those who approach the *Basilica*, and its multiple aspects, with new languages, and ever more engaging and appealing means of communication.