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Manuscript

On conservation issues of contemporary architecture: the technical design development and the ageing process of the Jubilee Church in Rome by Richard Meier

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Abstract

A vast amount of iconic buildings distinguished by complex geometries have been constructed in the last two decades in the United Kingdom, Germany, Spain, Portugal, France and Italy. Overall, the construction of these iconic buildings has led to technical innovations. As these buildings are often erected following customised construction details and bespoke technical solutions that are rarely tested in advance, measuring their ageing process has become crucial to understand if these geometries are sustainable in terms of the cost of their maintenance. This study aims to analyse the technical design development and the ageing process of the Jubilee Church in Rome by Richard Meier. Only fourteen years after the opening, this building is affected by extensive decay of construction materials due to both wrong technical design choices and lack of unaffordable maintenance work. This study aims to identify the causes of the premature decay of this building, recording retroactively its technical development and mapping the current state of damages.

Keywords

Meier; JubileeChurch; Decay; Technology; Contemporary; Conservation

1. Introduction

Over the last twenty years the production of buildings recognisable for their geometrical complexity has risen exponentially in Europe and in the world (Amin, 2000). This increase occurred after the opening of the Guggenheim museum in Bilbao in 1997; following that, the recourse of design narrative producing architecture with complex computer-generated and non-standard geometries became fashionable with more public and private clients requesting such a type of design product (Rybczynski, 2002). A vast amount of iconic buildings distinguished by complex geometries have been constructed in the last two decades in the United Kingdom, Germany, Spain, Portugal, France and Italy (Easterling, 2005; Gospodini, 2002; Jencks, 2005; Saunders, 2005; Sklair, 2006; Sudjic, 2005; Urry, 2007). Overall, the construction of these iconic buildings has led to technical innovations such as the use of new materials, the development of new steel joinery, the design of advanced formwork systems, the tailoring of new assembling procedures, bespoke building components and construction details being mass-customised with hybridised solutions from different companies' catalogues (Piroozfar, Piller, 2013; Erens, Verhulst, 1997).

As these buildings are often erected following customised construction details and bespoke technical solutions are rarely tested in advance, measuring their ageing process has become crucial to understand if these geometries are sustainable in terms of the cost of their maintenance. Several newspapers across Europe have targeted the ageing process of these iconic building reporting failures and technical issues, in some cases directly after the opening of these structures (Moore 2011; Quah 2014; Rogers, 2014).

This study aims to analyse the technical design development and the ageing process of a contemporary building designed by well-known American architect in Italy. This study aims to understand the contribution of the technical advisors and the client to the technical development of the design and to assess the quality of the measurement of the ageing process of this case study. This building is the Jubilee Church in Rome by Richard Meier (Meier, 2008).

This building has been chosen for this study because:

- Fourteen years after the opening, the building shows extensive signs of decay in the materials in its construction;
- the scheme is designed by a foreign architect who had never built anything in Italy before then;
- due to its iconic and innovative appearance, the building required an extensive form-engineering process followed by a series of mock-ups;
- following the form-engineering process, the building was constructed with differences from what was conceived at the competition stage;
- the engineering contribution focused on research on concrete, leading to the application of a new bespoke concrete mix which had never been tested before;
- Due to an increased budget, the building was constructed with a sensible reduction of its original size.

This paper aims to reconstruct retrospectively the technical development of this church and assess qualitatively the ageing process of the building with the following scopes:

- collecting data about the design development of this building and its ageing process in order to understand the causes which led to the decay of the building;
- providing information that can be used by architectural historians for their critical assessment of the relationship between the architect and the construction of his architecture;
- increasing the technical awareness of architectural designers and architectural students aiming to use interpretative solutions borrowed from this case study highlighting how the details of this church could have been improved;

- evaluating critically the outcome of the technical development by analysing qualitatively how the technical solutions have coped over time;
- estimating the cost of the conservation work to bring the building to its original state.

2. Research Methodology

During the construction process the author of this paper visited the building site of the case study regularly from 1999 until 2003. During these visits, the author interviewed the professionals involved in the technical development and construction of the building. This direct experience allowed the author to analyse how the technical development of the project was run and, in more detail, to measure how the engineering contribution modified the original scheme. To gather data on the nature of the collaboration between the teams of Richard Meier and his contractor, 'Lamaro Appalti', and his technical advisor during the construction phase, 'Italcementi Group', the archives of these companies were consulted.

In 2016 and 2017, in order to understand the outcome of the technical development, the author of this paper ran a technical survey to map the decay of the materials and details of the building fourteen years after the opening of the church.

3. The technical development of the church

The Jubilee Church was designed by Richard Meier and was completed in 2003. The church was one of several places of worship planned in the outskirts of Rome to celebrate the Roman Catholic Jubilee of the year 2000 with the programme entitled '50 churches for Rome 2000'. The programme was the outcome of an urban strategy put forward by the general authority of Rome together with the Vatican. According to the expectations of the Vatican, a new and more inclusive architectural language for religious buildings was demanded in order to offer more welcoming religious buildings which were more open to the city and had spaces for different social activities. The briefs for these new churches included small theatres, meeting rooms, playgrounds, parish houses and, of course, church halls.

For the Jubilee Church, the Vicariate launched an initial open architectural competition where 534 projects were submitted by Italians and foreign architects. Due to an overcrowded panel, conflicting assessing criteria and too many entry projects, the jury was not able to choose one winner (Falzetti, 2003). A second competition was then announced, but this time with restrictions: a much smaller panel and only six architects were invited: Tadao Ando, Santiago Calatrava, Richard Meier, Günter Behnisch, Peter Eisenman and Frank Gehry. The names of these internationally well-known architects suggests that the Vatican wanted to choose between proposals with international recognition, regardless of the religion of the architects or their previous experiences as church designers. The year of the second competition was 1994 (Falzetti, 2003).

Meier's winning proposal displayed its iconic power in three gigantic shells on the eastern side of the building. The church hall itself was conceived as a void confined between these shells and a secondary block where a theatre and the parish house were located. The shells and the secondary block are connected with a large glazed roof which encloses the church hall without obstructing its visual relationship with the city. Meier’s describes the design thus: ‘three circles of equal radius are the basis of the three shells that, together with the spine wall, constitute the body of the nave’ (Meier, 1997). Due to the complexity of the technical development of the building, the Church opened in 2003, three years after the deadline for the Holy Year (the year 2000).

The major design changes which occurred in the technical development of the project were:

- A change in the material of the shell, conceived to be plastered in stucco but built in exposed concrete;
- A change in the finish of the shell, conceived to have a solid surface but erected with a squared pattern;
- A slightly different orientation of the shells to optimise their production;
- The downsizing of the community centre at the northern end of the building;
- The elimination of the canopy above the entrance of the parish house on the back of the complex;
- The design modification of the wide pond on the back of the church, designed to reflect the curved geometries of the church.

Representing the most challenging aspect of the structure, the technical development of the church focused on the three double-curved walls. They were conceived as elements borrowed from spherical geometries. At the competition stage, the technical issues of the project were mainly solved with regards to the glazed roof, whereas the structure of the shells was left behind, assuming that Meir’s typical construction detailing approach would be applied (Nordenson, 2016). This typical approach consisted of building the shells with a composite solution where steel frame curved ribs were clad with precast concrete panels, 12.5 centimetres thick both on the inside and on the outside of each shell. The panels were supposed to be connected through steel-channels to the primary elements and insulated by polystyrene foam. The panels were to be plastered and painted in white to accomplish the finish desired by the architect (Mornati, 2016). The same detail can be seen used for the curved walls in the MACBA in Barcelona or for the High Museum in Atlanta (Fig.1).

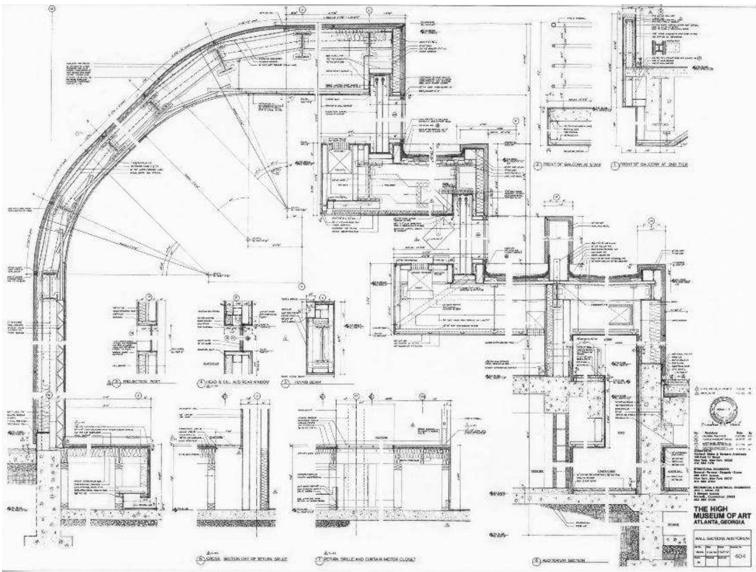

Figure 1. Construction detail of the roof of the High Museum in Atlanta (image courtesy by Richard Meir and Partners)

After being awarded, the project was analysed by the client's technical advisors. For the structural appraisal of the proposal, the Vicariate's technical consultants were Antonio Micheletti, Professor of Structural Engineering at the University of Rome 'La Sapienza' and former apprentice of Pier Luigi Nervi, and Ignazio Breccia Fratadocchi, supervisor at the technical building department of the Vicariate.

Micheletti judged the solution proposed for the shells as 'weak-boxy' (Baglione, 2003). Whilst the use of steel would have secured geometric precision, the plastered precast panels would guarantee the visual solidity required by the architect. However, Michetti warned the Vicariate that, due to the enormous size of the shells, the use of steel might cause thermal expansions with consequent cracks on the concrete cladding. The proposed solution seemed rational and viable for a building with a lifetime of 30, 40, 50 or even 60 years but not when compared with other churches in Rome whose durability spans many centuries (Falzetti, 2003; Baglione, 2003).

During the first steps of the technical development of this building, the Italcementi Group, international leaders in concrete manufacturing, made the offer to the Vatican to be the supplier of the concrete. This generous offer drove a substantial change in the project's development. On the one hand, the Italcementi pushed the idea of having the shells built in exposed concrete to maximise the visual impact of their sponsorship; but on the other hand, Richard Meier was reluctant to abandon the previous solution as he was concerned about the finish that the exposed concrete would have, both in terms of candour, visual solidity and the smoothness of the surface.

After the evaluation of the Vicariate's advisors and the sponsorship of Italcementi, the technical team was appointed as follows: Michetti was put in charge of the final structural design, whilst Italcementi became the technical advisor appointed for the technical development of the scheme. Following this arrangement, the engineer

Gennaro Guala, director of the Technical Centre of Italcementi Group developed the solutions for the construction process of the shells (Lyall, 2004).

During 1997, Richard Meier, Antonio Micheletti and Gennaro Guala met several times. The task then was to identify a new bespoke structural system and a building method tailored for the project which would be able to achieve both aesthetic firmness and structural rigidity. They discussed the technical assumptions and the structural solutions for the three shells. Whilst the engineers' approach was extremely respectful of the architectural proposal; the collaborative disposition of the designer allowed a mutual exchange of different ideas, welcoming important modifications to the original scheme (fig.2).

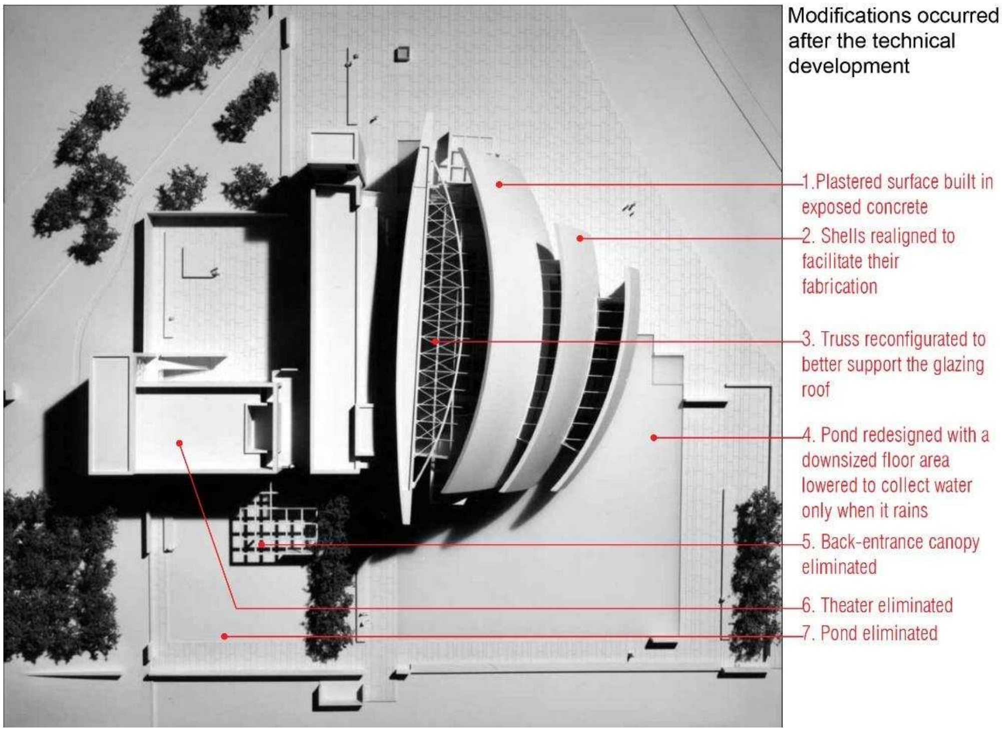

Figure 2. Picture of the competition model with the modification of the project occurred after the technical development (image courtesy by Richard Meir and Partners; drawing by the author)

3.1 Modification n.1: From plaster to exposed concrete

The request of long-durability coming from the client, together with the sponsorship of Italcementi required a change in the material of the building, which had to be built in concrete. To convince Meier to expose the concrete surface without relying on stucco, Italcementi tested a new whitening mix of concrete (latterly named TX millennium cement). The mix was added to Carrara marble powder and titanium dioxide to whiten the cement. Titanium dioxide is well-known as a pigment for use in paint and coatings to obtain a 'perfect white', but this was the first time it was mixed with cement (Nordenson, 2016). It was claimed that, with its photocatalytic actions the titanium dioxide could cause the oxidation of the organic particles within the smog which causes sediment on the building's surface (Baglione, 2003). Enrico Borgarello, director of research and development for Italcementi, claimed that, in this way, the cement would destroy air pollution and therefore the shells could keep their brightness for longer. In terms of insulation, the use of solid concrete would have replaced the need for polystyrene foam. In addition, at the Developed Design stage, a basement underneath the church hall was added for the implementation of a cooling-strategy.

3.2 Modification n.2: Square patterns

Once it was clear that the church would be built in concrete, several ideas were tested. The first decision was in relation to the use of prefabricated technology or cast-in-situ concrete. Each shell behaves like a double-curved vertical cantilevered wall, full-fixed to the ground. Horizontal actions (such as wind or earthquake) and the self-weight of the material tend to bend each shell toward the convex side of its geometry. This means that, due to its shape, the external side of each shell would be critically tensed while the convex side would be compressed. Concrete cannot support tension stress, therefore Guala and Micheletti, suggested using post-tensed concrete with the aim of increasing the compression inside of the walls in order to nullify any tensile effect. In this way, the main stress within the shells would only be compression, eliminating the risk of fissuring of the concrete and therefore assuring quality for the finish.

Following the decision to use cables within the double-curved walls, the engineers focused on analysing which casting technology was the most suitable. As previously mentioned, the intention of Richard Meier, was to erect the walls with a solid finish, suggesting a cast-in-situ solution. However, thoroughly pouring the material into a double curved formwork, filled by a tight weft of cable-cases was assessed as a difficult and expensive challenge. Therefore, in order to have more geometric control and more economic feasibility, Guala opted for prefabricating the shells by using precast blocks. Obtaining the curved walls by off-site prefabrication of the ashlars assured a precision which would otherwise be difficult to achieve with a concrete cast in situ. Also, dividing the shells into smaller components seemed a good idea in order to reduce the impact of potential failed attempts.

The teams of engineers then developed something that could be describe as a more advanced version of traditional stone-masonry. This was to guarantee the solidity and the firmness requested by the Vatican. Each shell was divided by parallels of latitudes and meridians exactly like a portion of a globe; this identified the lines through which each shape was dissected allowing the smaller components to be built off-site. In total, the surfaces of the three shells were divided in 256 fields. Each field was developed as a gigantic prefabricated ashlar in reinforced concrete, 3 meters high, 2 meters wide, and 12 tons in weight, perforated on both sides with cable-cases. The most important consequence of this aspect of the structural development was a change in the finish of the shells, which were previously solid and were now fragmented into giant bricks with exposed joints resulting in a squared pattern. Meier accepted this important change in the aesthetic of the church giving strict geometric constraints for the thickness of the joints which could not exceed 4 millimetres.

3.3. Modification n.3: Re-centring of the three shells

To improve the economic and construction feasibility of the shells, Guala asked Meier to slightly shift the position of the shells, which are different portions of the same sphere, in order to align their centres along the same line (Falzetti, 2003). Each shell can be seen to be either composed of wythes or courses. Every component of each wythe has the same curvature, whilst every component of each wythe is different. Aligning the centres of the shells meant increasing the number of wythes with the same curvature. This simple shift brought about a sensible benefit in the engineering process: instead of prefabricating 256 ashlars different in shape and size using 49 different moulds, the three shells could now be made combining blocks buildable using only 22 moulds and with a consequent reduction in costs and time. This approach is reminiscent of how Jørn Utzon and Ove Arup, after several attempts, engineered the Sydney Opera House's shells, choosing to mould the forms with spherical geometries in order to homogenise the different load-bearing ribs and therefore maximising the use of the same formwork. This modification can be seen when the drawing of the west elevation at the concept stage is compared with the same elevation at the technical design stage. At the concept stage, the tallest shell is more isolated from the other two whilst in the actual building the distance between each double-curved wall is comparatively equal.

3.4. Modification n.4: Elimination of the theatre and the downsizing of the community centre

In the competition brief, the figure of 5,000,000 USD was identified as the budget for the church. After the submission of the winning proposal the Vicariate asked to cut the community centre out of the scheme for two reasons. Firstly, the theatre was judged to be oversized compared with the needs of the community and secondly the project's cost was estimated to already be exceeding the budget designated by the Vatican (Falzetti, 2003).

The community centre was relocated at the Developed Design stage to the basement of the parish house. The basement is lit by natural light coming from a lowered courtyard beside the building.

3.5. Modification n.5: Reduction of the canopy

Following the reduction of the community centre, the back entrance of the additional block, originally conceived as a large canopy protruding from the building, was downsized. The canopy, previously designed to be similar to the one over the entrance of the church hall was downsized and framed within the space of the parish house.

3.6. Modification n.6: Downsizing of the pond surrounding the shells

In the drawings and model submitted during the competition, the three shells were surrounded by a wide pond bordering the south and west elevation of the building. The Vatican presented some concerns related to the cost of the maintenance of the pond. Following these concerns, the project of the pond was modified into a lowered stone paved area (23 x 23 meters) bordering the shells. This area would turn into a pond only during rainy days. Consequently, during the technical development stage, this area was downsized again and built as a 12 x 12 m. area.

4. The construction

The structural engineering solution of the church was finalised at the end of 1997. In order to meet the deadline of the year 2000, whilst the structural solution was almost finalised, the Vatican decided to find a construction company by following a procedure called ‘Licitazione Privata’ where two firms are invited to make an offer giving a total price for the whole construction.
The winning general contractor, named Lamaro Appalti, was appointed through a ‘Stipulated Sum Contract’. They were offered a single lump sum price for all the works agreed except for the supply and assembling of the glazed roof and glazed facades which were not included in the tender. The glass and its supports were delivered and fixed by the Frener & Reifer company using Shueco profiles assembled by following Richard Meir’s detailed drawings.

The most uncertain element was how the concrete blocks would be erected and assembled. Gennaro Guala, from Italcementi, designed a provisional and bespoke assembling machine which was able to erect the shells (fig.3, 4). This special building device was made by a mechanical hand, able to rotate in every direction, supported by a curved travelling-crane moving tangent to the side of the curved walls without interfering with their geometry. As the three walls have exactly the same curvature, the travelling-crane could erect all of them. After the development of the assembling procedures, on the 27th of October 1998 the general contractor signed the contract and the construction process started. In July 1999, after several attempts, the mock-up of one giant block was approved by Meier.

Figure 3. The travelling crane built to assemble the ashlars of the three shell. (Picture by the author, taken 04/04/2001).

Figure 4. The smaller shell after its completion. At its bottom some ashlars ready to me assembled for the medium-size shell. (Picture by the author, taken 04/04/2001).

Figure 5. The northern façade of the parish house during its construction. The shells are completed and the traveling-crane disassembled (Picture by the author, taken 26/06/2012).

The construction site was the place where a new and non-standard building system was developed and, most of all, refined. The site was the place where the workers were trained to learn how to use the bespoke travelling-crane, with training sessions at the beginning of the construction followed by an awareness progressively increased by daily experience.

The workers trained themselves gradually, familiarising themselves with the new construction system and becoming more confident every day. This sped up the process and no forecast about the construction progress could predict what actually happened: the workers assembled the first shell, the smallest one composed of 78 ashlars, in seven months; the shell in the middle, made with 104 elements, was erected in five months; the biggest shell, made with 176 bricks was built in only six months.

Except for the double-curved walls and the glazed façades, the parish house was built with traditional Italian methods such as concrete frames and a hollow-clay tiled flooring system in precast portions (predalle). To allow the crane to move freely on the tracks aligned to follow the spherical geometries without be interfered by the other rectangular parallelepiped of the composition, the parish house was only built up to the second floor before the erection of the shells. Only after their completion the blocks of the altar, the block with the pipe organ, and the roof of the parish house were completed (fig.5).

5. Decay Mapping

In May 2017, a technical survey was run by the author of this paper twelve years after the opening day of the church, to measure the ageing process of the church especially with regards to the innovative solutions developed. The survey focused on the exterior façade of the whole building and the interior of the church hall. This analysis showed the level of decay of the materials and some technical issues regarding mainly, but not exclusively, the impact of acid rain on the exterior façade of the building. The current parish priest, Federico Corrubolo, confirmed that the church has not had any maintenance work since the opening due to the high cost of maintenance. The effect of acid rain on the monuments in Rome is well-known (Charola, 1987; Camuffo, 1992). Acid Rain Effects produce a dry black deposition of Sulphur Dioxide together with Oxides of Nitrogen on building surfaces. Acids have a corrosive effect on limestone, sandstone, and marble.

The survey of the decay of the Jubilee Church revealed the following issues:

- Diffuse yellowing of the exposed concrete surfaces;
- Diffuse dry depositions of sulphur dioxide (SO2) and oxides of nitrogen (NOx) on specific areas of the building’s facades;
- Extensive dry depositions of sulphur dioxide (SO2) and oxides of nitrogen (NOx) on specific areas of the pavements surrounding the church;

- Extensive rusting on several parts of the building built in steel;
- One broken glass panel on the roof;
- Localised plaster detachment;
- Localised crumbling plaster and moulds due to water-damage;

5.1 State of the decay of the travertine pavement surrounding the building

The drainage system of the wide church square paved with travertine stones was severely underestimated in the design phase. As has been previously reported, a large pond was designed to surround the shells at the competition stage. Following the change during the Developed Design stage, a much smaller squared area of the external floor bordering the shells and the back of the church was constructed slightly lowered to collect the rain water and create a temporary pond, noticeable only when it rains. In addition to this solution, very few drains were arranged in the rest of the paved area. The whole area is 2400 square meters and the rain water is collected only by linear drains along the perimeter of the plot together with 3 (5 x 5 cm) drains at the edge of the lower area and 2 more (10 x 10 cm) drains in the middle of it (fig.6). With the effect of rain-water stagnation and without regular cleaning, the surface is affected by high levels of depositions of sulphur dioxide and oxides of nitrogen (fig.7). The level of the deposition rises along the temporary pond at the back of the church where clearly the rain cannot be collected. A long crack is visible on the travertine floor in an area near the small shell suggesting poor execution of the floor together with the supply of shallow travertine tiles not properly sized for both the usage and thermal excursion.

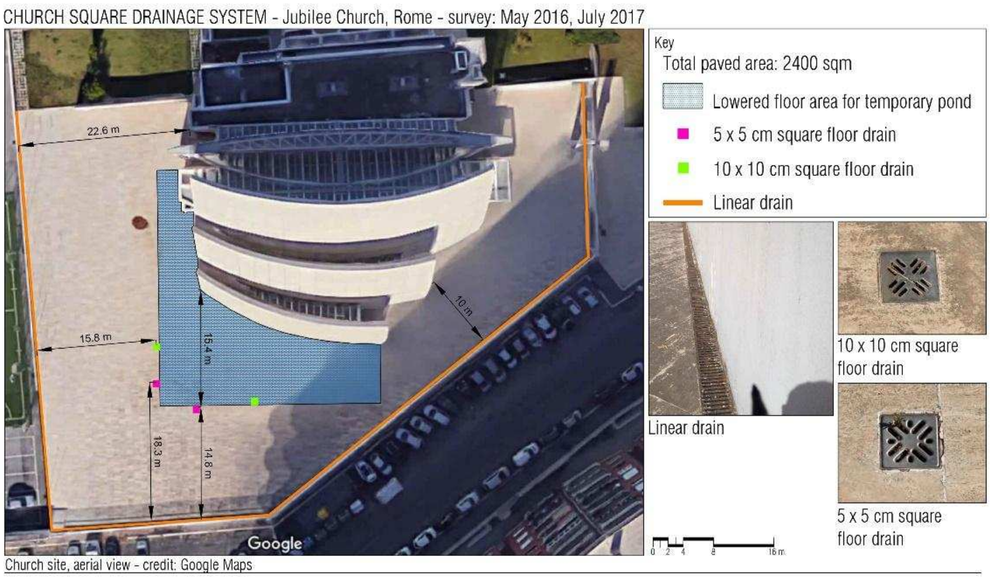

Figure 6. The drainage system of the church square (drawing and pictures by the author).

Figure 7. The area of the external pavement most affected by the acid rain deposits (Picture by the author, taken 22/05/2016).

5.2 State of the decay of the shells

The stagnation of rain-water on the external floor due to the lack of drains near the building and the impact of acid rain on the concrete surface has caused visible damage to the shells. Due to the spherical geometry, the rain washes the shell in two ways: on the convex side, the rain washes the whole surface from top to bottom, therefore the first course of blocks is the one washed the most from the rain water; on the concave side, without a flashing at the top of the shells, the rain washes the surface of the top course until the first joint acts as a drip edge, deflecting the water from the shell's surface. This is noticeable by the deposition of particles along only the highest course of blocks and on the top course of each shell. In detail, on the first course, concrete fissuring, moulds and washing-off of white pigmentation are visible where the shells meet the ground whilst extensive black stains are visible at the top of the northern side of each shell. The black deposition on the shells is more visible on the surfaces which constantly shaded, where the surface remains wet for longer and the sun cannot start the catalysing process with the dioxide of titanium contained in the TX Millennium concrete. This happens mostly at the back of the church, where the shells are closer to each other, or on the surfaces exposed to the north (fig. 8, 10, 12).

Regarding the whitening properties of the cement, after fourteen years the TX Millennium exposed concrete has yellowed extensively. Every block is yellowing in the middle whilst blackening and fissuring along the edges. This is why the rain stagnates on the wider joints between the concrete blocks, blackening them extensively (fig. 9, 11, 13). As this was the first time this cement mix was used it is not possible to compare this data with other case studies or measure the ageing process against the expectations of the Italcementi Group (fig. 14).

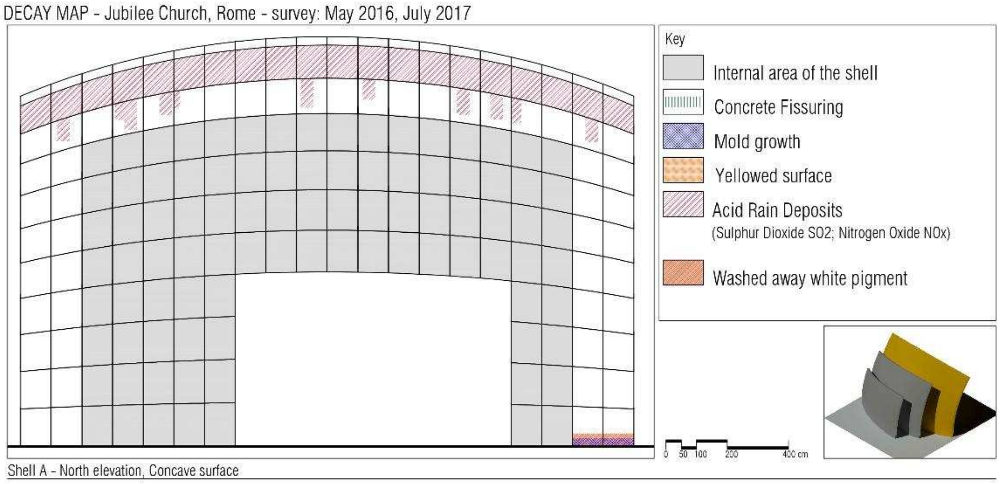

Figure 8. Decay map of the concave side of the large-size shell (drawing by the author).

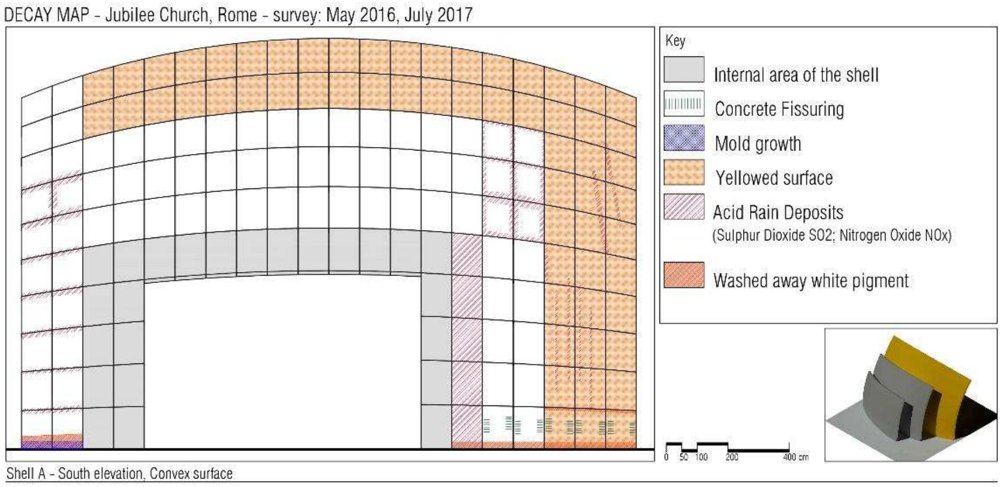

Figure 9. Decay map of the convex side of the large-size shell (drawing by the author).

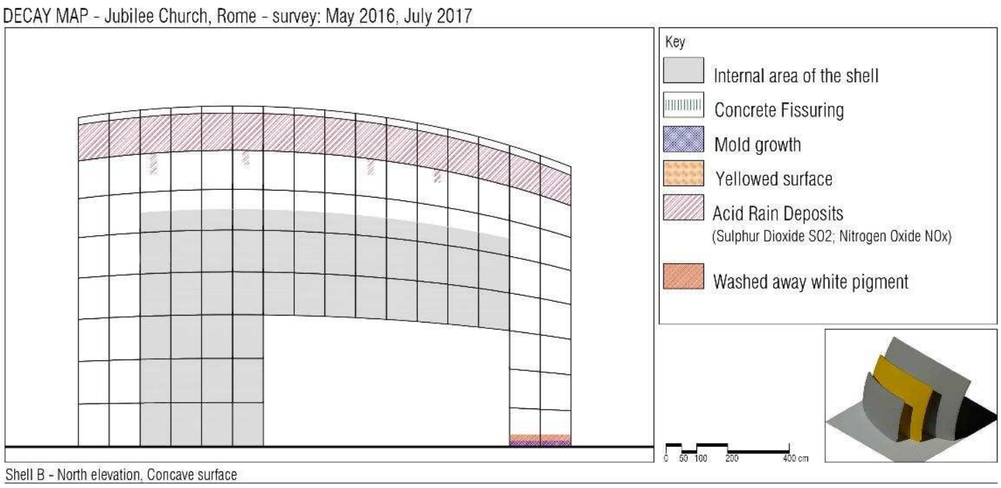

Figure 10. Decay map of the concave side of the medium-size shell (drawing by the author).

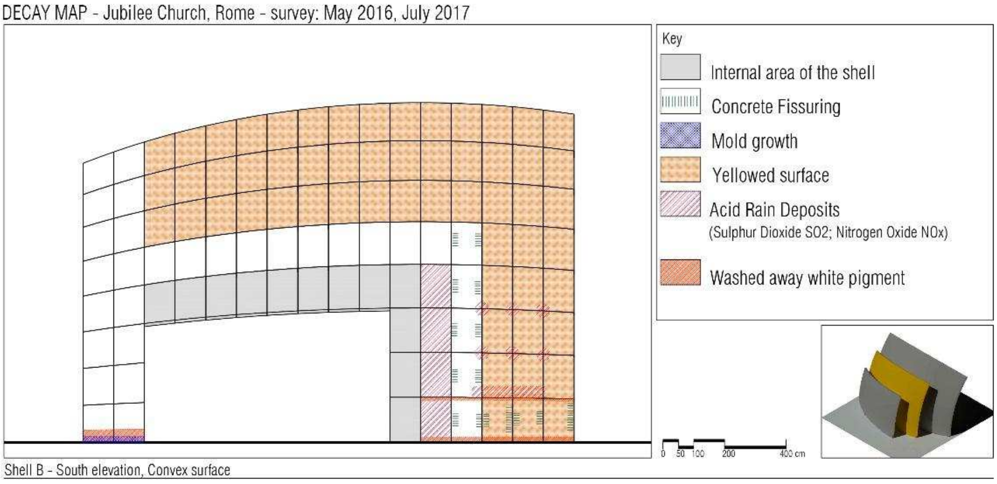

Figure 11. Decay map of the convex side of the medium-size shell (drawing by the author).

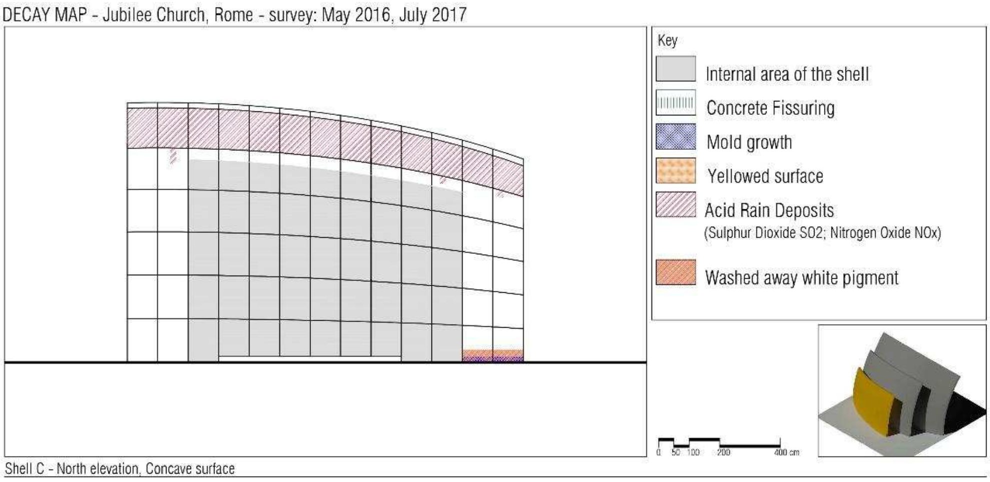

Figure 12. Decay map of the concave side of the small-size shell (drawing by the author).

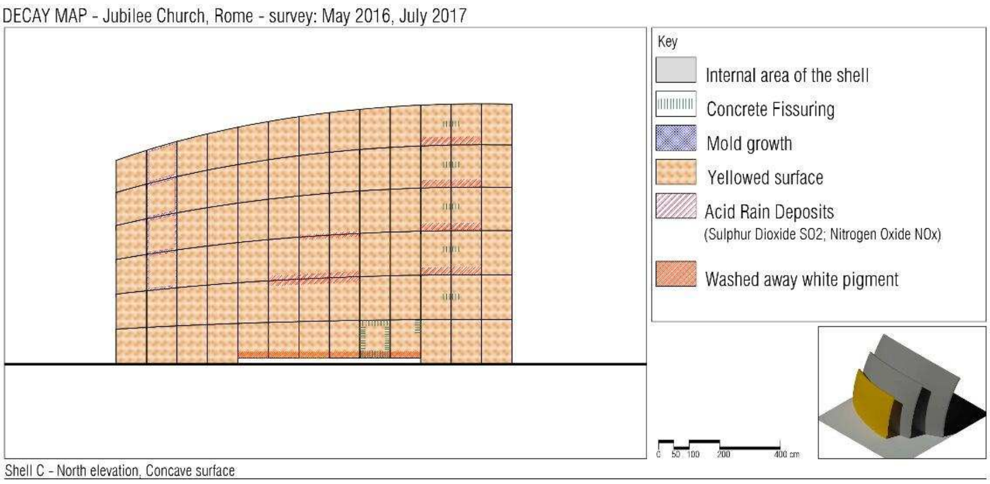

Figure 13. Decay map of the convex side of the small-size shell (drawing by the author).

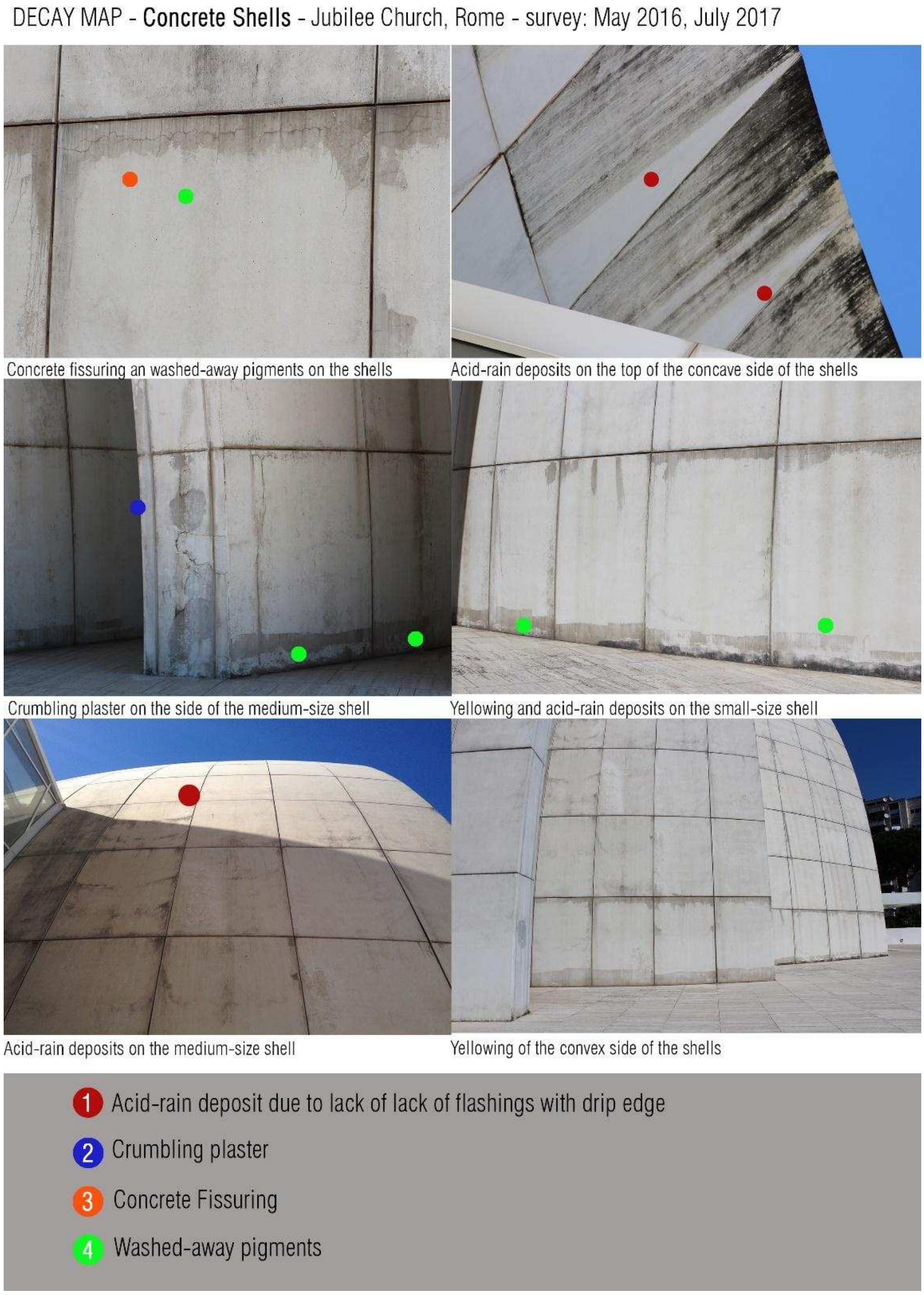

Figure 14. State of decay of the shells (Pictures by the author, taken 22/05/2016 and 28/07/2017).

5.3 State of decay of the steel elements in the church-hall

The mullions of the glazed roof are supported by pendula hanging from a curved steel hollow-sectioned beam, pinned at both ends to the solid northern walls of the church hall. The curved beam is then supported through steel-cables by a steel-truss which sits on the same northern wall.

The pinned joints connecting this wall with the curved beam and some of the pendula are visibly rusted, suggesting a poor level of galvanisation prior to their construction (fig. 15).

On the intrados of the curved beam and inside the cross bracing of the truss, large depositions of sulphur dioxide and oxides of nitrogen are visible from the inside of the church hall. Plaster detachment is visible on the wall against the steel truss (fig. 16).

Figure 15. Presence of rust on the pinned joint of the roof beam (Picture by the author, taken 22/05/2016).

Figure 16. Presence of acid rain deposits on the roof beam and on the roof truss. Some rusted roof pendula are visible as well as the crumbling plaster behind the steel truss (Picture by the author, taken 22/05/2016).

5.4 State of the decay of the glazed panels

In April 2012, a seagull flying over the church dropped an object from its beak onto the glazed roof. The impact broke a glass panel which has not been replaced yet due to the high cost, unaffordable for a small parish on the outskirts of Rome (fig.17). The rest of the glass panels and their mullions and transoms are in good-shape.

Figure 17. A broken glass panel of the roof. truss (Picture by the author, taken 22/05/2016).

5.5 State of the decay of the plastered blocks enclosing the church hall

The sacristy and the altar are designed into a plastered block which encloses the space of the hall on the west side of the church. The volume is located half inside and half outside the church. The part protruding on the outside is bordered by the lowered floor acting as a temporary pond when it rains. In the construction detail, no waterproofing membrane, nor a stone skirting board, nor a linear drain were designed where the block meets the travertine floor. Therefore, the stagnation of the water has caused diffuse crumbling plaster and visible mould at the bottom of the block (fig.18).

Figure 18. Mold growth at the bottom of the block of the altar.

5.6 State of the decay of the precinct wall

The whole surface of the precinct wall has been severely damaged by crumbling and detached plaster, together with black stains dripped from the top of the wall. This outcome suggests poor execution and construction detail, without a top flashing with a drip edge, not adjusted to cope with the weather conditions of Rome. Some stains of rust coming from the profile in steel at the top of the wall are also visible.

5.7 State of the decay of the parish house

On the northern façade of the parish house several damages have occurred. The balconies are built with a system of exposed steel girders supported by a reinforced concrete beam, plastered with stucco. Due to a poor level of galvanisation, all of the girders are visibly rusted while the concrete beams have experienced severe crumbling and detachment of the plaster. As the floor of the balconies is built in metal grill, rain water falls directly on these structural members which have not been built with proper waterproofing elements.

The northern façade of the parish house is severely damaged by the lack of flashing with drip edges. The windows are aligned with the plastered wall and they are not protected either by being set back or by canopies. In addition, the flashing topping that there is on the façade does not protrude enough to protect the walls from acid rain. The result is the presence of diffuse stains from black particles all along the façade and around the frames of the windows. On top of the east side of the retaining wall bordering the lowered courtyard, designed to naturally light up the basement of the parish house, extensive portions of detached plaster are visible. Again, this is due to a poor designed drainage system and poor execution (fig 19).

Figure 19. State of decay of the northern façade of the parish house truss (Picture by the author, taken 22/05/2016).

6. Results and Discussion

This paper aimed to analyse how the project of the Jubilee Church by Richard Meier was technically developed and how this development was modified and the scheme implemented contrary to the plans submitted at the competition stage. The engineering contributions of the contractor, technical designers and technical advisors focused on finding bespoke and innovative solutions for building the non-standard elements of the church, such as the three spherical shells and a large free-span glazed roof. During this development, some details and some standard building elements have been designed and executed without taking into account the local weather conditions. The technical survey run to measure the ageing process of this future monument of Rome demonstrated that, despite the changes in the technology and materials used to erect the shell which occurred over the technical development, the surface of these double-curved walls has severely decayed with the presence of concrete fissuring, blackening of joints, and yellowing of the whole surface of each shell.

7. Conclusion

This study highlighted that the high level of decay noticeable only fourteen years after the opening of the building is caused by a combination of the following factors:

- Design choices causing high cost of maintenance not affordable by a parish church located on the outskirts of Rome;
- Construction details not adjusted to acid rain effects such as the lack of extended flashing with drip edges;
- Engineering process focused mainly on the non-standard elements of the design, such as the concrete shells, neglecting other aspect of the construction detailing design such as the drainage system of the church square;
- Poor level of galvanisation for the steel elements;
- Poor level of execution and/or supply of inappropriate materials to some parts of the building such as the floor of the church square.

In this study, a cost for the restoration of the external portions of the shells has been calculated. Following the 2017 Italian price lists for procurement, the cost was estimated at 280,000 euros. In addition to this calculation, the cost of the restoration of the shells if they were built with the first design suggestion (steel frames clad with concrete panels, plastered and painted) put forward by Meir’s technical advisor has been estimated. This figure amounts to 130,000 euros, showing that, in fact, the original solution would have been more affordable to maintain.

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