The structural life of a Cathedral and the worksites of the Duomo di Milano

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ABSTRACT: The life of Milan Cathedral is described with the evolution of the structural system and the restorations carried out throughout the centuries. The organization of the Veneranda Fabbrica del Duomo di Milano is outlined, with the latest restoration interventions. The case study of the construction and restorations of the Tiburio with its supporting pillars is analyzed, from the initial design to the dramatic damage in the 20th century. The rebirth of the Cathedral was the fruit of restorations preserving the structural identity of the monument up to the present. The conclusions address the study of damage and maintenance and repair operations of monumental heritage buildings within a life cycle perspective, in relation to the underlying societal values.

1 INTRODUCTION

The Cathedral of Milan represents an example of a century long structural life, characterised by a long construction and ongoing restoration history. A central event along the period of time between the start of the Fabbrica in 1386 and the present is the risk of collapse of the Tiburio and the “rebirth” - as defined by the former Architect of the Fabbrica, Carlo Ferrari da Passano (1988) - that occurred in the 20th century.

Novel approaches in life-cycle assessment, maintenance planning, and optimal design of structural systems (Biondini and Frangopol, 2016) foresee their extension to built heritage. Historic structures must be restored according to general conservation criteria (Roca, 2011). Also the safety of people and the integrity of the possible artistic contents pose certain requirements on structural reliability. While facing these two main challenges, the design and the management of such a specific activity has to often deal with uncertainties of the most intimate static and mechanical behavior of the monument. The result is a complex engineering problem aiming to optimal solutions which, while granting the reliability requirements, cause the minimum possible alteration to the original features of the structure. And, as a matter of fact, the experience acquired day after day on the scaffoldings and while designing, should be preserved as a most valuable knowledge increase by the means of specific organisations established in order to take care of the monument through the centuries.

The case-study of the structural life of the Tiburio of the Cathedral is here presented to link this history to central topics of life cycle assessment: the damage of existing structures, its evolution in time, restoration interventions and the safety requirements of historic buildings for their present function. Moreover this case demonstrates that the conservation or the restoration of a heritage property can be oriented to preserve its authenticity (Roca 2011).

The Veneranda fabbrica del Duomo is described as the active institution carrying out the operations needed for the preservation of the life of the Cathedral. Whereas modern design and scientific concepts aim to a reference design service life of 50 or 100 years, heritage constructions often span a 5 to 10 times longer lifetime. Thus the survey and modelling of deterioration and time-variant structural performance meet a different temporal dimension, encompassing a past and often complex structural evolution. In addition these differences highlight the importance of maintenance within a life-cycle perspective, and the social and moral values of a society determining rules for this process.

2 THE FABBRICA DEL DUOMO AND THE TIBURIO RESTORATION CASE STUDY

2.1 *The Veneranda Fabbrica del Duomo*

The singular history of this institution is such that a brief summary is necessary. The Fabbrica of the Duomo of Milan (Venerable as dating back to the late XIV century) is the institution responsible for the conservation and development, as well as the maintenance of the cathedral. This is an ecclesiastical body endowed with legal authority by ancient statutory determination, for the purpose of worship and religion. It excludes all profit making activities.

There is a Board of Directors composed of 7 members who remain in office for 3 years, one of whom is elected President. Two are appointed by the diocesan ordinary and 5 by the ministry of the Interior, with the consent of the Archbishop.

Needless to say works of such entity, today as in the past demand large resources. In the course of its history the Fabbrica has been sustained by the donations of citizens, and by the introits of an important real estate patrimony formed by the numerous bequests made by those wishing to be remembered as associated with this great undertaking. The yields from these properties providing the necessary funds for the realization of such works arising from time to time.

However in the early years of the xviii century this efficient system of self-support fell victim, so to say, of History. On his arrival in Milan Napoleon, finding the Cathedral far from completion ordered the Fabbrica to sell of the entire property patrimony in order to speedily obtain the necessary resources in order to complete the facade.

There followed a very difficult period, with the Fabbrica obliged to recur to the Administrative Authority of the time for financial support, receiving which, to greater or lesser extent according to the interlocutors they were faced with, and within the historical context. Today faced once more with dramatic urgency to find new forms of financial support, for the first time in over 600 years the "Infinite Fabbrica" would run the risk of closure. From the tickets sold for guided tours and entry to the Terrazze in particular, together with specific fundraising campaigns (Adopt a spire, Adopt a statue) an adequate answer to the difficulties has been found.

As in every operative organisation the personnel employed on the front line (the 3 work sites, and the assistance to visitors and tourists) depend on the support of others to organise the work (from management to planning, to personnel and to logistics). The Fabbrica counts circa 200 employees subdivided in the following areas (Table 1).

Table 1 – Fabbrica del Duomo - Areas of activity

Administration	Technical activities	Culture	Tourism	Communication	Services
Private fundraising Advisory board International Patrons of the cathedral Raising of public funds and institutional relations Public funds and calls International relations and European projects Real Estate and Purchases	Technical office Candoglia quarry Marble worksite Cathedral The San Gottardo in corte church	Arts , Culture Museum The Archive - Library Musical chapel Cultural events and activities Department of Education	Monumental Complex Visitor service Ticket office Fast track Cathedral shop Guided tours	Press and communications office Press office Digital communication Photo and Video shooting	Safety measures Security Area Security General services.

The particular maintenance work on the cathedral can only be carried out by direct control of skilled workers of the Veneranda Fabbrica. There are approximately 100 people divided between 3 worksites, that of the Candoglia quarry, the marble carvers and the cathedral worksite, employees of the Institute founded by the Duke of Milan, Gian Galeazzo Visconti, in 1387; and from that time engaged, up to 1965, in the construction and particular maintenance (from 1842 to this day) of the cathedral.

The components of the Fabbrica work in the closest coordination, a delay in the chain of purchases has immediate effect on the possibility to proceed with work on the scaffolds; while unsatisfactory programming on the sites may compromise the visits of the faithful or visitors.

An error in daily consultation of the archives may compromise the research of scholars, or the necessary verifications regarding the worksites. Each of the areas listed above has its own work plan and procedures codified from time back, so that it is sought to combine the original procedures while keeping up to date, as regards the management profile. this is also true for all the extraordinary organisms of the Fabbricerias, Italian and European. Between which there is an ever growing network of contacts and the sharing of knowledge (see section 4).

2.2 *The restoration of the Tiburio*

March 2016 saw the start to erect scaffolding around the cathedral Tiburio. Despite delays caused by the SaRs-CoV-2 epidemic the intensity and precision of the work to date indicate the possible completion of this very demanding restoration by the end of 2024.

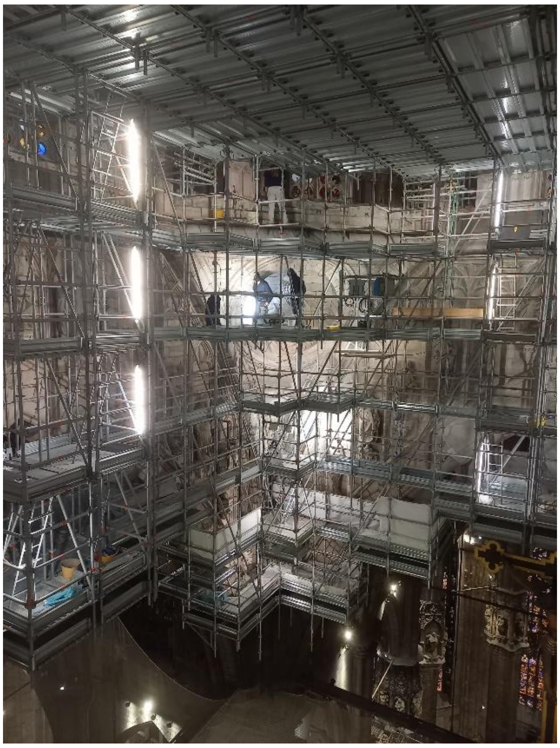

Figure 1 – The scaffolding for the Tiburio restoration

A few figures may serve to understand the complexity of the undertaking:

- 3.600 tons weight of the tiburio developed over 55 metres height, supported within the span of a system of 4 arches.
- The absence of precise mechanical and geometrical data about the nature and function of the supporting arch system, which was conceived and realised during the mid XV century and the first 20 years of the XVI (see section 3).
- A 35 year period during which the conception and the actuation of the supporting structural system was conceived.
- A workforce consisting of 96 men a day on the scaffolding.

- 480 man hours to mount and erect it.
- 1.750 man hours estimated for the restoration work
- 72 hours topographical monitoring calculated to control the the functionality of the structural system during restoration work.
- 8 load cells installed and controlled daily to govern the weight distribution of the provisional structure on the architecture of the tiburio.
- 95 man days to consult the Archives with an end to obtain necessary information for the development of the work
- 6 million euro the estimated cost of the intervention.
- 20 cubic metres of Candoglia marble for substitution and 200 cubic metres of marble restored in situ at a medium height of 75 m from the cathedral square.
- 76 marble statues restored

The ensuing activities required a workforce which at the lowest level received a 2 year formation period before they could operate with a certain degree of autonomy, in a team type formed by 3 men, one of whom being the supervisor.

It was possible to develop the work by virtue of a series of hoisting towers, designed for the purpose and constantly checked and maintained by specialised personnel, and with the additional efficiency of the site store depot, while operating right in the heart of Milan's historic centre.

3 HISTORY AND STRUCTURAL LIFE OF THE DUOMO

The great Milan cathedral (il Duomo) is a most imposing monument built in the Gothic style. Construction began in 1386. Late Gothic (the French style born some 200 years previously), was adopted more from political and economic motives than from architectural sensibilities. Almost as if to say that the social and economic field of reference was that north of the Alps.

The fact of being the 4th largest cathedral in the world for extension, and the 3rd in height, for the internal dimensions of the main nave, make it a very particular structure. The vertical system from floor to the terraces is built of buttresses, walls and piers of brick and blocks of serizzo, faced with Candoglia marble. The vaults are made of brick, with Candoglia ribs; the lateral buttressing is provided by diaphragm walls and iron ties (Coronelli et al., 2015). The upper part, from the terraces to the summit of the great spire, entirely built of Candoglia marble. This is a crystalline marble only extracted from the quarry of the same name as the town at the entrance to Val d'Ossola. Beautiful as it is to behold the marble presents structural problems: the presence of pyrite, plus the iron ties used over the centuries to join the units, frequently provoke sudden internal fracturing.

The history of the construction is here described underlining the different phases in time, followed by restoration. The sources used are mainly the writings of Ferrari da Passano (1988), Architect of the Fabbrica del Duomo from 1964 to 1988; these are based on this Author's experience and the Annales of the Fabbrica del Duomo, a unique record of the worksite activities from 1386 to the present. A description of the overall structural configuration can be found in Coronelli et al. (2015).

3.1 *Construction history*

3.1.1 *The Apse*

The construction started in 1386 with the apse proceeding from East to West, containing the choir. The geometry of the apse (Fig.2) is a half octagon in plan, covered by a half dome with triangular cells, and six interior pillars supporting the half dome are placed along the perimeter. These members together with six vertical buttresses, support five quadripartite vaults of trapezium shape in the deambulatory. Here the apse is closed by large decorated windows. The dimensions of these openings together with the slenderness of the buttresses raised the concern of the French consultant Mignot, that originated a documented controversy (Ferrari da Passano, 1988). The statements of the constructors underlined the key role of pointed arches and iron ties for the stability.

The choir is flanked by the sacristies on either side with perimetral walls, connected to the buttresses on the exterior perimeter, constituting a firm system with lateral load bearing capacity, that was the first part of the construction.

The following part constructed was the crossing with a structure with one nave and two aisles very similar to that of the longitudinal body, with a main nave and four aisles. The buttressing is provided by diaphragm walls and lateral buttresses walls, combined with iron ties (Coronelli et al., 2015)

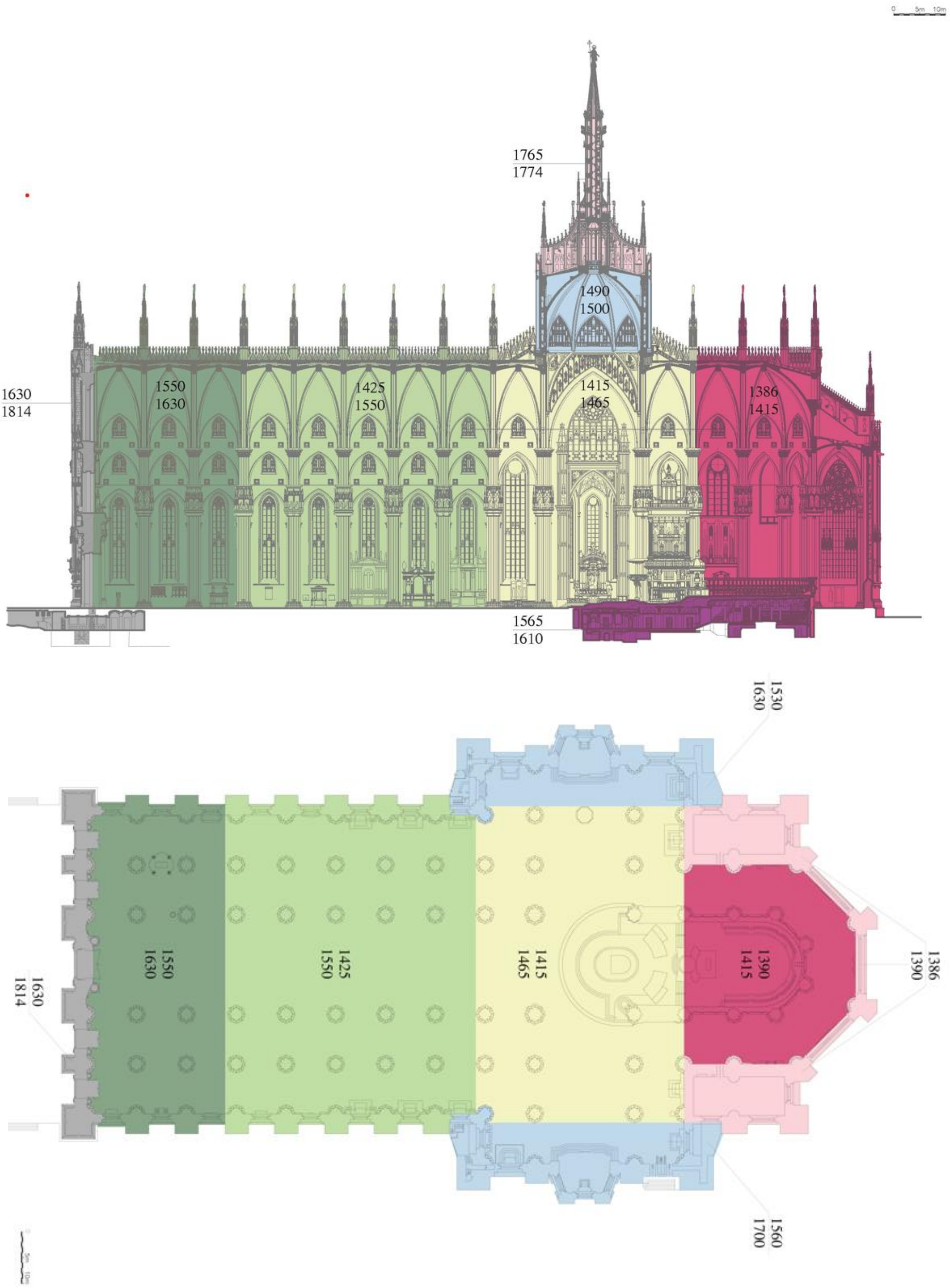

Figure 2. Parts of the Cathedral and years of construction

3.1.2 *The Tiburio and Dome*

The construction of the tiburio began with foundations and four pillars slightly larger than those of the other vertical members. At the beginning of the 15th century these were built, supporting the four 19.6m span pointed arches, the walls above the arches, the pendentives and the decorations. The choir backed by the apse, the transepts and the first bay of the nave and aisles surrounded this part of the fabric.

The discussion developed with foreign and Italian experts including Leonardo Da Vinci and Bramante amongst others. The solution adopted was proposed by Lombard personalities, first Giovanni Solari from 1452 and then Guiniforte Solari, who took the lead of the construction starting from 1459. This consists of four semi-circular arches hidden behind the walls above the pointed arches (Fig.3). Conceptually these act as load-relieving arches for the pointed arches.
The intrados radius is 8,6 m , a great depth and width of the cross section, ensuring a wide load path for the loads of the dome: at the crown 160 by 180cm, and increasing moving towards the supports. The cross-section is obtained with voissoirs in radial position, in a ring of constant depth (1,6m). Above this blocks are laid horizontally, reaching an extrados drawn by a circular line with a radius of nearly 18m and a centre at the springing line of the pointed arches. The material used is serizzo, a strong metamorphic stone quarried in Lombardy and Val d'Ossola.

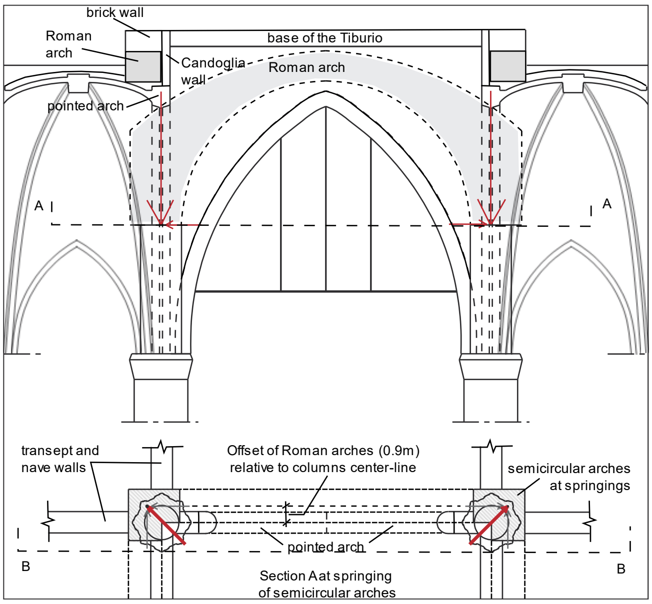

Figure 3. Arches supporting the Tiburio

The choice was made to build the arches supported on the pillars of the crossing, without demolishing the walls above the pointed arches; hence the arches lie in an off-set position (Fig.3, plan view) (Ferrari da Passano and Brivio, 1967). This layout increases the eccentricity of the reactions of the arches on top of the pillars (Ferrari da Passano, 1988).

As a consequence very relevant problems arose in the construction after the removal of the centering, as the pillar tops were displaced outwards under the arch thrusts. The ties of the Gothic arches below were all broken. The structures surrounding the Tiburio were damaged. As a consequence the construction was stopped around year 1470.

The system at the time was bearing only the weight of the new Roman arches and the masonry walls above. The arches were buttressed against the surrounding structure of the transepts, choir and nave. The walls in the choir and sacristies in particular definitely played a role in the lateral stability. Despite the damage the structure reached a new equilibrium that was the basis for the future of the construction.

This was undertaken under the guidance of Amadeo and Dolcebuono, and the dome was completed in year 1500. The whole structure was supported by the system of Gothic and Roman arches described above and is based on an octagonal geometric scheme, leading to concentrating the load on the drum in eight locations, interior to the span of the arches below.

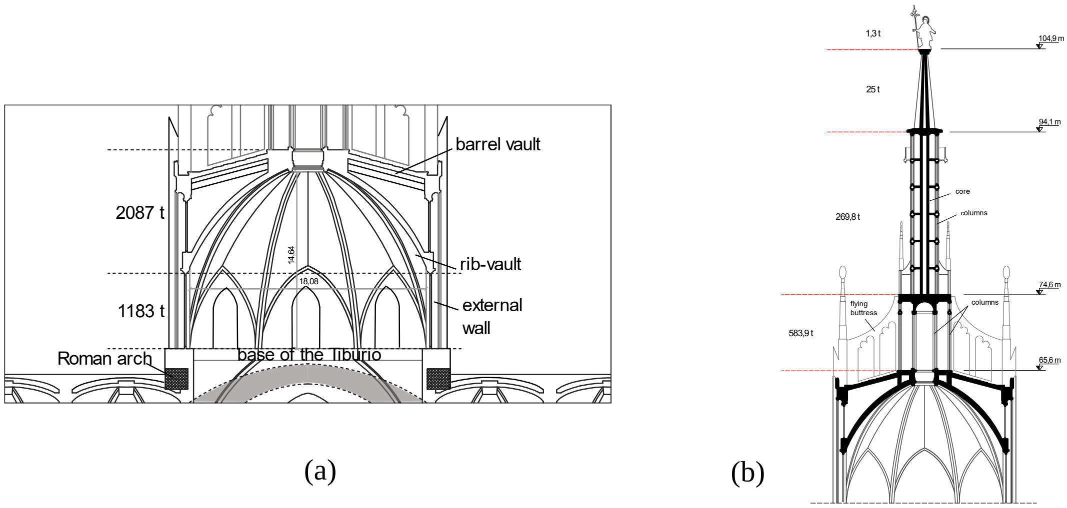

Figure 4. (a) Structure and weight of the Tiburio and Dome and (b) Tiburio with the main Spire

The dome (Fig.4) was built with the same characteristics of the existing construction – the half-dome of the apse in particular, with the same arches and vaults (Ferrari da Passano and Brivio, 1967). The plan is octagonal, connected to the square of the crossing with pendentives. The dimensions are the same of the apse with a span of 32 braccia (19,2 m), and the crown at 19,2m from that of the pointed arches of the crossing. The interior vaults are made of brick, with eight cells, and Candoglia marble ribs meeting in a central ring of brick and marble. Walls made of brick in vertical planes bear on the base and extend radially above each rib, creating a fan and connecting at the central ring. Barrel vaults span between adjacent radial walls at the top, to support the stone roof, and creating a chamber above the dome inner vaults. This is the same scheme used for the double vaults to support the roof above the naves (Coronelli et al, 2015).

The dome is enclosed within exterior vertical walls, along the perimeter of the octagon. Windows open at two levels, one looking into the interior of the church and the other into the chambers between the two vault systems. The walls connecting in the vertexes of the octagon form eight vertical members, with spires placed at their top. The weight of the walls sums with the forces transferred by the dome at the supports, bearing on the base of the Tiburio. The outwards components of these forces are balanced by steel ties lying in the horizontal octagonal ring at the base of the dome. The vertical components are transferred by vertical walls onto the semi-circular arches of the crossing.

Thus, following the history of the construction, the intensity and distribution of the loads on the semi-circular arches changed between years 1490 and 1500 with the construction of the tiburio, with increasing vertical forces and lateral thrusts on the underlying pillars. But further stages and changes were still to take place.

3.1.3 *The main spire and gugliotti*

The project to build a spire to crown the building dates back to the beginning of the construction (Ferrari da Passano, 1988). The main spire, “la Gran Guglia” was built in the 18th century, after studies to ascertain the safety for the underlying construction (Brivio and Repishti, 1998).

The final design (Fig.4b) was presented by Francesco Croce in 1764. Its base is at the level of 65,6m and reaches 104,9m at the feet of the statue of the Madonnina. The spire is a rather light structure, with a central marble cylindrical tube, and pillars on the outer perimeter. All the stone works are connected by a complicated system of iron ties, with longitudinal elements within the central void and transverse fastenings. The total weight bearing on the top of the tiburio is 884 tons.

The four gugliotti (Fig.1) are small towers with spires at the top, placed on the roof at the four corners of the square corresponding to the perimeter of the crossing. The first was built between 1507 and 1518 and the others followed much later in the second half of the 19th century. Their position corresponds to the pillars of the crossing, and their load flows directly onto these members. The overall axial force of each pillar increases by 100-150 tons , less than 5% of the total axial load, approximately equal to 3000 tons at the base of each pillar. Nevertheless significant damage showed in these vertical members with cracking of the outer Candoglia ring. This led to the closing of the Duomo at the end of the 19th century for restoration works, showing that these members were already close to their safety limit at the time.

3.2 *Restoration history*

Any action aiming to the conservation or the restoration of a heritage property should be oriented to preserve its authenticity (Roca 2011). In this perspective, this section provides a synthesis of the main structural restoration works related to the Tiburio and the piers of the crossing in the period ranging from the end of the 19th century until today. These have been the object of detailed reports by Ferrari da Passano and Brivio (1967) and Ferrari da Passano (1988).

The size of the cross-section, and the type and quality of construction were at the origin of the distress in the piers of the crossing. The cross-section is made of an outer ring of Candoglia marble; the thickness of this part is varying without a precise rule along the height. The interior is filled with mixed materials, including serizzo blocks, brick and mortar. The building of the Tiburio in the 16th century and then of the main Spire in the 18th century added high loads on these members. The configuration of the Roman arches caused eccentricity of these loads and lateral displacements of the pier.

In the second half of the 19th century, the piers of the crossing showed signs of severe damage. This indicates that the load effects were such to approach critical conditions for these members. Restorations were carried out extracting the damaged voissoirs, filling with lead the inner voids, and replacing new marble units.

In the 20th century the soil water table was lowered by 20m between 1950 and 1970 by the industrial water consumption in Milano. The soil subsidence caused settlements of the foundations. Measurements of the differential settlements over a period of 5 years from 1965 to 1970 showed rates higher than 1mm/year between points at 20m distance (Ferrari da Passano, 1988).

A survey of the piers in the crossing (Fig.5) and in the choir showed compression cracks in the blocks of the outer Candoglia skin, with an approximately vertical orientation. Monitoring showed a dramatic progression of phenomena, with crack widths were increasing in time and the formation of new damage and spalling of parts of the units.

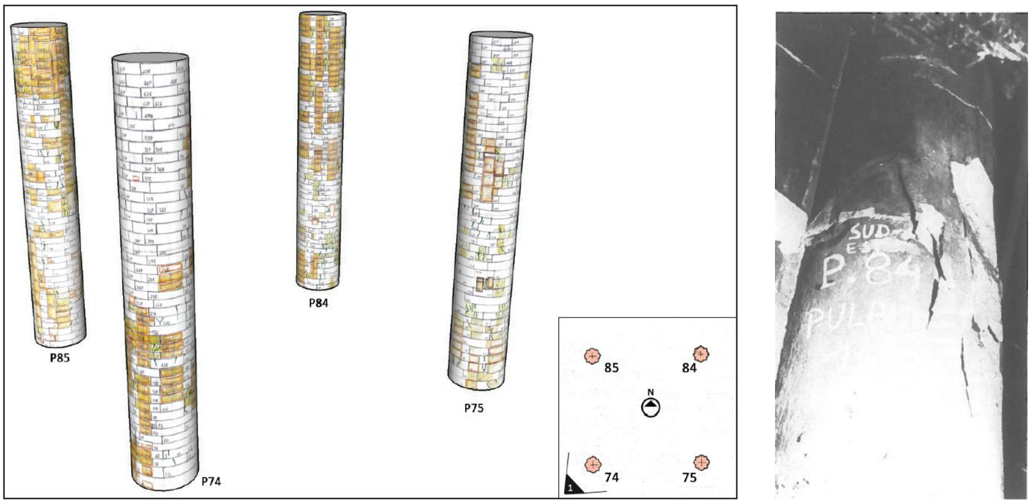

Figure 5. Survey before restoration: sketch of deterioration pattern of blocks and photograph of cracking.

To face the emergency a commission was formed in 1965 by the Fabbrica del Duomo and the Politecnico di Milano. The piers of the crossing were provisionally encased in reinforced concrete, while those of the choir with a steel structure. A geotechnical study showed that the load bearing capacity of the foundations was not the cause of the phenomena, whereas the settlements were compatible with a theoretic calculation of the effects of subsidence.

The interpretation of the conditions was carried out at the ISMES laboratory, resorting to a scaled experimental model of the whole Tiburio with the surrounding vaults and supporting vertical members (Ferrari da Passano and Oberti, 1983). Imposing differential foundation settlements, a redistribution of forces with overloading of the northern piers with respect to the southern was shown (Ferrari da Passano, 1988).

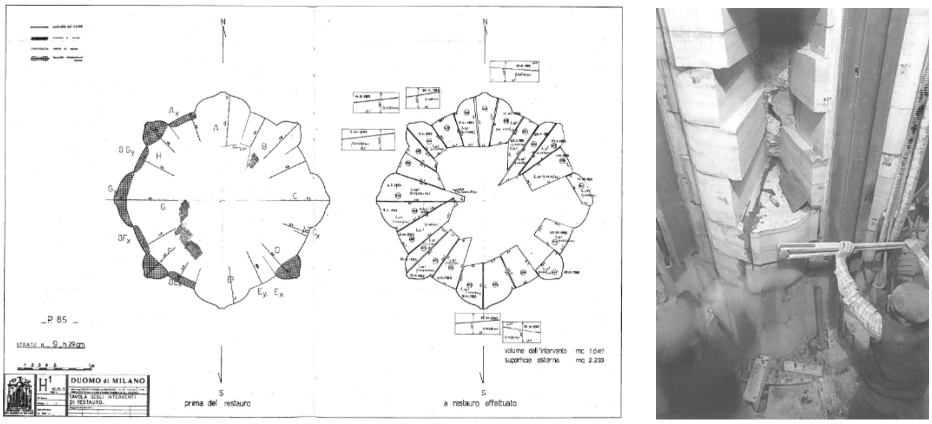

Figure 6. Survey and restoration: damaged and replaced units.

To stop the causes of the phenomena, the use of water was banned from industries surrounding the central part of Milan, hence stopping the lowering of the water table. This in turn gradually stopped the ground settlements.

The study of a restoration technique then started. Scaled masonry models of the piers were built and tested (Ferrari da Passano and Oberti, 1983). The solution adopted for the four main piers of the crossing, proposed by the Architect of the Veneranda Fabbrica, Carlo Ferrari da Passano, was inspired by the concept of maintaining the identity of the Cathedral by preserving its original structure.

After a detailed survey of the thickness of the outer Candoglia ring and of the damaged units (Fig.6), these were gradually replaced with new pieces of the same material and profile, penetrating deeper radially in to the core of the pier and thus providing an increased resistance. To provide safety to the operations, the reinforced concrete outer skin was gradually removed, exposing only the parts being restored. By 1980 the four piers supporting the Tiburio appeared sound again.

Another intervention on the Tiburio structure was the placing of steel ties connecting the four piers of the crossing, anchored within the walls of the transepts. These correspond to the original design of the crossing, where iron ties had been used before the failure caused during the construction of the Tiburio (see section 3.1). Finally, displacement monitoring on relevant points of the building began, and has been carried out with a period of six months up to today, highlighting essentially stable conditions.

It must be remarked that these choices reflect the concepts on the relation between structure and authenticity outlined by Roca (2011). The conditions of the piers were successfully improved by the restoration works described in this section; these members have been now in service for more than thirty years, and the elegance of the cathedral was restored (Fig.7).

Explanation of these past phenomena though was only partial. The experimental scaled model (Ferrari da Passano and Oberti, 1983) being elastic, made of materials obtained with epoxy resins, lead to estimates of the redistribution of loads with the ground settlements. These events could be examined and understood more deeply by numerical analysis with nonlinear constitutive models for the materials (Roca et al., 2013; Angjeliu et al., 2020). Another aspect to which attention should be devoted are creep effects (Binda, 2008). The effect of soil settlements evolution in time should be included. Thus a more thorough explanation of the phenomena that nearly led to the collapse of the Tiburio could be reached, and the present and future evolutions followed.

The last step in the 21st century is the restoration of the Tiburio (see section 2). With the scaffolding in position maintenance operations have been carried out on the sculpture and decorations. Units of masonry of the walls above the supporting arches has been replaced, and the mortar beds maintained. The ties connecting this system have been inspected, showing good conditions.

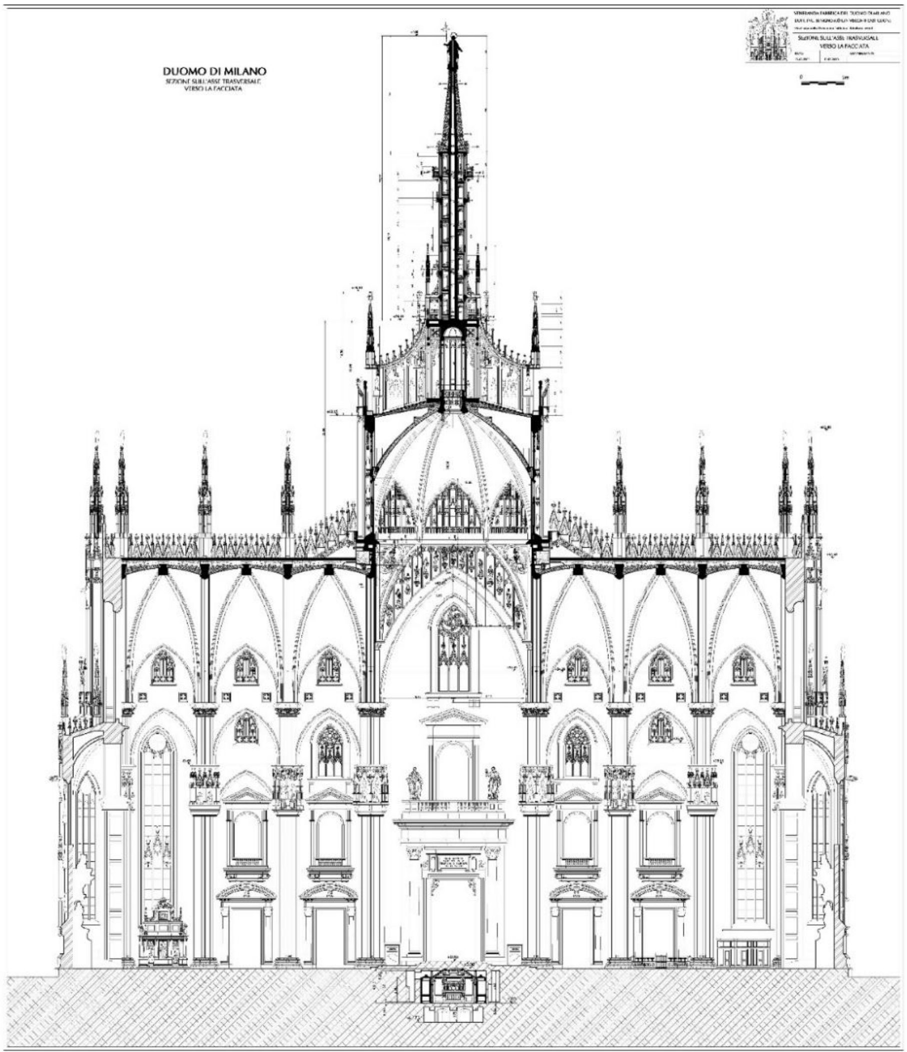

Figure 7 – Section of the crossing

4 INSPECTION AND MAINTENANCE

4.1 *The technical table of the Italian Fabbricerie*

One of the main aims of a restoration of a heritage structure is ascertaining the safety of people using or visiting the structure, with the possible risks limited to acceptable levels (Roca, 2011). Following the dramatic incident in Florence, in the Santa Croce cathedral, on the 20th October 2017, the leading technicians of the principal Italian Fabbricerie within AFI (Associazione Fabbricerie Italiane) decided to confront one another on their respective experiences and activities, to discuss the possibility of defining a code of practice for maintenance of such complex architectural organisms. For 18 months of monthly encounters and consultations, a document was formulated to underline the fundamental importance of periodical inspections; defining the operational modalities and criteria for the management and programming of the same inspections and verifications on all the elements at quota, characteristic of every monumental fabric, the degradation of which could present a danger to the public and private incolumity.

This was considered to be the prime, inexorable object to be reached, propedeutic to the definition of a code for programmed maintenance, to which each Fabbrica should comply according to the capacities and economical and financial possibilities of each.

To follow, a resume of the chief considerations which emerged in conclusion of the Technical table, regarding both the content and necessary action to be taken, in order to render the guidelines for inspection of cathedrals, fully operative.

4.2 *The conclusions of the AFI 2018-2019 activities*

With reference to public safety precautions, each Fabbrica possesses specifications which make it different, and has specific problems. Even though the type of problem is similar. Those of a structural nature (overloading, cracking, settlements etc.) being too different in the various cases must however be dealt with and resolved by each single Fabbrica.

On the other hand damage to decorative elements such as tiling, plaster or stone fragments of various dimensions, are a common phenomenon, constituting possible negative consequences for safety, and are by no way inferior to the structural problems.

Therefore it was agreed that in order to confront these problems from the safety point of view, monitoring of the architectural surfaces is fundamental. This can be undertaken essentially, by periodical visual inspection, eventually from hoists, or by workers specialised in operating at heights; the frequency and modality varying from case to case.

Each inspection is to be documented graphically, illustrating the area (prospects or parts of these, covering, characterising elements etc) and the architectonic or decorative elements of which they are composed or characterised by. The amount of detail will vary naturally, for each monumental fabric, but may also vary within the structure, as each possess intrinsic characteristics.

The evaluation must furnish a quantitative result, not only the conceptual. To this end the technical table has elaborated a procedure which, on the basis of inspection results, (that is the state of conservation in the inspected area), the estimated duration of the manufactured components of the same, and of the level of risk relative to its exposition, must report the degree of alert and establish the frequency of verifications to be made. To complete the evaluation it is essential to establish the expected duration of the manufacture defining the architectural surface, distinguished according to form, material and exposition.

5 CONCLUSIONS

In a life cycle analysis perspective, the study highlighted the description of damage, its evolution in time and the study of the causes. Two aspects that differentiate the structure of heritage buildings from modern construction are the higher uncertainties related to the geometrical complexity and of the materials effectively used. The case of the piers in the crossing of Milan Cathedral is emblematic with the differences between external and internal geometry and materials.

A specific type and pattern of mechanical damage, showing in the 19th and 20th century, related to overloading of the piers and their masonry texture, has been documented. This shows the need for the development of numerical structural and constitutive models capable of predicting effects of masonry creep in relation to different materials and textures. The engineering problem, tackled by the experts of the time, leading to successful restoration intervention and a true rebirth of the Cathedral at the end of the last century has been described.

The 21st century restoration activities on the Tiburio show the solution of a different type of damage, of relevant importance for monumental buildings and their present use. Operations carried out to maintain the decorations and sculptures, contemporarily provide means to avoid dramatic accidents, that have been the object of a technical discussion table of the Italian Fabbricerie.

When the concept of maintenance of the cultural patrimony assumes the aspect of physical care to an architecture (that is, to any expression of the building capacity of Man) the study of the best way to fulfil such an arduous task is enriched by certain, perhaps surprising observations for those who do not habitually frequent the scaffolding of a building site, or the tables at which restoration projects, or the economic aspects and financing of such, are planned.

One of the observations which is brought to the attention of those studying these processes, regards the realization that the significance of testimonies that vert on the cultural patrimony is seen to be in the majority of cases centered on a single case, independently of its nature or dimensions, be it a commemorative monument or building. Single constructions, were erected in the distant past, using building techniques and suffer the effects not only of the times when they were erected but also of the regional uses to which they were put, so that when faced with their conservation we have little information, or few designs to describe their constitution.

The knowledge and experience gathered by whomsoever has done conservation work on these goes to form a valuable capital, allowing to consider the best way to invest in the sector.

Knowledge is often gained from past errors, or from verifications made during the intervention, or from fortunate intuition during the course of the works; this together with the experience gained, leading inevitably to an affection towards the object, as well as satisfaction over a successful intervention, or a desire to improve on this when not entirely successful at a first attempt. It is natural that we strive toward improvement in our professional practice.

How are we to avoid the loss of such capital? How to make it more fruitful? By the formation of a group of persons essentially drawn from skilled operators, for the constant maintenance of a chosen cultural object. A group of workers, of varied experience, according to the specifics of the monument, to acquire in depth and transmit the method of intervention, increasingly gaining understanding of the nature and characteristics of the same, and with a greater knowledge measure the resources necessary. Such a group to be composed, as foresaid, of skilled workers: that is to say, artisans specialized in the sector, allowing for them to develop and investigate modalities for the intervention, and to be in a condition in which to dedicate themselves with serenity, to the monument in question, without having to submit to managerial impositions.

The management, for commercial reasons and bearing in mind the above mentioned difficulties incurred in intervention (unusual techniques of the times, lack of specific technical information, etc.) must find an economic balance which however could sometimes penalize the quality of the intervention. Small scale public or private administrations, as well as great cultural institutions such as Museums or Foundations could make the most of their most significant assets, finding in an economy of scale solutions to questions of costs and benefits.

The permanent maintenance group must certainly be enriched by the indispensable contribution of the design engineers; but these may be autonomous professionals, accustomed to operating in the market. The commissioning body must formulate clearly the request to supervise activities of the workforce, while taking a long view, as the planning of the maintenance operations at the very best will be projected for tens of years, and for centuries to come. Therefore inevitably a period beyond that of individual involvement. An unimaginable stimulus this, to give of one's best.

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