Multilevel approach to the analysis of the historic arch bridges in the Park of Monza

A. Saisi  
*Politecnico of Milan, DIS-Department of Structural Engineering, Milan, Italy*

L. Valsasnini  
*Consulting Architect, Monza, Italy*

ABSTRACT: The paper describes the characteristics and the evolution of the historic masonry bridges in the Park of the Royal Palace in Monza. The bridges are systematically classified and studied taking into account their evolution until the present situation, surveying the structure and its materials, the building techniques, the maintenance and decay problems, the effects of the past intervention.

1 INTRODUCTION

The Park of the Royal Palace in Monza is the most extended European historic park surrounded by walls, originally planned by Eugene de Behaurnais at the beginning of the 19th century on the model of the great French parks (Cantalupi, 1854), (de Giacomi, 1989).

Fields, pre-existing roads, irrigation ditch, the Lambro river, infrastructures, farms, watermills, villas and gardens were included inside of the walls, nearly as a compendium of the Lombardia region agricultural territory. With the Park evolution, the crossing of the Lambro river and of the irrigation ditches was accurately designed from the infrastructural and landscape point of view.

Hence, the bridges are strictly connected to the construction of the Park as important features within the historic landscape and elements of the territorial infrastructural system.

At the beginning of the 20th century, the original design of the Park had been altered from the introduction of new functions and structures, far from the surrounding atmosphere and environment. In spite of this, the Park of Monza is still today a peculiar landscape, characterized from remarkable historic and cultural values and inserted in an atmosphere apparently natural, but on the contrary, carefully designed (Municipality of Monza, 1988).

The bridges of the Park have different function, from simple footbridges to roadway bridges. The states of preservation are different as well as the intervention carried out in the past.

In some case the adequacy criteria to the new function and traffic loads, required a complete alteration of the historic feature and masonry arch structure. The interventions since the ‘50s did not follow the basic principles of restoration and of the compatibility with the traditional structural system and environment.

In the paper, the historic evolution of the Park and of its infrastructures, as essential features of the historic landscape, is discussed (Rusnak and Boothby, 1998).

The bridges are systematically classified and studied: (i) taking into account their evolution until the present situation and reconstructing the changes by archives and documentary research (Re, 1998); (ii) surveying the structure and its materials, the building techniques, the maintenance and decay problems, and the effects of the past intervention in order to define specific maintenance strategies. A geometrical survey of the surface problems and defects allowed the localisation of the most problematic area, suggesting the further control by inspection and non-destructive tests, as well.
2 THE PARK ENVIRONMENT

2.1 History

Giuseppe Piermarini designed the Villa Reale or Royal Palace in Monza for the archduke Ferdinand of Austria, Governor-General of Austrian Lombardy, as a symbol of the magnificence of the Hapsburg court in Lombardia. On 17th April 1777, building work began under the direction of the imperial royal architect Piermarini and in only three years, he accomplished the construction of this stately palace. Nearby, the Villa lays on the banks of the Lambro, surrounded by its park, the largest enclosed parks in Europe (Municipality of Monza, 1988).

In 1805, under a decree issued by Napoleon Bonaparte, a great walled park was made around the palace. The Park was used as a hunting ground and for farming. When Napoleon fell, the Austrians reoccupied the villa. In 1859, when Lombardy was annexed to Piedmont, the palace passed to the Savoia, the Italian royal family.

On the assassination of King Umberto I, occurred in Monza on 29th July 1900, the royal family abandoned the palace, which was steadily stripped of its furniture, fittings and household equipment, and finally shut up and abandoned. In 1921, the villa became public property pending authorisation of its testamentary transfer by the Savoia family to the Municipalities of Monza and Milan, which was achieved only in 1994.

The Park, created from 1805 on an original plan of the architect Luigi Canonica, and successively by Giacomo Tazzini, as an extension of the gardens of the Royal Palace, was opened to the public in 1817. Luigi Villoresi strictly collaborated in the botanic planning.

Peculiarly interesting are the paths connecting the several villas of the park, the radial rows of trees and the square network with diagonal paths in the north. Fig. 1 shows a topographic map of 1838. The map shows the numerous architectures of the park, both the previous ones and the new with the substantial works by Canonica and Tazzini. It enhances the various landscapes and crops: the woodland to north, the land in crop in the middle and the garden of the Royal Palace to south.

2.2 The hydraulic system

At the time of its foundation, at the begin of the 1800's, the park was in an area of intense use of water both from the Lambro and from the numerous sources located near the riverbed, concentrated in the north east area of the Park. Furthermore, in the North-east area the stream Molgorana flows into the Lambro (Casati, 1986), (Casati, 1989).

In fact, the map drew by Pietro Antonio Barca in 1615 shows a concentration of hydraulic works with several irrigation ditches. Some of them were ancient, as the Gallarana ditch, built in 1476, the Ghiringhella ditch in 1502 and the Pelucca ditch in 1521.

With the park construction, the ditches were inside the walls. A new ditch was dug in the west area of the park to feed the Royal Palace Lake. The ditches (Fig. 2) were in use until 1955, when the request of irrigation water decreased.

Sluices and other hydraulic infrastructures were built in order to have a local elevation of the level of the river; in this way the Lambro water flew into the ditches and moved the wheels of the watermills.

In the park the two Lambro sluices, still existing, are one near the Bertoli’s bridge, and feed the ditch of the watermill Mulini Asciutti, and the other close to the mill of the Cantone; a third sluice, on the Molinara ditch, was close the St. George watermill.

Besides the previous mentioned watermills (Mulini Asciutti, Cantone, St. George) until the firsts decades of the XIXth cent., other 10 watermills existed inside the Park area as it is possible to observe in 1615 Barca map. Some of them were demolished during the divert works of the river around 1833.

The present watermills were built on the place of the original in the first decade of 1800's, while the flourmill of the Cantone was modified in 1840. The Mulini Asciutti mill is the only one that still conserves one working wheel with the mechanism and it is used for demonstration to schoolchildren.
2.3 Maintenance problems

Preservation of a designed landscape often involves intervention on of existing elements: pruning and rejuvenation of trees and bushes, dredging of ponds, maintenance of bridges and walks. Each component of the park environment must be integrated within an overall set of strategies for the preservation. In fact, historic canals, farms, pavilions, landscapes, rivers, and scenic views are all part of the cultural heritage of the Park but require a different set of maintenance strategies.

Cultural resource managers must often balance the opposing requirements of encouraging visitors by providing amenities for their safety and comfort, and discouraging them from imposing varieties of inadvertent harm to the resource. Inadequate managerial/maintenance practices managing visitation stresses, maintenance, and restoration requires continuous attention to the needs of the place being preserved. A variety of technologies should be improved in order to be more cost-effective. Systematic maintenance is crucial to the conservation of sites and structures, or the elements of a landscape. In fact, quality of maintenance is as important as its regularity.

Urban parks, containing both landscape and structural elements, are subject to increased visitation, but also both minor and major vandalism.

The description and documentation of all aspects of our heritage and history are a vital part of historic preservation.

3 THE BRIDGES

The Park foundation involved the necessity to cross the Lambro in several points with the designed pathways. In fact, in the maps of 1615 and of 1721 the only bridge was the Grazie
Bridge, in the south limit of the Park. The extant bridges, then, are strictly correlated with the park environment design as part of the original boulevard construction. Initially built by wood elements, like appears in a plan kept at the Cultural Heritage Superintendence of Milan, they were replaced by masonry structures because of their quick decay.

The bridges were designed as much for ornamental effect as for load-bearing capability by the most famous architects and engineers involved in the Palace work in the XIX\textsuperscript{th} century, as L. Canonica and G. Tazzini.

The bridge structures incorporate, in fact, a type of ornamentation usually reserved for municipal bridges, more visible, or buildings. These ornamental details include brick masonry oculi, stone and brick alternation in the masonry, flared, protruding or sculptured keystones, tooled margins on the stones. The architectonic details and the materials typical of the bridges in the Park enhance the qualities of their design. The bridges, such as many other buildings in the Park, were built by a variety of materials typical of the Lombardia tradition of the time. Peculiarly, the use of brick masonry and a local natural conglomerate from the Adda river is commonly used in the Milan region.

At present, most of the bridges are closed to regular vehicular traffic and converted into a pedestrian walkway over the park. The car access is allowed only for the (few) residents.

Bridges varied considerably in their dimension, masonry techniques and structural typology (Fig. 3). It is interesting to stress that while the masonry arch bridges are preserved in their general characteristics, the past intervention on other bridge typologies could be also substantially.

This is the case of the Bertoli’s bridge, originally designed by G. Tazzini (Fig. 4) with a documented aesthetic accuracy being an important element of the landscape design. In fact, from the bridge the waterfall of the sluice is still visible, even the massive embankment built after 1976 flood. The structure had the piers and the abutment in brick masonry with “ceppo” coating. The original deck composed by a wooden grid supported by inclined rafters, was substitute by r.c. beams and asphalted despite its limited use.

Figure 3: Example of bridges in the Park.

Figure 4: The Bertoli’s Bridge in a drawing of 1853.
3.1 Bridge of the Chains

The Bridge of the Chains is a skewed, double-span arch bridge that carries a paved section of one of the most spectacular path in the Park (Fig. 5). The bridge is historically significant as one of the most picturesque setting and design of any arch bridge in the park. In fact, the bridge was designed as part of a scenic boulevard, which runs from the Royal Palace to the Chestnut Circus (Fig. 7). The design by L. Canonica and L. Fossati dates back to 1820.

The bridge was built by brick masonry with insertion of light-grey locally quarried conglomerate voussoirs (Fig. 8). The brick masonry of the sides forms a decorative contrast with the rough stone voussoirs. The voussoirs are well blocked and uniform. The parapet typology with granite elements and chains gives the name to the bridge. Four stone columns with 1.50 m of diameter support the two flat arches in the riverbed. The humpback is repeated in the lines of a string-course marking the roadway level. Lion heads, rather decayed, decorate the keystones (Fig. 9). Interesting is the ancient pavements with pebbles and granite flag stones for the coach passage, typical of the time. The bridge overall width is about 18.0 m.
3.2 Cavriga Bridge

As the other main bridges of the Park, the Cavriga was designed by G. Tazzini in 1831 (Fig. 10) as much for ornamental effect as for load-bearing capability according the appointment letter request. The single-span was request in order to avoid damages and obstruction by logs and branches transported by the river during the floods. The structure is in brick masonry with regular stone block facing (Figs. 11-12). The current parapets design is still in conformity to the original drafts of G. Tazzini, event probably repaired in the past. A string-course marks the roadway level. As an ornamental flourish, the keystones protrude slightly from the arch face.

Among the Park bridges, the Cavriga is the only one that carries an asphalted and busy street, being the car access allowed only for the (few) residents. The street is open to the normal traffic is and important thoroughfare. In spite of this, the bridge shows several damages due to the presence of vegetation.

4 ANALYSIS METHODOLOGY

The analysis touches very different approaches: history, geometric definition, characterisation of the materials, typological description, pathologies. The bridges were individually examined to determine their characteristics and state of preservation.

On the geometrical survey, an inventory of all the materials and the localisation and the assessment of the decaying phenomena were carried out. The defects were identified by direct visual inspections on the bridges.

Mention of corrosion, spalling, scouring, and other observations on the condition of the bridge are intended as only descriptive; they should not be interpreted as an evaluation of the bridge's safety or structural condition. Finally, the section describes the evolution of the bridge if its present appearance resulted from more than one building episode.

4.1 Documentary research

The historical archive investigation had the aim to understand the main construction events of hand-manufactured goods, but also to analyse the different techniques of maintenance and re-
pairing interventions due to decay phenomena already occurred in the past. Accurate historical and archive document research gave a thorough knowledge of the building techniques, as well as the used materials. In many cases, the original drawings were available, as well as numerous historical pictures and photographs (Cassanelli, 1999), (Mulazzani and Crespi 1985), (Municipality of Monza, 1985). Interesting information supplied by the original design documents concerns also the foundation techniques, in wooden piles (Fig. 13). The documentary evidence of the building works and modification accomplished on the bridges between the end of nineteenth century and the first decades of the twentieth century as well as between 1950 and 1970 was important to understand the current situation.

A direct visual survey of the masonry construction technique, carried out on site, supported this information. The material survey of the masonry allowed also detecting the marks of practices carried out in the past with different materials. This information is a basic starting point for the preservation project.

4.2 Material and decay mapping

Materials and decay pathologies were surveyed and mapped. The bridges are built by different materials. Being used in different localisation with different function (Fig. 14), the mapping was a fundamental phase in the analysis. The architectonic details and the materials typical of the buildings in the Park enhance the qualities of the design.

The bridges display a variety of materials that are typical of the Lombardia building tradition of the time. Granite is used for the parapets, a porous natural conglomerate called “ceppo” as coating, mainly for the voussoir, bricks masonry for the structure. The natural conglomerate is grey, locally quarried, rubble stone. In some case, the “ceppo” coats the spandrel walls, the curved wing walls and the buttresses. Otherwise, the elevations display brick-faced, with stone insertion. The arches are ornamented, also in small bridges, by stone/brick voussoir alternation or decorative elements. Stone railings often border the roadway. Coating in “ceppo” blocks (25-30 centimetres thick), is mainly with roughly worked surfaces, but also with smoothly worked blocks is present.

To prevent scour, the bottom of the abutments had been encased in concrete and which apparently is an alteration to the bridge’s original design.

Figure 13: Abutments founded on wooden piles.

Figure 14: (a) Detail of the “ceppo”; (b) keystone in “ceppo” in the brick arch; (c) granite and “ceppo” voussoirs.

4.2.1 Evaluation of the state of preservation

A number of decaying phenomena are presently affecting the bridges, even if materials aging and lack of regular maintenance seems the main cause of structural degradation of the bridge. The Park environment could be also aggressive, due the recent floods effects, freeze/thaw cycles. However, due to the different localisation and use, the bridges show a great variety of problems.

The damages can be broadly classified in categories: (i) those resulting from low resistance performance, (ii) those due to durability problems, which have potential of reducing the resistant capacity of the main structural elements. The failures caused due to climatic conditions e.g. rain, disruptive forces due to freeing and thawing of frost and abrasive actions of floating particles carried by wind, are demonstrated by erosion of surface of arch spandrel walls, abutments, joints infilling etc. The brick masonry shows in some cases gaps due to the water flowing ac-
Further damages are correlated with the repair intervention but also maintenance problems (Fig. 15-16). The decay pathologies survey showed in addition the lack or deep erosion of mortar joints and repair with different mortar; “ceppo” blocks do not show decay phenomena due to its high porosity.

Biological attack by mosses often covers the masonry part over the water flowing line, while roots of upper plants cause damage and material expulsion. Finally the whole surface, in the submerged part, is coated by whitish consistent sediment, very thick attributable to a diffused alga on masonry.

Even not accessible to the vehicular traffic, in some case the residual agriculture activities produce some damages for the traffic passage.

The common neglected maintenance, which may become the contributory reasons for the failure, is growth of vegetation and improper maintenance of drainage. In certain conditions, trees and peculiarly their roots cause serious damage (Fig. 16). The growth of vegetation results in deterioration of joint infill (mortar) and consequent loosening of masonry units, sliding/bulging and cracks in spandrels, cracks in abutments and wings and other defects.

![Figure 15: (a) Lack of mortar in the joints and (b) efflorescence.](image1)

![Figure 16: (a,b) Damages caused by the vegetation](image2)

5 CONCLUSION

Historic structures, which include houses, public buildings, bridges, monuments, as well as others represent to the general public the most obvious and important tangible reminders of the diversity and richness of the country’s cultural heritage. Any repair has to take into account not only defects and damages identified, but also the main features of the bridge, the intervention costs and operation difficulties. The management of existing historical bridges might be tackled by means of a specific maintenance system.

The methodological approach by classification and analysis of the bridges characteristic and state of preservation carried out in the case of the Monza Park, could be the base for such work, programming a systematic control and maintenance of the identified problems in each bridge.

Despite alterations to the original parapets and pavements, and some deterioration of the surface, the bridges retain the most significant features of their original design, especially in terms of the configuration of the arch and the precision of the stonework. However, serious damages by trees were found, that could be prevented by a vegetation control.

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