Restoration of bridges built with the dry stone technique

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ABSTRACT: The mountainous interior of the province of Castellón and Teruel is characterised by omnipresent dry stone structures, for instance, shepherds' or farmers' huts, walls around fields or terraces, ramps, stairs, pavements or wells. The bridge in the Pobleta de San Miguel fits into this category; it is an extraordinary work of medieval vernacular engineering that was built by combining lime-bonded masonry techniques around the single arch with the dry stone methods typical in the area. The original pavement of the bridge is made with pebbles from the river arranged in chain. The restoration project included drawing up a meticulous survey, with an exhaustive study of the constructive system. The work involved the individual selection and precise placement of thousands of stones of different shapes and sizes, from the pebbles in the pavement to the large blocks weighing several tons used to channel the course of the river or form the bank.

1 THE BRIDGE

The bridge over the Río de Truchas in Pobleta de San Miguel is located between the regions of Aragon and the Valencian Community. La Pobleta is a medieval village with about twenty houses, a chapel and a defensive tower directly related to the control of the bridge's passage.

Upstream, at about fifty meters away, there is another relatively new bridge, where the road traffic passes nowadays. This bridge has released the old bridge of its main function of road traffic and has consigned it to a minimum function of pedestrian and cattle passage for the locals. But the bridge has acquired a new function: it has become a historical symbol where the inhabitants of the area feel reflected; thus, it is not unusual to find different types of celebrations or recently married couples that go to the bridge to have their pictures taken.

Figure 1: The bridge and the defensive tower

The bridge, built in stone, has only one arch slightly pointed, with springs that search for the verticality. The arch in all its extension is formed by well worked voussoirs taken with lime mortar, with indented bond as binding stones to be joined with the upper masonry. The arch settles on a mass of rock, masonry and lime that has been exposed due to the action of the river floods.

The construction of stilted arches in the bridges increases their water-drainage capacity as it happens in this case but, at the same time, it has several disadvantages since, as it has only one arch, the bulged grade lines as a result of the height that reaches the arch stone cannot be avoided. The size of the bridge arch led to the construction of large piers to avoid a still more uneven grade line of steep ramps and slopes. These piers were built with dry stone methods.

The pavement of the bridge consists of a washed pebble covering from the river itself that forms a series of drawings, partly lost as a result of the customary passage of sheep and cows and also due to the vandalism of some people, who in the last years, have removed pebbles from the pavement to throw them to the river for fun when its water level was high. It has been object of different repair works, so that the imprints and the design corresponding to each one of them can be traced.

There is water in the river bed only seasonally. In any case, there are records and memory of considerable floods and volume of flow that reached more than three meters in depth with respect to the bottom of the river bed. In the immediate surroundings of the bridge, next to the river bed, there are some river bank trees, vegetation and lawn.

The ashlar masonry arch has a diameter of 15.40 m. and a height of 7 m., and is built with yellowish limestone voussoirs. The arch is flanked by masonry placed with lime mortar with a dimension of more or less 6 m. per side. The piers on both sides, built in dry stone methods, stretch 15-16 m to each side.

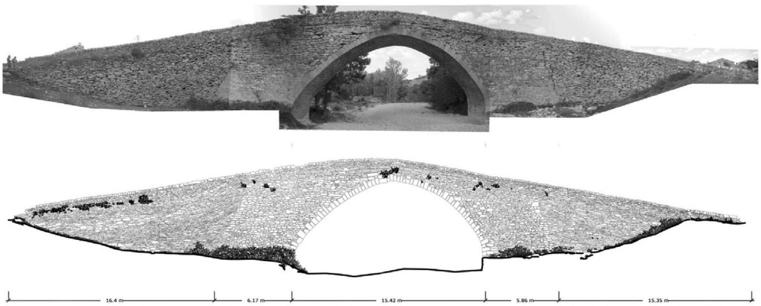

Figure 2: Photo and geometric survey of the bridge

The intrados of the bridge's arch is built, between both side ashlar masonry arches, with limestone masonry placed with lime mortar. The base of the arch was built with several lines of limestone ashlar masonry to form a strong base on the natural rock of the river bed.

The parapet was built during the 20th century with dry stone ashlar masonry, with small grayish yellow limestone slates, placed occasionally with cement mortar. In the central part of the bridge, between the parapet and the lower masonry, two large limestone lines are identified (with lengths of up to 1 m and thickness ranging from 30 to 40 cm) that have been identified based on the observation of the other bridges of the area, with two very clear functional elements: the lower line has a function of pavement containment, whereas the upper line worked as a sort of rail for the carts in the outside edges of the bridge.

2 THE PAVEMENT

Two types of pavement are clearly identified in the road of the bridge. The first one, possibly the original one, consists of a stone pavement of small white pebbles, arranged in strips separated by longitudinal rails formed by the pebbles placed and arranged in a row. In this pavement, the chains are also identified, arranged in a cross-sectional position with respect to the road and approximately positioned every 2.5 m. The second, possibly a repair with respect to the first one, consists of an irregular river pebble pavement of larger dimensions and two different colors, white and yellow. In both cases, the pavements are built in the following way: there is a layer of earth with variable thickness on the structure of the bridge; the pebbles or the small rough stones are settled on this earth layer; the joints between pebbles or rough stones are filled with earth where in most of the cases a spontaneous vegetation grows which contributes with its roots to the compaction of the earth and the resistance of the pavement.

The degradation conditions and, mainly, the lack of material in the pavement, has allowed to identify the stones that corresponded to the structural base on which the pavement was placed. Large limestone slates constitute the last stone line of the structure of the bridge.

Figure 3: Bridge pavement with traces of rails and chains

3 HISTORICAL DATA

The present location of Pobleta de San Miguel (Monfort, 1999: 141) is on an old Muslim village called “trouts’ river”. The chronicles of the Christian Reconquest record that king Jaume I was here in his advance against the Muslim forces, wading across the river by a bridge or structure missing nowadays (Soldevilla, 2000). In the new organization of the region, this village was dependent on the new capital, Morella, after the 14th century. In this century, Villafranca was forced to undertake public works, many of them paid for by its capital, Morella (Corresa, 2003: 13). Therefore, the construction of the bridge could date between the 14th and the 16th century.

The dry stone technique was used for the construction of slopes or steep banks in many other places in the area of the Maestrat, in the Valencian part as well as in the Aragon part, in addition to the areas adjacent to Catalonia. The steep banks of many towns of the interior of the Valencian Community nowadays follow this method of construction, based on the rise of small retaining walls with the stone extracted from the land and arranged so that it can withstand the land of the terrace (Besó, 2001). Not only were built small walls of this type, but also long walls for cattle paths, small refuges, paths for animals, lot lines, walls, property lines, ramps and entries and even, pools, superficial wells and bridges (García & Zaragoza, 1983).

The walls built have different uses. In the case of the bridge of Pobleta de San Miguel, the sides must be sturdy in order to withstand and to resist the large floods that characterize the rivers and watercourses of the Mediterranean area, which during most of the year are dry or with little volume of flow. Río de las Truchas is not behind the rest of rivers of this area and has experienced these same large floods. According to Fidel Alejo Puig Izquierdo, at the beginning of the 20th century one of these floods clogged the arch of the bridge and possibly the dry stone walls gave way due to the water pressure that was more than four meters high (Puig, 2001: 8).

In order to complement the lack of direct documentary data on the history and the vicissitudes of the bridge, a stratigraphic survey has been performed and a hypothesis of constructive periods has been established, which has been documented in the corresponding plans. At the moment the bridge of Pobleta de San Miguel presents different construction or transformation phases, perhaps difficult to distinguish because of the construction technique used: the dry stone method. Normally, the constructive stratigraphic analysis is based on the data provided by the different construction techniques as well as on the superposition of joints and renderings. It is obvious the nonexistence of joints and renderings in a dry stone ashlar masonry, so that the reading will have to be based mainly on the different construction techniques and the possible differences among them. In total, six possible phases of construction for the bridge and two for the pavement have been identified, which have been documented in the corresponding plans.

4 PATHOLOGIES

At the time of drafting the restoration project, the bridge displayed an acceptable general state in its vertical surface. The ashlar masonry that creates the central arch and purfles it was placed with mortar and its joint suffered from a loss of material and erosion, but within an acceptable level. The dry stone ashlar masonry in the piers and the parapet were also in a good conservation conditions. A marked undulation was seen at the plant level that could even reach 30 cm. between the different partial areas of the facing. This undulation could have partly been due to the original construction of the bridge and to a continued and impetuous claim by some exceptional floods of the river or, on the other hand, to possible successive repair works.

The arch intrados displayed areas of strong washed of the joints and areas where that same washing had produced the calcification of the surface to a certain degree. None of the two areas, in spite of these alterations, displayed structural problems that would require an urgent repair.

The surfaces were partially affected by the presence of upper and lower vegetation. The upper vegetation offered a higher threat since it deepened its roots between the joints of the stones. It was located in the base of the piers of the bridge and at the height of its pavement on the face, that is to say, where the water penetrated the joints between stones in search for an exit. The presence of river bank trees in the immediate proximity of the bridge was not considered a great threat for its survival or structural stability.

The two most degradating phenomena present in the pavement of the bridge were the major gaps in the pebble layer and the presence of upper vegetation. The pavement of the bridge has suffered considerably with the passage of time and traffic of cattle, since it has been object, even in recent times, of vandalism by some inhabitants of the village who, as said above, used to remove stones and throw them to the river in the days of flood just to see the pebbles skimming the surface of the water. These vandalism acts together with the action of atmospheric agents and the passage of time and people, have caused a very accused phenomenon of loss of pavement material.

Grass grows between the pebbles or small rough stones of both types of pavement, which was not considered as a true affection to its presence and health. On the contrary, the growth of grass was considered as an element that increased the compaction of the earth in the joints between such pebbles consolidating the pavement itself. In addition, it was considered that the vegetation became an important element for the traditional image of the bridge. The upper vegetation is accumulated, mainly, in the joints of the existing pavement (the original pavement as well as the replacement pavement), in this case being spontaneous grass, and mainly little bushes on the sides of the road in an adjacent position to the parapet. However, the gaps in the pavement represented, without a doubt, the true and most important phenomenon of degradation. It can be stated that the gaps reached more that 70% of the total surface of the pavement, calculating also the pavement found after the cleaning of the vegetation.

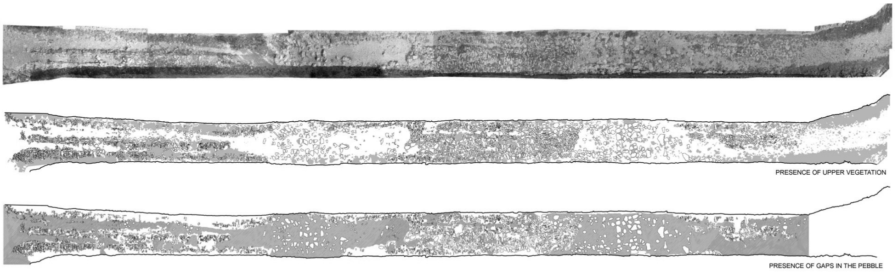

Figure 4: Pavement photografic survey and pathologies survey (vegetation and gaps)

Likewise, the pathologies derived from the hydraulic system of the set were analyzed. The seasonal levels of the water volume of the river were studied from the oral sources of the inhabitants of the village, which have marked the levels that the river reached in its greater floods. On the other hand, the current flow is due to a large extent to the construction of a new bridge next to the medieval bridge, with three arches and two piers, which caused a widening of the river and diverted the current that flowed towards the southern pier of the medieval bridge, undermining its foundations and jeopardizing its survival, in spite of the existence of a wing wall that channeled water towards the bridge arch. The erosion added in this shore threatened uprooting the river bank trees which, dragged by the current, could clog the bridge arches. Therefore, the river with its sporadic floods represented the highest risk for the integrity of the bridge itself since it lacked hydrodynamic defenses and, therefore, its correct settlement as well as the side walls at the piers that channel water in a medium level were of great importance.

5 GENERAL PROJECT CRITERIA

The medieval bridge of Pobleta de San Miguel represented a place of great charm not only by the bridge itself but also by its surroundings. It was a medieval bridge located in an almost always dry river located in the shore of a small village whose buildings appear in an original state and practically unharmed. The bridge itself presented similar conditions, it needed attention, but was very well conserved in its aspect and original character.

It was a precious monument that is in perfect balance between its state of alteration due to the passage of time and its conservation, which owed its special aura to several factors: the conservation of the nucleus of the town with its almond shape in the shore of the river and its small ermitage square; the conservation of the pavements of the streets and the threshing floors, mixed with the spontaneous vegetation; the conservation of the materials in the houses (dry stone masonry) that belongs to the place and, consequently, is perfectly integrated in the landscape; the conservation of the monument formed by the watchtower and the bridge, slightly isolated from the nucleus of the town; etc. Any action in this monument could have altered this balance and have disturbed the aura of the monument (Mileto, 2006).

It should be noted, as mentioned above, that the bridge had presented alterations in the surface due to the passage of time which did not reach to be deterioration and that, on the contrary, had to be conserved and safeguarded at all costs by the value of antiquity of the monument that, in this case, was a priority on the rest. They are alterations due to the presence of lower vegetation (lichens), dirt, small collapses and deformations in the facings, etc. In addition, it should be considered that the existence of an adjacent bridge, used for the road traffic, saved the medieval bridge the responsibility to functionally and structurally meet the usual demands, so that it was enough with its conservation for pedestrian and cattle use.

It was considered important to apply also to the surroundings of the bridge the same criteria of minimum intervention and maximum conservation, in a way compatible with the improvements that are considered important or necessary for the conservation of the bridge as well as for a higher improvement of the monument.

6 THE INTERVENTION IN THE PAVEMENT

In relation to the gaps of the bridge pavement, the replacement intervention of the bridge was considered correct. It was an operation aimed at the conservation of the structure of the bridge since the loss of the upper layer (pavement) allowed the continuous erosion of the structure with the progressive loss of the stones that are part of the structure itself, due to the use (passage of pedestrians and ovine and bovine cattle), to the atmospheric agents (infiltration of water, ice, snow, wind erosion) or to vandalic actions (voluntary removal of stones). The objective was to stop the process of loss of the few remains of the pavement, to avoid its complete disappearance.

In order to complete works on the pavement, a series of possibilities were studied until reaching the most suitable modality. From the first moment, two criteria were considered for the replacement of the pavement. In the first place, the conservation of the still existing pavement remains was considered fundamental since its high construction quality as well as its aesthetic quality was valued. Secondly, any type of completion with materials other than the existing ones was discarded (foreign stones, bricks, etc.) with the objective that the reintegration of the pavement, although distinguishable, could be integrated sufficiently with the monument without affecting its aura. Given the need to complete what was left of the pavement), it was considered the possibility of completing it with pebbles from the river. In order to decide the pattern to use in the new pavement, a detailed study of the construction technique and the patterns of different pavements present was performed in similar monuments, in the surroundings of the town and in the bridge itself.

Two different types of pavement were identified in the pavement of the bridge, as said previously. The first one, possibly original, consisted of small white river pebbles arranged in lines perpendicular to the direction of the slope of the bridge. In this pavement, three rails were identified in the direction of the slope: one in the central position with respect to the road and two laterals at about 80 cm. from the central rail and about 90 cm. from the parapet. In this same pavement, chains were also found at about 2.5 m. away throughout the slope of the bridge. The second pavement, located in the central part of the bridge and possibly built as a repair of the first one, consisted of a white river pebble pavement of greater size with respect to the pebbles used in the first pavement and small yellow limestone rough stones. The arrangement of the elements did not present a clear geometric order although it presented a tendency to appear arranged. This same type of pavement was found in the street of the village.

The integration of the pavement has been performed having into account the following criteria. In the first place, the pavement built respects the traditional technique so that the reintegration is not a simple aesthetic solution but a constructive response to a constructive and functional problem of the bridge. Secondly, the few remains of the existing pavement were entirely kept, as the traditional technique and its constructive value, as well as by their perception value related to the aura of the monument. Thirdly, taking into consideration that the repair pavement was kept in a greater percentage with respect to the original, it was decided to conserve both pavements. The conservation of both pavements entailed the difficulty to find a pattern that could integrate with both as a third phase of harmonious repair with the existing paving. For all these reasons, it was carried out the reintegration of the existing pavement with small white washed river pebbles, similar to those that form the first type of pavement, thus creating chains perpendicular to the direction of the slope, with pebbles of greater size and greater depth, placed at an approximate distance of 2.5 m. to each other, which complete the existing chains and form the new ones. However, the rails were not built to avoid a geometric conflict too contrasting with the design of the second type of pavement, thus isolating it in the center of the road of the bridge.

The stone pavement was built in the traditional way by placing pebbles on a layer of dry earth, sand and a small proportion of lime that later on was watered several times so that it took consistency. Approximately 30,000 pebbles were used for the repair works, which were taken from the river itself and were selected one by one by an architect member of the team, permanently on the site so that they could be integrated perfectly with the existing pavement. The reintegration of the pavement was performed in two different situations: where the old pavement was completely lost and where there were remains of it or of the repair works. In the first case, the aim was to create a new surface that respected the pattern and the texture of the existing pavement although it was distinguished by its greater regularity of execution. In the second case, the task consisted of making a pavement that completely respected the existing remains, respecting and appearing among them, and adapting to complex situations of changes of slope and grade line, lack of flatness and old ruts and tracks left by carriages. In both cases, the new pavement was developed attempting to create a homogenous and neutral layer that could be integrated in the different situations found, so that it could always be distinguished as part of a same intervention and be integrated with the remains from the first pavement as well as from the second one. The grass in the joints of the existing pavement was not removed, since it was an element of compaction of the pavement and its removal could cause the loss of part of the remains. At the same time, it is considered that with time, grass will have to grow in the joints of the new pavement which will allow its compaction, in addition to the definitive integration with the existing pavement, without considering it as a degradation element.

Figure 5: Constructive techniques used in the restoration and view of the finished restoration

7 THE INTERVENTION IN THE SURROUNDINGS

The intervention in the surroundings of the bridge has been carried out with the objective of conserving as much as possible the aura that characterizes the monument. Therefore, all the performances have focused on the minimum intervention, on one hand, necessary to arrange and to enhance the value of the bridge itself and, on the other hand, to solve the threats of the river bed.

In the first place, the paths that lead to the bridge have been repaired simply with gravel; a small parking lot has also been built in an open gravel area, a series of big natural stones have been arranged in the river shore to create improvised seats for visitors, the existing electricity substations with lamps have been covered with the dry stone technique so that they were integrated with the surroundings and new substations with lamps have been built with the same construction technique, the electrical system which visually affected the immediate surroundings of the bridge was buried, the surroundings have been equipped with litter bins, signposting and interpretation panels. Secondly, a series of works related to the river bed have been performed: the gravel of the river bed has been channeled from the center of the bridge bay to avoid the whirlpool that undermines the southern pier of the arch of the bridge and strikes its foundations; large pebbles have been placed in the point of diversion of the channel to make the river lose energy and divert it; the Eastern wing wall has been extended and increased in a line. Likewise, in the western shore, it has been attenuated the risk of uprooting of the river bank trees with the construction of a dry stone wall of 15 m. in length and 70 cm in height, well settled in foundations on the bottom of the river bed.

Figure 6: The bridge and surroundings after the restoration

8 CONCLUSION

All the actions on the bridge and its surroundings have been performed with the conservation of the aura of the monument and its place always in mind. The performance has attempted to be as unnoticed as possible, and respecting the character of the monument and the surroundings as much as possible, avoiding all type of imposition to the monument. The new elements added have attempted to integrate themselves in the monument by the construction technique, material, color and texture to avoid distracting a delicate place where there is still the air of the past, fragile by its natural, rural and almost unreal, but powerful character by its extraordinary capacity to transmit a long history and a secular presence.

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