RECONSTRUCTION OF PLEČNIK'S FOOTBRIDGE AT PRAGUE CASTLE

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Summary

The sample of not sustainable way of reconstruction of small but important and significant structure of Plecnik´s foot bridge located at Prague Castle area is discussed at this contribution. The structure was strongly impaired 10 years after complex reconstruction. This damage and degradation was caused mainly due to malfunctioning of new waterproofing and frozen water in the new drainage system of the bridge deck.

Keywords: waterproofing, bridge, reconstruction design, structural survey

1 Introduction

Plecnik's footbridge (see Fig. 1, 2) is now about 80 years old, but its historicizing architectural forms give a substantially older impression, and link very well with the structurally much older parts of the Castle in its vicinity. The technical solution of the drainage system and many details were designed and implemented in way that they would require rather intensive maintenance of structure. However, the need for maintenance was to some extent neglected over the years, and the structure had therefore become dilapidated. In the course of adaptation work carried out at Prague Castle in the 1st Czechoslovak Republic period, the Fourth Courtyard with the Na baště garden was newly designed by architect Plečnik. The first ideas on the form and function of these parterres emerged when Plecnik was first planning the conceptual work for Prague Castle. In the early 1930s, a new idea emerged for the footbridge, which extended the original concept (the first sketches are from around 1921). The original concept had basically respected the traditional functions of the garden and the courtyard, with a peripheral road from Hradčanské Square through Na baště garden. This route was to be connected with the new footbridge structure along the Spanish Hall with the space in front of the Paccassi gate. Josip Plecnik submitted the final project to the Artistic Board on 25th October 1927. In December 1929, a company was selected to construct the footbridge. Incomplete available

information suggests that that Plecnik's footbridge was finished by 1932 or by March 1933. The Prague Castle archives contain drawings and photographs from 1932–1933.

The main lengthwise part of Plecnik's footbridge is formed by a series of massive brick vaulted arches increasing in height in the direction from the Powder Bridge towards the Fourth Courtyard, in proportion to the descent of the parallel ramp on the side of the Deer Ditch. The back of the vaults between the linear walls is filled with lean coarse-grained concrete, and the bridge deck is also made of concrete. The handrails – columns and massive hand railing on both sides – were made from Mrákotín granite.

Fig. 1, 2 *Bad state of bridge 10 years after complex reconstruction during 1995–1996. Left, an overall view of the bridge deck in 2005. Right, a view of the arches towards Deer Ditch. There is seepage of water from the malfunctioning water insulation and damaged a broken gargoyle taking the water from the gullies in the bridge deck.*

2 Structural and technical survey

In April 2006, specialists from the Klokner Institute of CTU in Prague carried out a structural and technical survey of the building. The structure was in deteriorated condition, mainly due to the effects of leakage and frost. The main trouble was with rainwater leakage, capillary action of humidity, and salt action. The next step was to elaborate a suitable design for the reconstruction work. This was also done by specialists from the Klokner Institute of CTU in Prague, with the aim of seeking a solution to the unsatisfactory situation. Obvious marks of degradation of structures due to leakage and frost effects are shown in the following photographs, together with a brief description of the main causes.

The diagnosis showed that the gargoyles freeze during the winter season, and slush and water from melting snow accumulate in this part of the footbridge. The freezing begins in the elbow-bend of the sewerage pipe, from where the ice plug grows in both directions (see Fig. 3, 4). The ice start to melt gradually later and a water column is formed on the upper side. This water then leaks through the untight joints of the sewerage back to the structure above the arches.

Further leakage came from cracks between the hand-railing and the cobblestone pavement. Water penetrating the structure by this route had gradually separated the plaster of the side walls and was leaking between the pavement and the walls. This was proved by the fact that we found icicles hanging from this crack on the north side of the open arches.

The drip ledges of the covering elements, i.e. the bottom line of the granite hand--railing and the granite gargoyles are a separate issue. Their lapping in front of the face of the vertical structures is small, and if they are provided with a weather groove, it is semi--circular in shape. This unsuitable shape, together with the small gradient of the bottom surface of the water nib, the slightly inclined front of the masonry and the wind activity in the Deer Ditch, often allow the water to make its way back to the front of the masonry. There are drip plates below the outlet of the gargoyles in the ramp paving. The paving of the descending ramp leads laterally, directly to the footbridge. There is no section with a reverse slope to form a linear gutter to protect the footing.

Fig. 3,4 *Left – view of a fully frozen inlet, right – view of a partially frozen pipe from the inlet to a gargoyle*

Another source of water is the ascending staircase at the end of the main line of the footbridge across the former Hácha's shelter towards the Na baště garden, where water leaks on to the steps and on to the slab underneath the first arch of Plecnik's footbridge.

The problem of an inadequate outlet for the water from the surface of the footbridge is further emphasized by its shaping, with each drain having a separate watershed. However, the lateral line at the end of the footbridge has no watershed. The water has to overflow to the main line, and it often leaks down into former electricity substation room. With this arrangement, a blockage of the sewerage drainage unavoidably fills the watershed with water and melting slush. The water later gradually overflows into neighbouring areas. The first minor reconstructions of the footbridge were probably carried out in 1957–1958, when the adjacent restaurant pavilion was built according to design of Moravec.

3 Reconstruction in the 1990s

First radical reconstruction was carried out in 1995–1996. During this reconstruction, the original cobble gravel on the concrete was removed. This had been laid in the 1930s, during the First Czechoslovak Republic period, and the base plates above the brick bearing walls were carefully finished.

After water jetting took place, a concrete slab was made. It was reinforced by a KARI mesh, and was covered with a silicate water-insulation crystallic-type paint.

The insulation work was carried out over an area of about 90 m^2 in October 1995. An 80 mm layer of concrete was laid first. Final layer of a new 32/63 mm cobblestone pavement laid on the cement bed about 20–25 mm in thickness.

The bridge deck was still drained by eight inlets placed in the linear axis of the footbridge, six of which led to the gargoyles on the north side in the direction of the Deer Ditch. The brick bearing parts of the footbridge were plastered with maintenance plasters.

The joints of the hand-railing elements made of granite were sealed with silicone cement, and the balusters made from artificial stone received local repairs. However, the tightness of the bridge deck was subsequently damaged again. This was demonstrated mainly by infiltration of water into the bottom face of the arches, soaking and degradation of the plaster on the brick substructure, and leakage into the former substation. The bad condition of the bridge in 2005, about 10 years after the reconstruction, is shown in Fig. 1 and Fig. 2.

4 Concept for the new reconstruction work

Based on results of a structural and technical survey during 2006, the following repairs were designed:

- optimize the drainage system for the surface of the bridge deck,
- execute functional, permanent, tight and reliable water insulation of the bridge deck,
- secure the sewerage system against freezing up,
- prevent water from the adjacent staircase getting on to the footbridge,
- modify the gargoyles and drip plates,
- repair the drainage of the north courtyard,
- reconstruct the brick substructure.

To optimize the drainage, the proposed technical solution connected all the drains of the main line by a linear neck gutter, so that there would be free run off through any of the drains. However, this proposal was not acceptable to the heritage authority, and emphasis was therefore put on preventing the sewerage system freezing up.

We designed additional two inlets on the lateral line of the footbridge, which had previously had no drainage of its own, and we proposed unifying its surface with the main line. This design was approved by the heritage protection authority. In order to prevent repeated freezing of the sewerage system, a system for heating the sewerage drainage leading from the inlets to the gargoyles was designed (see Fig. 3, 4).

Water coming from the adjacent staircase could only be dealt with by a structural intervention in this part, and this was not possible within the designed reconstruction.

It was not possible to modify the gradient of the gargoyles, so only a drip groove was made in the end of the bottom part of the gutter, and fronts were added after the installation of new sewerage piping. The drip plates remained unchanged in this phase, as it would have required an intervention in the arrangement of the whole lateral section of the parallel downward ramp in order to reconstruct them.

The drainage of the north courtyard was reviewed, together with horizontal water insulation for both the footbridge and the Spanish Hall. There was no drainage of the surface of the water insulation, and there was a technically inadequate sufficient connection to both structures. The extent of the design of the reconstruction was limited to modifying the lateral drainage gutter, a lateral change of gradient from the buildings, and a replica of the mosaic paving in accordance with Plecnik's original concept in other similar areas.

The rehabilitation of the soaked, humid and partially alkaline masonry was designed in three stages. First: knock down the plasters and allow them to dry naturally, in order to stabilize the humidity. Second: apply a temporary lime plaster to remove the salt from masonry. Finally, after necessary modification of the details, apply the final maintenance plaster, which should be protected with a colourless hydrophobic finish to deal with dripping, leaking and splashing water.

Fig. 5 *North side Plecnik's footbridge in spring 2006*

5 Reconstruction in 2006

The reconstruction process was divided into two phases. The first phase focused on eliminating the sources of damage, i.e. water insulation and drainage of the structure. The second phase focused on remedying the damage to the masonry of the substructure and the plaster, i.e. restoring the original appearance. The first phase of the reconstruction, carried out by CSI Saman, s.r.o. in the 2006 construction season, consisted of removing the cobblestone pavement, constructing heated drains for the gargoyles, repairing and levelling the foundation, installing BAKOR screed asphalt modified water insulation, and constructing a new modified spread concrete footing and a replica of the original cobblestone pavement. This phase included finishing, draining and repaving the north courtyard, including renovating the ceiling of the substation below the room near the Pacassi gate – a suspended ceiling lateral with the footbridge line.

The construction work started in September 2006, and was restricted by the exposed construction site conditions and by the use of Prague Castle for public and official events. First, the granite hand railing was protected and covered, and then the demolition work on the bridge deck was commenced (see Fig. 6, 7). The cobblestone pavement of the main line

and the mosaic strips of lateral line set in the concrete were demolished using light manual electric hammers.

Beneath the paving, only thin layers of cement crust with numerous cracks were found. They were covering rough patchy concrete and the partly exposed brick masonry of the vault lines. These layers were also removed. The crowns of the vaults formed natural watersheds and the lean concrete among them was removed in a way that would allow the shape of the foundation beneath the new water insulation to be modified.

Fig. 6 *Demolition works on the bridge deck in autumn 2006*

It was also necessary to demolish the existing downcomers to the gargoyles up to the point where they bent (Fig. 6), in order to install new pipes in the original pipe with the heating system. After the new pipes had been installed, the heating cables and the thermal insulation of the vertical parts of the piping were mechanically protected and covered in concrete. The connection with the heating was set in the linear joint on the left side of the footbridge. After high-pressure water jetting, the foundation for the Bakor water-insulation screed was silica-fume modified concrete (Fig. 8). The water insulation was installed as a basin shape retracted under the edge of the handrail ledgers. First, the horizontal linear edge strip of Bakor 790-11 screed was applied with a polyester reinforcing insert. Then, area basin insulation was installed in a two-layer version with a reinforcing insert, leading out on the side of the linear stones up to a height of about 20mm below their upper edge. The installed insulation was covered with a layer of Bakor Globeglas No. 8 for the walking load (Fig. 9). During this phase, the drain plates were also prepared and were set in hot modified asphalt screed and covered with reinforced screed up to the edge of the vertical sewerage outlet. When this work was being done, the option of a natural outlet for water from the whole area of the insulated surface was carefully considered.

Fig. 7 *Substrate prepared by high pressure water before the electric cables were installed and the surface was restored*

Fig. 8, 9 *Left – view of the new substrate for water insulation, right – working on the first layer and details of the BAKOR water insulation system*

After the insulation had been installed, work began on the new modified concrete reinforced slab (Fig. 10). First the steel welded mesh reinforcement was laid and bound, and then the slab was concreted. The concreting was done at night, in order not to disrupt the operation of the Castle. At 8 p.m., a mobile pump with a 46 m arm arrived. Directly in the concrete plant, the finished concrete mixture was supplemented with Ad-Mix 50 modification additives based on micro-silica. This could be done because of the short transportation time. Re-milling on site was therefore not necessary. Fresh concrete mixture set by pumps was spread on the site, compacted and manually arranged into the gradients needed for each drainage area with diagonal neck gutters. The surface was smoothed manually and was jetted with a curing agent against excessive water evaporation. On the next day, lateral contraction cuts were made on the watersheds, and the bridge deck was protected against night frosts.

Fig. 10 *Concreting of final bridge decks that covers water proofing layer*

Fig. 11 *Working on the new cobblestone paving, laid on top of the new modify concrete slab, situation in November 2006*

After about one week of maturing, the weather improved and it was possible to start with the cobblestone paving (Fig. 11). The pavement with selected and washed cobblestones was first laid as a sample, and after approval it was fully placed. The cobbles were first placed into SAN B B30 micro-concrete using a tile laying technology, and were finally sealed with special SAN B R2 modified mortar polymers (Premix Ltd.). The linear joints along the hand-railing, and around the bottom part of drains remained loose during this work with the use of a polystyrene insert. After the paving was finished, the joints were cleaned and filled with Bakor 590-13 modified asphalt sealing compound. In order to reduce the colour contrast, the warm compound was cover up with dry silica sand. The existing concrete pavement in the north courtyard (Fig. 12) was demolished, and its bed was removed.

Fig. 12, 13 *Left view of the north courtyard, before restoration. Right – after restoration*

The foundation was cleaned down to the protective water insulation geotextile of the heating channel leading under the whole courtyard. At the same time, the original lateral drainage gutter in front of the entry to the substation was demolished. The original gutter had no bottom, and was not fitted with inlets on the insulation level. The new gutter was provided with inlet openings from the courtyard and door side. The existing insulation was completed from both sides with a new strip of elevated mortar fillet, and the shape of the surface of the courtyard was modified into a bilateral gradient with a linear neck gutter in the middle. The upper area of the gutter with cast iron grids was also shaped in a similar manner. The paving was done with black and white segmentation, on the basis of preserved sketches by Josip Plecnik, attempting to keep the proportions in relation to the dimensions of the area (Fig. 13).

The last part of the reconstruction involved renovating the suspended ceiling of the reinforced ceiling of the former substation, below part of the lateral line (Fig. 14). The renovation was made in a standard manner: demolition, high-pressure water jetting, passivation of further corrosion of the exposed steel reinforcement, local coarse reshaping, fine screed over the area, and protective cement modified paint (SAN B system, produced by Premix Ltd.)

Fig. 14, 15*: Left – ceiling surface prepared by high-pressure water, new plastic pipes for draining a small part of Plecnik's footbridge, right – the footbridge after restoration*

In this area, part of the wall parallel with the linear axis of the footbridge, the switchboard with automatic control of the heating system is located. After full installation, the heating system and the inlets and outlets to the gargoyles were successfully tested and put into automatic operation.

6 Conclusion

The reconstruction work carried out in the 1990s obviously did not have the required effect, because the basic causes of the degradation were neglected and the solutions and materials chosen for the work were unsuitable.

The first phase of the latest reconstruction of the footbridge was finished at the end of 2006, and the work was handed over to the client. The second phase of the reconstruction was carried out during the construction season in 2007. It involved knocking down old plasters from the brick masonry and replacing them with a layer of lime mortar to absorb most of the harmful salts.

This so called lost layer of oversalted mortar will after some time also be knocked down and later provided with a new high-quality maintenance plaster system. The functionality of the drainage system, and the heating and water insulation for it, have been tested in the course of several freezing episodes in recent winter seasons. The new solution has proved successful in current operation, and meets all requirements of the heritage authority. In terms of sustainable development, the less than ten-year lifetime of the previous reconstruction can only be assessed as satisfactory. Neither the materials nor the workmanship were adequate an properly realised. The original design by Plecnik include some design defects, too. This caused remarkable demand of maintenance to protect structure against deterioration. However, the structure of the Castle has an important history, and its style characteristics and aesthetic influence need to be considered in a wide context and needs to be maintained for the future.

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