Do Modern Materials Need a New Conservation Approach? Approaches to Restoring Sandwich Panels, Polyurethane Foam and Shotcrete

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Two recent conservation-restoration projects demonstrate that structures of the more recent past require us to handle materials which do not belong to the corpus of classic building materials. Conservation experience of these materials scarcely exists. The two listed structures are briefly introduced and the treatment of their specific materials is described. The conservation-restoration experience gained raises the question of whether or not new materials require a new philosophy to express the conservation-restoration approach to monuments of relatively recent date.

I. The Berlin Circulation and Cavitation Tank

The first project is the Circulation and Cavitation Tank in Berlin (*Umlauftank 2*) (Fig. 1). This structure is situated on a prominent site in the heart of Berlin close to the main axis connecting the western and eastern parts of Berlin. The tank is visually well known, since one of the main railway and suburban train lines pass by directly. And yet to most citizens and visitors its function has been a mystery since its erection in 1974. Even if the pink tube indicates some technical operation is in operation, it neither reveals its purpose nor the medium circulating in it. The inner life of the blue box remains a secret as does the reason why it is propped up on top of the giant pink 'serpent' by a slender green steel structure (Fig. 2).

In fact, the Circulation Tank is a research facility, today operated by the Technical University of Berlin. The tank contains 3300 tonnes of water, the water being driven by a huge propeller and two ship diesel engines. The top part of the tube is only half filled. A large opening allows access to the water, which appears as a steady running flow. Depth and speed can be varied. This section allows hydrodynamic and maritime experiments in and under water with all sorts of vessels and propellers in model scale. The blue box with five storeys serves as a laboratory building. The pink tube is insulated by foam in order to keep the water temperature to some degree constant throughout the year. Scientific tests need stable conditions for comparable results.

The Circulation Tank is one of about 80 similar facilities worldwide. It is the biggest of its kind. But more important is that it is the only one which found an original architectural expression for its function. All other circulation tanks are hidden in industrial sheds as sheer machinery or they are partly dug into the ground. The Berlin Circulation Tank is a hybrid of a machine and a building. The singularity of this building type makes it exceptionally difficult to decipher and to understand. The way this structure was designed by civil engineer Christian Boes and architect Ludwig Leo (1924–2012) has made it an outstanding work of architecture. It has found its place in building history as well as in the townscape of Berlin. There it stands, still somehow puzzling.

Fig. 1: Berlin, Circulation and Cavitation Tank (© adb Ewerien und Obermann)

Fig. 2: South elevation after restoration, 2017 (© adb Ewerien und Obermann)

Materials

Only the two main materials of the construction of the Circulation Tank will be discussed: the pink tube and the covering façades of the blue laboratory building.

The tube is made of curved steel plates, 17 mm thick. The whole welded construction is covered with about 40 mm of polyurethane foam (PU foam), directly sprayed upon the steel and finally painted with a pink coating. Polyurethane foam is commonly used as an insulation material, which is mostly available as boards and usually covered and protected by other weatherproof materials. It is not very resistant to UV light and tends to absorb water after several years. The condition in which the foam was found in 2013 before restoration was characterised by gaps in the coating and by the foam beginning to decay. Many parts of the surface showed cracks or even voids. In some gaps, vegetation had started to grow. Earlier repairs with inappropriate materials such as mortar were also found. Mortar fillings did not coalesce with the PU foam.

Fig. 3: Polyurethane foam with typical damages, 2013 (© adb Ewerien und Obermann)

Fig. 4: Sandwich panels with faded coating and corrosion, 2013 (© adb Ewerien und Obermann)

The façade of the laboratory building is made of sandwich panels. They were industrially produced and consist of a core of polyurethane foam in between two layers of galvanised steel sheets. The outward sheet is coated in blue, the one towards the rooms in white. The panels had lost their colour in the more than 40 years of their existence. The coating had not been renewed since construction. More concerning than the loss of colour were the spots of corrosion that on some of the panels appeared to be covering large areas (Figs. 3 and 4).

The conservation-restoration planning of sandwich panels

The planning team tried to develop repair solutions for these two materials with their specific damages. The aim was to apply established conservation principles, such as retaining as much of the original fabric as possible. Both materials had never been subject to conservation interventions before. It was also clear that polyurethane foam even after restoration would not transform into an endorsed cladding material with reliable durability.

The repair concept evolved was to identify the corroded areas within the panels, to cut them out and to peel them off the PU core. The void would have been filled up in order to achieve a level plane with the surrounding surface, onto which a new repair sheet of steel would have been glued within the next stage. The detailing made provisions for the joints between the panels. The new sheet would have to slip within the existing pleat of the neighbouring panel. Different sorts of glue were investigated and selected in order to fulfil different requirements, such as durability, flexibility and changing temperatures (Fig. 5).

With this concept, only 12 % of the panels would need to be repaired, another 13 % with a filling of asbestos would have to be exchanged for health and safety reasons on account of noxious matter anyway, and the majority of 75 % could be conserved.

For experimental repair methods with little existing experience it is good practice to evaluate samples before the actual restoration. During the planning process various samples were carried out. They involved different types of steel sheets as well as different surfaces and coatings. The original colour had been undoubtedly identified. Beside the technical evaluation also the level of gloss was tested and debated. Heat and frost were simulated in order to control thermal deformation. And last but not least, the repair sheets were tested for their adherence to their substrate.

The concept and tests were convincing. Final doubts had to be resolved since some irregularities appeared. Only when the scaffolding had been constructed could the panels be scrutinized intensively. A special device allowed inspection of the depth of the panels. The *eddy current method* is an electronic method used for example to detect fine cracks in components of aeroplanes. This instrument was able to identify transformations on the rear side of the steel sheet facing towards the PU core. Since the detector has the size of only about five centimetres it took several weeks to inspect all panels centimetre by centimetre.

The result was disastrous. Two lessons had to be learned: First, the steel had separated from the foam in many places, forming a gap. The result was loss or at least severe reduction of the stability of the panel as a self-supporting structural element. Second, and even worse, the outer steel sheets were corroding on their internal side attached to the foam. Despite the galvanising, most corrosion found had developed from the inside and not as previously assumed from the outside of the panel. The results of the *eddy current method* detection were validated by openings. At the end of the process, the result was that all panels were identified as being at least partially damaged although their appearance from outside had suggested a good condition. There was not a single sound element found on any of the façades. The first assessment of the visible damages had been completely misleading and wrong.

This painful process of learning culminated in the realisation that there was no possible repair method for corrosion within the compound element of a sandwich panel without its dismantling and complete destruction. The intention of a thoughtful repair ended in the exchange and renewal of all sandwich panels. That they are still being produced in the same way, in the same dimension and colour, was cold consolation.

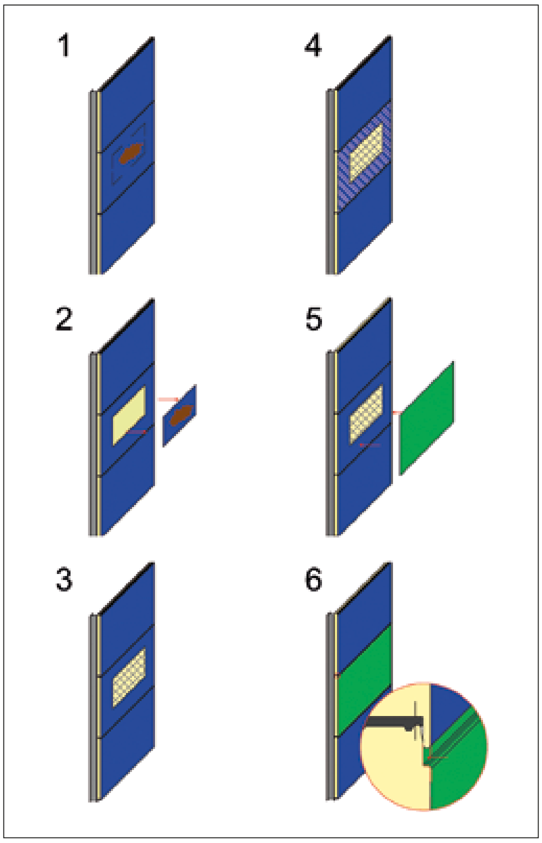

Fig. 5: Repair concept for the sandwich panels (© adb Ewerien und Obermann)

Fig. 6: Fresh foam being sprayed into the prepared voids (© adb Ewerien und Obermann)

Preserving polyurethane foam

The attempt to repair the pink foam in a traditional way was more successful. Repair samples had also been tested in advance. The repair of masonry had been the role model, although solid stone appears as the complete opposite to the unstable polyurethane foam. Responding to the two main categories of damage, two major repair principles were implemented. First, damaged spots were cut out down to the steel bottom. That was handily achieved with a simple kitchen knife. Preferably rectangular outlines were carved out, just as it is commonly done to repair stone. To guarantee a durable bond with the adjacent foam an undercut was formed, similar to mortar-based repairs in masonry. The void, wider on its bottom than on the surface, was filled by spraying in new foam. The two-component material turns from liquid into stiff foam within seconds. While hardening, the foam expands. Spraying foam needs experience in order to anticipate the amount and allow for expansion. In most cases the new infill expanded slightly over the edges and had to be cut back. Finally, a quick and very thin overspray was applied to adapt to the typical granular texture (Fig. 6).

The second repair principle applied to areas with single cracks or a network of cracks which did not need to be cut out deeply. A survey had shown that the cracks usually ended at a depth of only a few centimetres. Those areas were ground down to the sound material. The recesses were levelled by overspraying fresh foam. Finally, and after washing the remaining surface with water, the pink coating was added.

The result is that most of the foam has survived and especially its irregular hand-crafted character. On closer inspection, the repair work can be clearly perceived. A closer look also indicates that the foam is not a high-quality material. The emblematic character of the large-format building, however, emerges to its full effect only from a distance (Fig. 7).

Fig. 7: Polyurethane foam after restoration, 2017 (© adb Ewerien und Obermann)

Fig. 8: The decks of the laboratory; the top of the water tube appears on the lower deck, painted green (© adb Ewerien und Obermann)

Conserving the interiors

The blue laboratory box is used as workshop to build and adjust models of vessels in wood and resin. Office space is also available. The interiors had been heavily used and were severely worn after more than 40 years of intensive use.

The architecture again is breathtaking and genuine. Maritime research issues have found their expression in a maritime architecture. The five different floors in the building are still called *decks*, just as the architect Ludwig Leo entitled them in his drawings. The similarity to the decks of a ship is obvious.

The interior looks clean and appealing after restoration. Effectively only straightforward conservation work took place on these decks. The interventions were minimal. Apart from the new shell of sandwich panels, nothing had to be replaced. Only the white partition walls were repainted. All the other surfaces, such as the green and black steel members, were intensively yet carefully cleaned. Conservators used damp, curd soap and brushes. The floor, after decades of heavy workshop use, is still the original floor due to intensive cleaning with scalpels and various complementary means of cleaning and polishing. Cracks and holes in the orange textile barriers were stitched and darned on-site by textile conservator-restorers. Missing cords in the barriers on the top deck could be reproduced in the same manner and colour (Fig. 8).

II. The Observation Deck in Binz (Rügen) by Ulrich Müther

The second model project to be presented was much smaller. Again, it is rather a structure than a conventional building (Fig. 9). It was designed and created by Ulrich Müther (1934–2007). He was a civil engineer who lived on the small island of Rügen in the Baltic Sea.

Hyperbolic paraboloids

Ulrich Müther had specialized in concrete shells. He led a community-owned company in the GDR. From the 1960s and mainly up to the 1980s he designed and carried out approximately 60 to 70 structures, most of them as concrete shells. He became famous for the construction of hyperbolic paraboloids, a geometric surface which is inflected in two opposite directions comparable to a horse saddle. It was Müther who coined the concise term *hypar shell* for the built version of the mathematical phenomenon. Together with Heinz Isler (Switzerland), Félix Candela (Mexico/Spain) and Frei Otto (West Germany) he was one of the international protagonists of this light and wide-spanning construction type.

Müther combined the hypar shells in different ways to outstanding spaces. A single hypar shell could serve as an open but covered space, as for instance a bus stop (Fig. 10). Two, three or four hypar shells of larger size were arranged to

Fig. 9: Observation deck for lifeguards at the beach of Binz/Rügen (© Wüstenrot Stiftung)

exhibition halls and other public spaces. One of his masterpieces was the *Maple Leaf*, a composition of five hyperbolic paraboloid concrete shells. It served as a canteen for the East German Ministry of Construction in Berlin. Sadly, it was demolished in 2000.

Another proof that his work belonging to the recent past is still in danger is a multi-purpose hall in Magdeburg whose future is uncertain. It consists of four hypar shells (Fig. 11).

Müther's construction company operated on the island of Rügen. There, supported by the GDR government, he had the opportunity to experiment with structures of shotcrete, his favoured material. Concrete was shot on a fine mesh of steel and reinforcement, sometimes even without a wooden shuttering. In this context a series of trial constructions were created from which he could gain experience for taller buildings. One of those experimental buildings was an observation deck for lifeguards – often referred to as "rescue tower" – at the beach of Binz (Rügen), built in 1975. In this case the shape is not a hypar shell: the shape is bent in two directions, but not in the opposite ones.

His construction plans, which are safely stored at the Müther Archive at the University of Wismar, reveal that the

Fig. 10: Hypar shell for small-scale experimental structure: bus stop in Binz/Rügen (© adb Ewerien und Obermann)

Fig. 11: Multi-purpose hall in Magdeburg (built 1969); endangered structure of four hypar shells, with temporary support in the centre (© Sebastian Schmidt)

Fig. 12: Inside the deck before restoration (2015): frozen condensation on the windows, water and mould on the concrete shell (© adb Ewerien und Obermann)

shell was planned and most probably realised with a thickness of only seven centimetres. Six years later Müther was commissioned to provide a second observation deck further down the same beach. Instead of building the identical structure he tested out the limits of material and geometry and reduced the thickness of the shell down to only four centimetres.

From a structural point of view, it is a superb work. In some other respects, however, it is a failure. This becomes clear in winter. The windows are frosted, water drips from the ceiling and all surfaces are wet and mouldy. Due to the extreme dampness the wooden window frames had rotted from inside and out. Heating and ventilation were non-existent. Only four centimetres of concrete, rapid weather changes at the coast, no insulation and no space for heating cause severe problems to the inner climate and serious harm to the fabric (Fig. 12).

Retrofitting an experimental structure

How could an experimental structure possibly be turned into a functional and long-lasting building? Three main measures were taken:

First: Instead of single glazing, double-glazed panes with a thickness of only 12 mm were inserted without any effect on the frame dimensions. A sample was tested and positively evaluated in respect of appearance, colour and reflection. The completely decayed frames were reconstructed in thermically processed timber, which promises high resistance towards rot.

Second: To avoid or minimise condensate on the concrete surfaces two options were explored. The first option was a plaster with highly insulating characteristics. A notable physical effect on the room climate would have afforded a layer of several centimetres on the inner side of the concrete shell. This corresponds to the thickness of the concrete itself. It would have been impossible to hide this extra layer at the edges and would have been clearly visible at the windows. The other option was to install very thin electric heating wires which were set into a filling of only a few millimetres and which could fade out at the windows. Neither wires nor filling is visible at all. Electronic sensors for temperature and dampness decide when to slightly warm up the shell in order to avoid condensation. With computer-based climate simulations it became clear that these two measures on their own would not be sufficient.

The third component was the most challenging. The idea was to warm up the building slightly and to provoke air circulation. A pipe of about fifty metres length carries air into the building. The air is pre-warmed in a distant and existing facility building and remains warm because the pipe runs below ground at more than a metre in depth. The air runs into the building through a new duct within the shaft of the tower and disperses under the floor. It leaves through slim gaps in

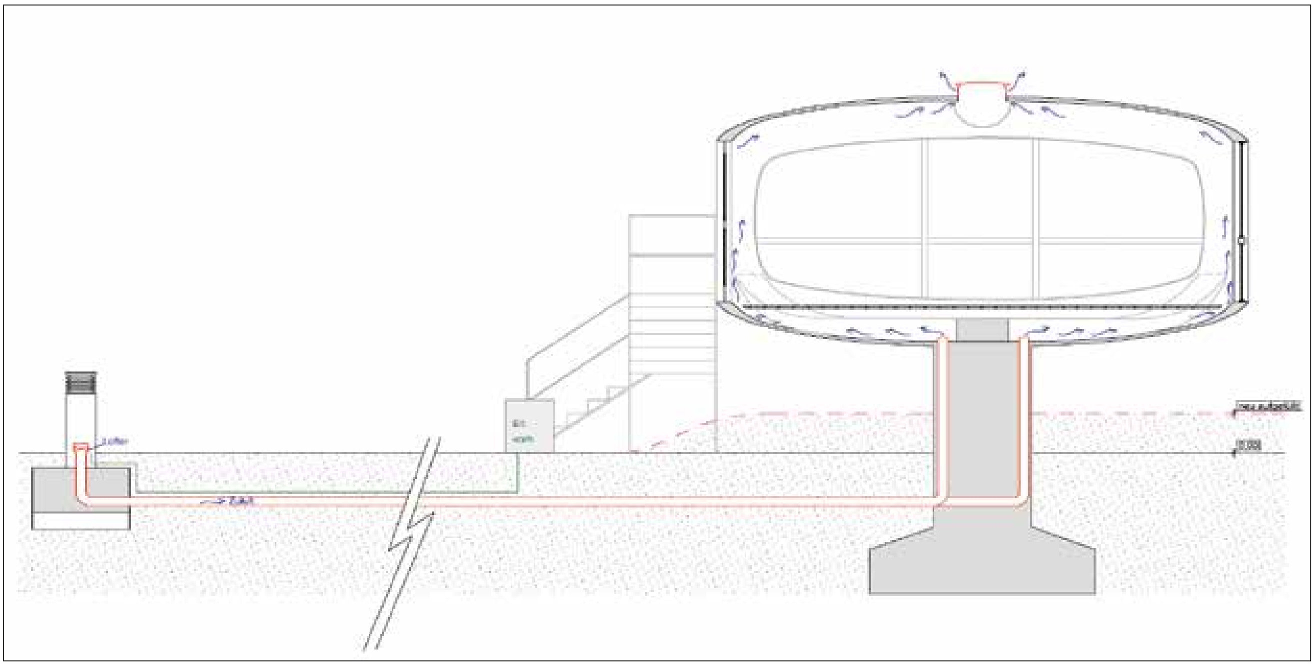

Fig. 13: Ventilation scheme (© adb Ewerien und Obermann)

Fig. 14: View from the former observation deck over the beach of Binz (© Wüstenrot Stiftung)

the floor near the windows from where it can absorb possible condensate passing by the glazing. The humid air then exits through an existing hole in the ceiling. There is absolutely no visual impact of this installation. The uncertain measure of drilling a vertical hole through the massive shaft proceeded successfully (Fig. 13).

The rescue tower is now used not only in summer but also in spring and autumn. It can be hired for civil wedding ceremonies (Fig. 14). The earlier observation deck, however, was destroyed as early as 1993.

Conclusion

The question if new materials need new approaches to conservation practice is provocative but can decisively be answered after evaluating the two model projects presented.

Modern materials often require new methods for inspection and analysis. Modern materials may also involve new repair techniques. The planning instruments however remain the same:

- detailed analysis;
- thorough planning;
- considering alternatives at any stage of planning;
- evaluating samples and tests.

Samples and tests become the more important the less potential repair methods are proven or reliable. Financial means for sample tests and their appraisal are as crucial as time for their preparation and evaluation.

- The conservation claims are the same as with traditionally constructed buildings, namely:
- retaining as much of the original fabric as possible;
- minimal intervention in the fabric;
- preservation rather than repair (as done with the interior of the Circulation Tank);
- repair rather than renewal (as for instance the repair of the polyurethane foam);
- renewal only as a last resort, when all other possibilities have failed.

In buildings of the recent past, pure repair and restoration may sometimes be sufficient. No improvements or technical upgrades took place at the Circulation Tank. Even a model conservation practice, however, cannot convert buildings or materials involved into better quality. Industrially produced sandwich panels or covers of PU foam will remain mediocre fabric.

Retrofitting – in the sense of implementing technical improvements or enhancing technical standards – as carried out at the rescue tower can be helpful. Sometimes they may even be vital if technical solutions prevent the building from further decay.