Concrete: Too young for conservation?

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**ABSTRACT:** The 20th century built heritage is one of the new conservation challenges, due to its architectural differences from the traditional heritage and new materials. One major new material is concrete; its quantity and importance for the new heritage requires a tailored conservation approach. Until now, there is a dependence on a repair approach. The dangers of such an approach for the cultural-historical values of the original concrete will be shown by the means of a case study, Fort Bezuiden Spaarndam (1901), part of the UNESCO World Heritage Site Defence Line of Amsterdam. An underlying problem is that concrete is too young for conservation experts, causing a dependence on concrete repair expertises. The used repair techniques are developed for structural aims, not integrating conservation aims. Fundamental research on the history of concrete and suitable conservation approaches and techniques is therefore needed.

1 INTRODUCTION

With the aging of the 20th century building stock, we are now facing the challenge to evaluate them and make selections for objects which should be kept as part of our built cultural heritage. It is consistent that the values which justified the selection should be preserved and respected during any intervention. Interventions cannot be avoided as aging often goes along with some degree of deterioration. The demands for interventions according to (international) conservation guidelines are applicable for the entire built heritage, independent from age or construction type.

However, for the implementation of the demands a tailored conservation approach for the 20th century built heritage is needed. The new heritage does not only differ in architecture, structure, quantity, and building typology from the traditional heritage, but also in the used materials such as concrete. The different material properties make a transfer of knowledge and experience gained with traditional materials such as brick and mortar less feasible.

For concrete, the current approach is often a conventional repair approach as no tailored conservation approach exists. As in practice a loss of values correlated to the original concrete is often encountered, the question arises if this is a pure technical problem such as incompatible repair materials or a more fundamental problem such as the way concrete conservation projects are approached.

During this research, studies of completed interventions of historic concrete buildings indicated a relation between the following of repair approaches and the loss of monumental values. In this paper, this relation will be illustrated by means of the case study Fort Bezuiden Spaarndam, the Netherlands. It shows that there are general, underlying problems in the field of concrete conservation which endanger values, independent from the technical performance of a repair.

2 METHODOLOGY

The current research aims at understanding the relation between the loss of value and following a repair approach. To evaluate the impact of a repair approach, case studies of former concrete conservation projects in the Netherlands have been carried out. In this paper the results of the case study Fort Bezuiden Spaarndam, part of the Defence Line of Amsterdam (*Stelling van Amsterdam*), will be presented to explain the underlying problems of the preservation of values of historic concrete.
During the research, the most important involved parties were interviewed (architect, surveyor, and concrete repair company) to understand their background, knowledge, and experience and to see where the dependence on concrete repair experts starts. Literature, documents, and surveys related to the fort, its construction and conservation were consulted to investigate the historical background, conservation aims, and conservation process. During a visual inspection in November 2006, the performance and impact of the conservation was evaluated.

The study focused on concrete which was used for exterior elements, stressing the complexity to balance technical, aesthetical and conservation demands, meaning a minimal loss of existing fabric and a maximal preservation of values. Additionally, petrographic analyses of samples were made to determine the concrete composition and possible damage. To evaluate the suitability of standard concrete surveys for conservation tasks, literature and guidelines related to concrete assessment were studied.

3 BACKGROUNDS OF REPAIR AND CONSERVATION

To understand why following a repair approach in a conservational context can endanger values, it is necessary to understand why and how the main aims of repair and conservation diverge radically. Repair methods are usually developed to preserve a structural function for a limited lifetime, lately also influenced by sustainability aspects. Surveys focus on physical and mechanical properties and the criteria for the choice of a repair approach are, beside the structural performance, the service life, economical issues, and the possibilities of maintenance (ENV 1504-09 1997).

Conservation, however, is much more than fulfilling technical and financial requirements. Besides considering structural performance and safety, the preservation of the authenticity of and values attached to the site, building and material must be considered. The value and authenticity of the cultural heritage is understood in ‘artistic, historic, social, and scientific dimensions’ and the conservation principles ‘respect . . . the existing fabric’ and the cultural heritage should be preserved for ‘present and future generations’ (ICOMOS 1999).

Yet, due to the youth of the field of concrete conservation, concrete repair experts are entrusted with concrete conservation projects. Although these experts have considerable knowledge of the technical aspects, they are not trained in specific conservation aspects, as the complexity and variety of monumental values and authenticity or the properties of historic concrete. Because conservation experts often do not have sufficient knowledge on the material, an evaluation of the suitability of such a process is difficult.

Figure 1. Site plan of Fort Bezuiden Spaarndam.

4 FORT BEZUIDEN SPAARNDAM

4.1 Historical background of the Defence Line of Amsterdam

The Defence Line of Amsterdam, the Netherlands (1880–1920), is a ring of fortifications (45 forts) around Amsterdam, intended to defend the city by systematic inundation in case of an attack. This ingenious defence technique was one justification for the listing as a UNESCO World Heritage Site in 1996. In connection with the listing, attention was drawn to the need for conservation and re-use, as the condition of many forts declined after the military function of the forts ceased in the 1960s. Fort Bezuiden Spaarndam (1901), a provincial monument in the province North Holland, was constructed as part of the Defence Line of Amsterdam.

4.2 Historical background of Fort Bezuiden Spaarndam

Fort Bezuiden Spaarndam is a non-reinforced concrete fort built in 1901. It was planned as a standard model of the Defence Line of Amsterdam on a fort island with two cupolas with disappearing turrets (Fig. 1). The fort itself did not suffer from major damages during the Second World War, though the cupolas were blown up by the German occupation army. The remains of the cupolas still lay spread around the grounds. Since the cease of the military function in 1960, the fort was used for agricultural storage.

4.3 Historical background of the concrete of Fort Bezuiden Spaarndam

To recognise the historical value of the original concrete, it is necessary to understand the construction and technology history of the late 19th century. Knowledge of concrete and its construction was mainly based on empiric studies; standard design codes only
appeared at the beginning of the 20th century. In this context, the knowledge gained from the construction of the Defence Line of Amsterdam was important for the Netherlands, where early concrete technology was dominated by the army corps of engineers (e.g. Scharroo 1910). The first Dutch reinforced concrete guidelines *Eerste Gewapend-Beton-Voorschriften* from 1912 were influenced by the experience gained during the construction of the Defence Line of Amsterdam (Noord-Holland 1996).

Therefore, the forts of the Defence Line of Amsterdam are the tangible artefacts of this pioneer phase of concrete technology. Initially, the forts were built as traditional brick constructions; yet the invention of brisance grenades demanded new and stronger construction methods. Hence from 1897 onwards, the forts were built as non-reinforced concrete constructions, later as reinforced concrete constructions (ICOMOS 1996). This transition from brick to reinforced concrete and the still preserved high degree of authenticity was part of the justification for the Netherlands to nominate the Defence Line of Amsterdam as a UNESCO World Heritage Site (ICOMOS 1996). The value of the concrete as a preservable cultural-historical artefact was stated prior in the description of the Fort Bezuiden Spaarndam in connection with the listing as a provincial monument in the early 1990s (Provincie Noord-Holland 1998).

5 CONSERVATION 1996–1999

Fort Bezuiden Spaarndam was one of the first forts to be restored after the listing of the Defence Line of Amsterdam as a World Heritage Site in 1996. It was supposed to be a role-model conservation project with extra subsidies and attention, as further forts needed restoration in the near future. The first aim was to find a new locally orientated function for the fort, which should be compatible with the surrounding nature recreation area. In 1996, it was decided to use the northern wing as a day nursery, the postern as an art gallery, and the southern wing as storage.

The task of conservation was handed over to a restoration architect, who had experience with the conservation of a brick fort, but no experience with the material concrete. This is not unusual for the late 1990s, as little knowledge and experience with the conservation of concrete existed. The heritage care authorities of the province North Holland had no specialist for the material concrete either, and an external concrete expert was entrusted with the survey of the fort.

5.1 The survey of the concrete

The survey did not differ from standard, non-conservation concrete surveys. The assignment was to assess the technical state of the concrete and to determine the causes of the encountered leaching, cracking, and leakages. Several cores were taken, not only to determine the composition and damage causes, but also to gain information on the wall construction.

It was stated that the walls were massive concrete and the concrete was composed of cement with ground granulated blast furnace slag (GGBS) and crushed rocks (granite, porphyry) as aggregates. The following damages were assessed in the survey:

- shrinkage cracks
- cracks along casting segments caused by missing expansion joints
- water bearing cracks with leaching
- map cracking caused by the formation of thaumasite or ettringite.

The advice was to reconstruct the missing earth shelter of the roof and to seal the roof to prevent further infiltrations. Cracks that influenced the structural performance should be injected; the injection of other cracks was optional. In general, the condition of the concrete, considering the construction time and method, was stated as good and with adequate repairs, the building could last another 100 years.

5.2 Repair of the concrete shell

The main goal of the intervention was to repair the outer shell of the fort in a way that would solve the problems ‘for once and for all’, repairing the roof and treating all cracks. As a detailed advice for repair techniques was not commissioned, the choice of an adequate repair technique was left to the executing concrete repair company. In 1997, the repair campaign of the fort started and included for the exterior concrete walls following intervention steps:

- high water pressure cleaning of the façade
- filling of cracks with standard repair mortars
- injection of cracks with micro-cement
- creating expansion joints along the cracked vertical segment joints.

No specific requirements concerning durability and compatibility were prescribed. The concrete repair works were not supervised by external experts. Maintenance and regular inspections were not planned, since it was assumed that the repairs would be long lasting.

6 EVALUATION OF THE CONSERVATION PROCESS

Although intended to be a role-model conservation project, the approach of Fort Bezuiden Spaarndam is an example of a concrete repair approach. This
case shows the problems resulting from an unsuitable approach and reflects an underlying problem of concrete conservation: unawareness of the values of historic concrete. Examples from the survey and execution illustrate the consequences and show how valuable information could have been gained or values preserved.

First, the crucial phase of assessment and decision-making was not guided by adequate experts who understood both the material, including its history, and conservation principles. Consequently, values attached to the concrete were neither determined nor the impact of the repair techniques on the values attached to the concrete evaluated.

However, it is possible to gain information on possible values during a survey (Heinemann 2007). A review of the conservation process shows how values could have been detected and thus incorporated in the conservation process; it also reinforces that knowledge on the material, its history, conservation aims and repair techniques is needed, and that trained experts for these tasks are still missing.

6.1 Present condition 2006

A visual inspection of the performance and impact of the interventions was made during a site visit of Fort Bezuiden Spaarndam in 2006. From far distance, the impact of the repaired cracks was already visible, changing the appearance from a monolithic structure to a patched structure (Fig. 2). On closer examination, it appeared that the repaired cracks next to the newly created expansion joints re-cracked and the concrete of the casemates showed map-cracking with leaching and local disintegration. On several places on the main façade, traces of camouflage paint were found that were not documented in former surveys. The interior of the fort showed no signs of infiltrations or re-cracking, and according to the tenants, who appreciated the interior of the fort (day nursery and art gallery), the climatic conditions were satisfactory.

6.2 Awareness of values

The visual impact of the conservation on the façade raised the question why the aesthetical values of the monument were not respected. A possible aesthetical value of a building is usually widely accepted and the visual impact of a repair technique can be evaluated without large-scale research. However, standard repair techniques do not consider aesthetical compatibility.

Therefore, the question arose how the conservation of concrete was realised and if values were considered in the process. During our investigation, it became apparent that the concrete was only perceived as the structural material of the shell. This reflects the underlying problem of concrete conservation, that concrete is often not seen as a valuable historical material.

In the case of Fort Bezuiden Spaarndam, it was officially stated that the original concrete was valuable in the justification for the listing as a UNESCO World Heritage Site (ICOMOS 1996) and as a provincial monument in 1992 (Noord-Holland 1998). The original concrete is important because of its uniqueness and remains of this phase of the technical development of concrete in Europe are rare. However, an implementation of the preservation of and awareness for these values was missing in the conservation process.

This unawareness led to the commission of a standard (i.e. purely technical) survey of the concrete which was not adapted to the needs of conservation. Without sufficient knowledge of historic concrete and possible values, the weaknesses of a purely technical survey in this context were not seen. Consequently, the correlation between values, the material, and the state of conservation was not determined. Therefore, the values were not further integrated in the conservation process.

Figure 2. Gorge façade after repair.
6.3 Survey of the surface

Aesthetics are criteria for the value assessment of buildings and for the compatibility of conservation techniques. Therefore, it is important to describe the surface of a monument during a survey. For technical surveys, as it was commissioned at Fort Bezuiden Spaarndam, a description of the surface is not included as it usually does not influence the mechanical or physical properties of the concrete.

A description of the properties of the surface such as colour, texture, deposits, weathering, or traces of former events can be used to evaluate the impact of an intervention (e.g. material loss due to cleaning) or help to adapt the structure and colour of a repair mortar to the surrounding concrete.

Other essential information which should have been documented is the presence of camouflage paint traces and the original surface finish. Further colour-historical research should have been carried out to evaluate the options for reconstruction of the paint and to broaden the historical knowledge of the forts. As this case was supposed to be a role-model, opportunities to study the forts in connection with the survey should have been taken.

How far the cleaning of the façade with high-water pressure caused losses of the original surface, and with it historical information, cannot be determined now, since there is no detailed documentation of the façade to refer to. Given experience with façade cleaning, however, such a loss is highly likely. It also shows how easily standard approaches are followed, and consequences for the monument and its values are not considered.

6.4 Survey of the composition and construction

An analysis of the composition, structure, and cause of damage of concrete, as for example by petrographic examination, is not standard, as it might not always be necessary to diagnose the cause of damage. However, if samples are taken, they can be used to gain insight into the composition and construction of historic concrete. Besides giving relevant technical information, it can reveal important historical information, and therefore indicate value.

Historic concrete differs from modern concrete. In the case of Fort Spaarndam Bezuiden, it is known that it was constructed in a time when concrete constructions were not standardised. Also the statement that the concrete is a rare remainder of concrete development should have led to an investigation of the samples from a historical point of view as well.

Our petrographic analysis of samples of the southern cupola and of the main building show that the concrete is composed of a coarse-grained Portland cement and not ground granulated blast furnace slag (GGBS) cement as described in the survey. The coarse aggregate was crushed porphyry from Quenast, Belgium, and the fine aggregate river sand (Fig. 3).

From the study of historical documents, we found out that crushed rock was assumed to be superior to gravel because of its rough and angular surface which was supposed to improve the bond to the cement paste. The use of crushed rock and in particular porphyry of Quenast as an aggregate was advised in contemporary books (Kloes 1908). In the construction plans of the fort from 1900, it can be seen that a differentiation between the used aggregates and function of the concrete element was made. For important elements, the use of porphyry was designed, while secondary elements where designed with cheaper gravel or even with rubble.

The high amount of voids and the average to high capillary porosity of the concrete mentioned in the survey can be explained with knowledge of the composition and construction method. They are in this case typical, because the rough shape of the aggregate complicated the manual compaction. To obtain the workability, the use of a higher water-cement ratio was common. Both the compaction and the high water-cement ratio influence the porosity and durability of concrete.

Another result from the composition is the occurrence of alkali-silica reaction (ASR) (Fig. 4). The used aggregate, porphyry of Quenast, is now known to be alkali-silica reactive (Nijland et al. 2003). When used in combination with Ordinary Portland Cement, which, in contrast to the GGBS cement that was wrongly considered to be present in the original survey, ASR is not inhibited. With knowledge of the construction history of concrete certain damage types can be explained, here the assumed superior combination of porphyry and Ordinary Portland Cement causing ASR.

![Figure 3. Microphotograph showing detail of the cement paste, with relics of unhydrated Portland clinker (indicated as calcium silicates C2S and C3S), and no blast furnace slag at all (view 0.7 x 0.45 mm, plane polarized light).](image)
It has to be kept in mind that the perception of cement types differed from our current perception. At the time, the use of Ordinary Portland Cement was preferred to the use of blast furnace slag cement. Latter was assumed to be of poor quality, mainly because it was a cheap waste product. It became, due to economic reasons, only widely used in the Netherlands from the 1920s onwards.

A petrographic analysis of the concrete can also tell stories about the history of a building. A section through the surface (Fig. 5) shows three layers of a lime based layers on the surface. The core was taken before the surface was cleaned with high-water pressure. Therefore it cannot be determined if they are remains of a finish (Noord-Holland 1996) or deposits. If the indications from the thin section would have been used prior to the intervention, research could have been carried out in situ and decisions made if the surface is preservable. Yet it is likely that the high pressure cleaning of the façade affected this layer of the surface. As no references were found on the building anymore nor could be found in the documentation of the project, the amount of loss of original fabric cannot be said.

With historical and technical knowledge, a petrographic analysis can help to determine the authenticity of the original concrete, which is important when decisions have to be made of how much material loss is acceptable. The results from our petrographic analysis show that the composition of the concrete of Fort Bezuiden Spaarndam is of high quality relative to the state of the art of 1900. The given historical information confirms the value of the authentic concrete and any intervention should respect that value.

6.5 Advices and decision-making

As the assignment of the survey was pure technical, additional historical aspects of the concrete were not considered. As a result, no special treatment respecting the historical values (significance of original concrete and the visual appearance) was advised. The choice of the repair techniques was done by the restoration architect and the concrete repair company. Neither of them was familiar with the properties of historic concrete and the complexity and consequences of repair choices were not seen. One example of the consequences is the repair approach of the cracks caused by thermal movements.

A common problem of the forts of the Defence Line of Amsterdam is the lack of expansion joints. Expansion joints were not common at that time, in the 1920s there was still discussion if expansion joints are needed (Kleinlogel 1927). Also here the missing insight into the properties of concrete caused damage, cracking, which becomes a historical evidence of the trials and errors of the technological development.

The concrete forts of the Defence Line of Amsterdam are approximately 150 m long, most of them not reinforced. The stresses caused by thermal movement caused regular linear cracks along the weakest points, usually the casting segments. Cases of severe structural damage are not known, as each casting segment is equivalent to one vault and the cracks appeared at the points of support in the middle of the cross walls. Yet, the ingress of aggressive agents can be facilitated by the cracks. As there was no reinforcement, corrosion was not possible but the composition of the concrete was ASR sensitive, a reaction which needs water and can lead to severe damage. However, no signs for increased deterioration were visible next to the cracks.

During the restoration campaign of Fort Bezuiden Spaarndam it was decided to repair the outer shell ‘properly’, which included a repair of the cracks caused by thermal stresses. The idea was to compensate the thermal stresses with expansion joints, which
would be intersected. The façade was cleaned with high water pressure and the cracks injected. The injection was originally carried out with a polyurethane injection resin. The high porosity, the numerous voids along the segment joints and the thickness of the wall (1.25 m) complicated the work. As a complete filling of the cracks was unlikely, the cracks were injected with non-elastic micro cement instead. As the thermal stresses would be compensated by the new joints, the elasticity of the mortar was not considered important.

After patching and injecting, the exterior façade was vertically intersected (0.05 cm–0.10 cm depth) along the casting segments with the idea to create expansion joints which would prevent further cracking of the concrete. The dimensions (width, depth) of the cut were not based on calculations but on the working experience of the contractor with non-reinforced industrial floors. A possible effectiveness of the intervention was not studied prior to application, neither tryouts on a limited scale were done nor by simulations.

As the concrete is not reinforced, the structure is sensitive to stresses; instead of releasing the structure from stresses, stresses concentrated at the end of the intersection. The reappearance of cracks in the patched area within less than a decade indicates that the intervention does not work (Figs 6–7).

This intervention required an unnecessary material loss and as it failed, a ‘repair of the repair’ may follow, causing further material loss. A simpler approach by not filling the cracks and preventing water ingress by fixing the roof, as it was done anyway, should have been tried instead. Together with a long-time monitoring of the moisture ingress through the cracks and of the crack movement, a major intervention could have been prevented or delayed and insight would have been gained on the damage mechanisms, allowing the choice of an appropriate conservation approach.

7 CONCLUSIONS

The primary problem of the concrete conservation of Fort Bezuiden Spaarndam is not technical such as the performance of a repair technique. The problem lies in an approach, which does not respect the concrete as a historical valuable material: a repair approach instead of a conservation approach. Yet there is another underlying problem in the field of conservation: concrete seems to be simply too young for heritage stakeholders.

7.1 Conservation Fort Bezuiden Spaarndam

Monumental values were lost during the conservation of Fort Bezuiden Spaarndam, because the concrete was primarily understood as a structural and not a historical material. Together with a dependence on repair experts which are trained to perceive concrete from a structural point of view, little attention was given to the values correlated to the original concrete. The conservation experts could not evaluate if the approach was suitable for historic concrete as they had no experience with the material.
Similar to a repair process, the survey focused on physical properties of the concrete and did not integrate historical relevant aspects as the unique composition of the concrete or the traces of camouflage paint. Consequently, the amount of lost original concrete and related values was not considered.

Support and guidance for the involved parties by concrete conservation experts was not possible, as the field of concrete conservation barely existed and the complexity of concrete conservation was not understood. Therefore, possible conservation aims, the cultural-historical values, the significance of the state of the building and their relationship could not be discussed openly before starting the conservation campaign. Such discussion should not be limited to possible re-use or economical issues, but should include tangible and intangible values of the building/material as well.

A critical review of the repair approaches was not taken into account, as it was assumed that repair experts have sufficient knowledge of the material. There was no awareness for the fundamental differences between a repair and conservation, therefore the influence of a repair approach on the values was not considered.

However, this case is not isolated and it is likely that the results would have been similar if the conservation would have been carried out by other people. The fundamental problem of concrete conservation is that the conservation process is often not guided by conservation experts which understand both the material and conservation principles.

7.2 Concrete conservation

Values and their preservation are key issues of heritage care. The value of age, that, as Riegl (Riegl 1903) says, even ‘appeals the masses’ is often not seen since to the ‘youth’ of concrete buildings and the more sophisticated historical values need art-historical knowledge to be recognised. Until now, this art-historical knowledge hardly exists and this reflects itself in the (value) assessment of historic concrete buildings. For the majority of restoration stakeholders, concrete buildings are too young, as their working field is mainly buildings prior to 1900.

It is necessary to overcome the knowledge gap concerning 20th century buildings in the working field and education of conservation experts. Parallel, it is necessary to develop a tailored conservation approach to overcome the dependence on a pure repair approach. When applying repair techniques, one should not rely on the fact that concrete repair has been carried out for decades, but assessed whether they are applicable, since they were developed for different aims.

As long as there is a dependence on a repair approach, the background of repair experts has to be kept in mind. It is the task of the conservation expert to explain the diverging requirements for conservation towards repair experts. This requires sufficient knowledge of the material concrete from the conservation expert; otherwise the deficiency of a repair approach cannot be seen and may bring to risk the values which were the initial reason for listing and conservation.

As long as concrete conservation projects are still isolated cases and no clear guidelines or references for concrete conservation exist, general guidelines such as the Venice Charter (ICOMOS 1964) should be consulted to evaluate possible approaches. Finally, discussions of possible values of concrete are needed to see that it can be more than a greyish bearing material. As concrete was initially mainly understood as a structural material and only later the architectural values were discovered, we have to make now a similar evolution: from structural repairs to conservation.

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REFERENCES


