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Concrete heritage in the Netherlands. Valuation and conservation of concrete and reinforced concrete structures

Introduction

Architecturally speaking, the term Concrete Heritage is not self-explanatory. It may concern the use of concrete in buildings that qualify as architectural heritage, but it may just as well apply to the historical or architectural qualities of the material itself. In other words: are we referring to a material or building component that is part of a larger scheme that represents heritage values, or does it concern the heritage values of the material or building component as such? This distinction is important when dealing with the conservation or transformation of buildings that feature concrete.

Since the introduction of reinforced concrete as a building material, the use of concrete in buildings that are now regarded as architectural heritage has increasingly been based upon conceptual design principles. From the late-19th century on there has been a tendency in architecture towards a higher degree of truthfulness in the use of materials and constructions. In the Netherlands, the works of Pierre Cuypers (1827–1921) and Hendrik Petrus Berlage (1856–1934) are powerful expressions of these ideas, featuring exposed structural elements of iron, steel and concrete without any cladding.

Inspired by the introduction of steel structural frame or skeleton structures for utilitarian buildings in the USA in the 1880s, the architectural avant-garde of the early 1920s introduced structural frames in timber, steel and (mostly) reinforced concrete to a wider variety of building types in Europe.

Frame and infill

At the onset of the era of the Modern Movement, a new generation of architects took such ideas to another level by their radical choice to differentiate between "load bearing" and "dividing" constructions in buildings [1], [2]. The concept of "spiritual economy" [3] lead to the construction principle of load bearing structural frames with light infills for an envelope and interior partitions.

In his publication *Hoogbouw*, or *High rise construction*, the Dutch Modern Movement architect Jan Duiker (1890–1935) argued in 1930: *It is required, through clear calculation of loads on to beams, on to supporting columns, and on to the fully loaded foundation piles, to try the most economical solution, which, at the same time, will be the lightest. Cantilevered constructions will reduce the static moments considerably, and reduce the intervals of supports* [4, p. 33]. This way, the load bearing structure is reduced to floor slabs with beams on minimal bearings, which is convincingly demonstrated by the slender concrete structural frame of Duiker's "Zonnestraal" sanatorium of 1928 (Fig. 1).

It is evident that the use of structural frames as such was not new to building practice at the time, though most of the buildings based on such principles concerned industrial or utilitarian structures. A major advantage of eliminating the load bearing function from dividing constructions was that façades could be designed without any constructional constraints to allow daylight and fresh air to enter where-ever necessary, introducing large expanses of glazing and series of operable windows. "Heavy brickwork" was rejected as a material for façades. Another aim was to advance the industrialisation of the building process through the "dry" assemblage of prefabricated

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Fig. 1. "Zonnestraal" sanatorium, main building (1928) after restoration in 2003. View through one of the driveways that were restored (photo: © M. Kievits/S. Voeten, 2003, WDJArchitecten Archives)

Il. 1. Sanatorium „Zonnestraal", budynek główny (1928) po renowacji w 2003 r. Widok przez jeden z odrestaurowanych podjazdów (fot. © M. Kievits/S. Voeten, 2003, WDJArchitecten Archives)

building components – an idea that was borrowed from the automobile industry[1].

Dividing constructions like façades and interior partitions often concern steel or timber framed glazing, or other non-structural light infills. Next to a range of panels in glass, metal, natural fibres and composite materials, all kinds of light concrete products emerged, such as pumice or slag concrete block and cellular concrete ("aerocrete") made by using compressed air or other gasses [1, p. 50], [5], [6, p. 116]. The experimental use of cementitious materials for light façade panels[2] started to develop from the early 1920s on[3].

From columns-and-beams to mushroom floors

Similar to the ancient Greek masters who modelled their natural stone structures according to traditional timber buildings, the design of early reinforced concrete constructions was borrowed from common building technologies in timber and cast iron. Also, the famed Hennebique system[4] was based on the use of columns and a structural grid of primary and secondary beams to support the floor slabs. In contrast to timber and iron structures however, Hennebique's system involved a monolithic structure. Next to the Monnier system, Hennebique's was one of the most widespread structural systems in reinforced concrete, and it has often been used in the Netherlands. The reinforced concrete frame of the former sanatorium "Zonnestraal" for instance, has a similar structure of main beams and lighter secondary beams (Fig. 2).

For this building, designed between by 1926–1928 by Jan Duiker en Bernard Bijvoet (1889–1979), the structur-

[1] A strong tendency towards prefabrication of building components emerged in order to cut down construction time and save costs, particularly for housing. The most important experiment in this field in the Netherlands is no doubt Betondorp, or *Concrete Village*, built between 1923–1928 in Amsterdam, set up as a test site for various experimental construction systems [5].

[2] Some of the construction systems tested at Betondorp feature light precast panels that were fixed against a structural frame. The 1931 Dresselhuys Pavilion at sanatorium "Zonnestraal" features (probably prefabricated) spandrel panels made of clayed-wire-mesh with several layers of cementitious plaster on both sides. The 50 mm thick panels are about 1.50 m wide and between 1.00 m and 2.00 m tall [7, p. 42].

[3] The systematic recording and analysis of innovative light concrete materials and building components is a growing field of knowledge but the conservation and repair of light concrete as an infill component and/or a finishing material is still insufficiently explored.

[4] The French engineer François Hennebique (1842–1921) was the first to obtain a patent for reinforced concrete structures based on a monolithic system of floor slabs, beam grids and columns (Brussels, 1892). In 1903, priority was given to the patent of Monier from 1878.

Fig. 2. "Zonnestraal" sanatorium, main building (1928), ground floor during the restoration works. The render and plaster finishes have been blasted off revealing the slenderness of the actual reinforced concrete structure. The metal brackets involve a repair that dates to the time of construction (photo: © WDJArchitecten, around 2002)

Il. 2. Sanatorium „Zonnestraal", budynek główny (1928), parter w trakcie prac konserwatorskich. Usunięcie tynków uwidoczniło smukłość oryginalnej konstrukcji żelbetowej. Metalowe wzmocnienia ukazują naprawę z czasów budowy (fot. © WDJArchitecten, około 2002)

Fig. 3. The Van Nelle Factory in 1930. The cantilever of the floors reduces the static moments which allows for a more economic design of the reinforced concrete slabs. Also, the curtain wall could run uninterruptedly over the full height of the building (photo: © E. van Ojen 1930, "Historisch Archief de Wed. J. van Nelle, Stadsarchief Rotterdam")

Il. 3. Fabryka Van Nelle w 1930 r. Wspornikowe wysunięcie stropów zmniejsza momenty statyczne, co pozwala na bardziej ekonomiczne projektowanie płyt żelbetowych. Ponadto ściana osłonowa mogła przebiegać nieprzerwanie na całej wysokości budynku (fot. © E. van Ojen 1930, „Historisch Archief de Wed. J. van Nelle, Stadsarchief Rotterdam")

al consultant and concrete pioneer Jan Gerko Wiebenga (1886–1974)[5] designed the load bearing frame. Thanks to the orthogonal structure the calculations remained relatively straightforward. The idea of designing each component of a construction to respond to a particular set of forces, rather than accepting the worst case as leading in dimensioning the other beams, lead to a strong variation in size and shape of beams and columns. Material was economised on by tapering the beams at their bearings and at cantilevers. Despite the complicated shuttering, requiring a lot of hand work to have all the form work made to measure, this was an economic solution at times of expensive materials and cheap labour. Today, the laborious form works would not pay off due to high labour costs.

The obstruction of daylight by the floor beams was regarded as a disadvantage of this system, and contrasted with the principles of the Modern Movement. For the daylight factory for the Van Nelle company in Rotterdam, designed between 1925–1931 by the architects Jan Brinkman (1902–1949) and Leendert van der Vlugt (1894–1936), Wiebenga therefore proposed a reinforced concrete frame with smooth floor slabs on octagonal mushroom columns – almost simultaneously with his structural design for the sanatorium buildings (Figs. 3, 4). Thanks to the absence of floor beams, half a meter of construction height was saved from each floor, thereby reducing the height of the building by 3.50 m. The reduction of the façade surface, and also of the

Fig. 4. The Van Nelle Factory interior shortly before completion in 1928. The octagonal mushroom-head columns allowed for the use of floorslabs without beams. The flush ceilings benefit daylight conditions. The columns feature metal rails on four sides for the fixing of production equipment (photo: J. Kamman, Historisch Archief de Wed. J. van Nelle, Stadsarchief Rotterdam)

Il. 4. Wnętrze fabryki Van Nelle na krótko przed ukończeniem w 1928 r. Ośmioboczne filary grzybkowe pozwoliły na zastosowanie płyt stropowych bez belek. Równa powierzchnia stropu. To korzystnie wpływało na oświetlenie wnętrz światłem dziennym. Kolumny wyposażone są z czterech stron w metalowe szyny do mocowania urządzeń produkcyjnych (fot. J. Kamman, Historisch Archief de Wed. J. van Nelle, Stadsarchief Rotterdam)

[5] Jan Gerko Wiebenga was a major concrete pioneer in the Netherlands. Together with L.C. van der Vlugt he designed the Technical Schools in Groningen with a reinforced concrete structural frame and flexible floorplans as early as 1922–1923. After a few years in the USA, he became involved in the design of both sanatorium "Zonnestraal" and the Van Nelle factories in 1926 [8].

operational cost for vertical transportation of products and workers were seen as major benefits[6]. Yet, Wiebenga was not easy on himself as, at the time, the calculation of the omnidirectional pattern of forces around the reinforced concrete column heads was in no way common practice[7].

As one of the most expert reinforced concrete engineers of the era, Wiebenga was so up-to-date about new developments in his field that he was often successful in challenging the building inspectorate and ruling standards. He was annoyed by the limitations that were imposed by such regulations: *One moves the buoys with the tide* […] *it is now more than time to break with the system to establish simple rules, that may appear understandable also to non-experts* […] *New regulations must be edited in such a way that only experts can understand them and (they) should be limited to the definition of standards that define the relationship between design, calculation, permissible stresses and material qualities* [11, pp. 188, 189].

As a civil engineer, on the other hand, Wiebenga was pragmatic and he repeatedly proposed heavier constructions if he expected those to be more economic in terms of construction time or cheaper materials[8]. Duiker on the other hand, departed from the theoretical concept of "spiritual economy", in which the use of materials was to be economized.

Calculation

The introduction of reinforced concrete for architectural purposes in the Netherlands was around 1900. In 1912 the first Reinforced Concrete Codes were published after a German example of 1903, followed by a new edition in 1918. Some of the assumptions about concrete technology deviate significantly from those on which present day regulations are based.

For instance, one was not aware of the effect of the alkalinity of cement and its role in protecting the reinforcement against corrosion. The devastating effects of curing-agents like calcium chlorides were unknown. The relationship between water-cement ratio and compression strength was known, but the connection with porosity was not recognised. Today this is a main source of failure as a result of carbonation due to high CO_2 levels caused by air pollution.

The reinforced concrete constructions that were designed with primary and secondary beams were calculated as beams on two supports[9]. The reinforcements to mushroom columns were placed orthogonally and, similarly to beam structures, were calculated accordingly. Although one acknowledged that monolithic concrete constructions are statically indefinite and the theory of elasticity applied, one was not yet fully aware of how to take full advantage of this knowledge. As a result, for security reasons, lower material stresses were accepted than would be used today. This, of course, contrasts with the principle of the economic use of materials that was embraced by the architects of the Modern Movement – one may say that the slender structural frame of sanatorium "Zonnestraal" is a true miracle.

Progressive collapse was not taken into account, while today we would rather take the collapse of the building as a whole as a reference[10]. Finally, expansion joints were not required, though sometimes still made[11].

Execution

When it comes to the execution of the works generally we see that the lack of experience and sophistication of equipment on site were not helpful to the quality of early architectural concrete [10, particularly: pp. 90, 97–109]. In particular mixing concrete by hand did not result in a homogeneous mortar so that the quality of such concrete often shows great variety. This was often worsened by the use of wheelbarrows for onsite transportation and the consequent load by load pouring of the slurry (Fig. 5).

Due to the slender dimensions it appeared sometimes difficult to fit the reinforcement into the form work, leaving the steel often too close to the surface resulting in a lack of cover of the reinforcement steel. It was not unusual to mix the mortars with additional water to fill the narrow form works. As a result, the concrete is often porous, with a great variety in compression strength and showing gravel pockets. The plaster on the concrete surfaces unintentionally provided some protection to the reinforcement due to it is alkaline character. At the same time it concealed the irregularities of the concrete surface. It was only after the World War II that the use of exposed reinforced concrete become more mainstream.

Inside or out

At the sanatorium, Duiker made use of the cantilevering roofs as canopies in order to allow the curing patients to sit outdoors but protected from the direct sunlight. The steel fronts of the façades have therefore been set back,

[6] Remarkably, Van der Vlugt used the mushroom floor system himself already in 1924 in a Rotterdam warehouse but for the Van Nelle factory the architects initially would not give up their proposal for a beam structure. The client eventually preferred Wiebenga's proposal partly because of these advantages for the company's business operations [9, p. 61].

[7] The mushroom floor system was patented by the American C. Turner in 1906. The first known European example is an experimental structure patented by R. Maillart in 1908, and his design for the Giesshübel department store in Zürich of 1910. The initial complex pattern of reinforcement nets was simplified around 1910 by the introduction of a single orthogonal reinforcement net, which eased calculations [9, p. 61]. At the Van Nelle Factory, the orthogonal reinforcement around the column heads was placed diagonally, as can be seen on photographs that were made during construction [10, pp. 107, 113].

[8] Such arguments are mentioned in footnote 17, as part of the discussion about the choice for a beam structure or flush floor slabs for the Van Nelle factory [9, pp. 59–61].

[9] As early as 1886 Hennebique argued that tensile forces in reinforced concrete should be absorbed entirely by the reinforcement steel, and that the reinforcement should therefore not be evenly distributed but mainly be placed where these forces occur, i.e., at the bottom (in the middle of the beams) and at the top (where the beams are supported).

[10] For example Vermaas [12] and Wattjes [13].

[11] At the sanatorium, dilatations are completely absent, but at the much longer structures of the Van Nelle factory, expansion joints have been provided.

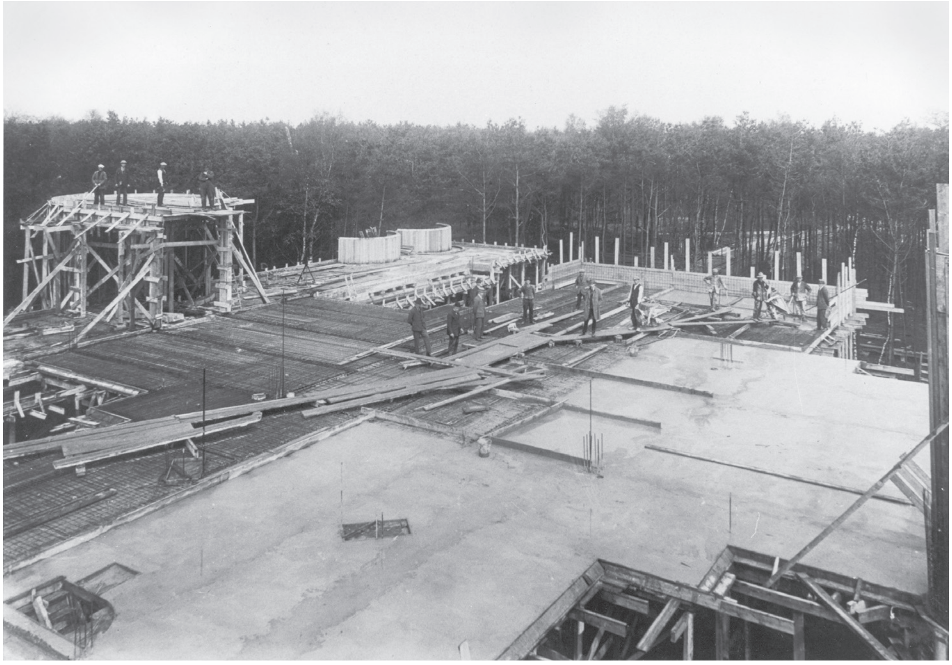

Fig. 5. "Zonnestraal" sanatorium, main building during construction around 1927. The concrete slurry was mixed by hand which resulted in inhomogeneity, which was worsened by the onsite transportation in small batches by wheel barrows (right) (photographer unknown, from Duiker's personal archive, coll. Jelles and Alberts, HNI Rotterdam)

Il. 5. Sanatorium „Zonnestraal", budynek główny w trakcie budowy około 1927. Zaprawa betonowa była mieszana ręcznie, co powodowało jej niejednorodność, którą pogarszał transport taczkami (po prawej) (fotograf nieznany, z osobistego archiwum Duikera, kol. Jelles i Alberts, HNI Rotterdam)

between the concrete columns. This way, the concrete columns were not only part of the load bearing structure, but became just as well part of the separation between inside and outside – a mix of functions that reminded the despised brickwork façades. Also the reinforced concrete beams and floor slabs continued from the inside to the exterior.

When concrete components are not adapted to these circumstances, for instance by thermal insulation, strong thermal stresses may occur as well as problems related to building physics, such as interstitial condensation that may cause corrosion of reinforcement, or surface condensation causing mould growth. At the same time we have to realise that in case of a sanatorium where the windows were always open – winter and summer – a high similarity occurs between indoor and outdoor temperatures, avoiding much of such problems in reality.

Why reinforced concrete?

Most sanatoriums in the Netherlands were constructed with traditional materials or – in case of temporary structures – in timber. A question therefore was why the architects and Wiebenga decided to use reinforced concrete. There were various advantages attached to the choice of reinforced concrete. Despite the limitations in calculation methods, the unprecedented plastic potentials of "the miracle material" allowed for greater architectural freedom in form and shape. An early examples is the Goetheanum in Dornach, Switzerland, designed by Rudolf Steiner in 1925–1928.

Also hygiene benefited from this "jointless material", which was an issue in case of buildings for healthcare or education, but just as well for the processing of foodstuffs. At the manufacturing plant for tobacco, coffee and tea of Van Nelle also the material's high fire resistance was essential to limit the fire insurance premium.

An apparent disadvantage of the material has always been that the building is actually constructed twice: first as a timber formwork, then poured concrete. The durability of the material is a positive property, although less so for buildings that are not intended to last for a very long time, like the sanatorium[12]. A particularity that is frequently escapes the attention is the initial unsuitability of reinforced concrete to easily attach other building components against it. To fix the steel window frames, hand rails and light fixtures at the sanatorium, numerous blocks of soft wood were embedded in the concrete, which are now among the most vulnerable spots, retaining humidity and posing serious threads to the durability of the concrete.

Instead, at the factory, where changes in production lines were expected to be particularly frequent, all columns feature metal rails at four sides, allowing the easy fixing and later repositioning of machinery and conveyor belts with track bolts (Fig. 4). To the same end, a grid of metal dowels was embedded in the floor slabs at regular intervals. With the introduction of the electric power tools like drill hammers – around 1923 in the US and five years later in Europe – this became much easier, but the Van Nelle buildings were largely completed by then[13].

Cladding and dressing

Due to the lack of precision in the formwork – that was relatively irrelevant as the material would be covered anyway – irregularities are frequently found in the surfaces of older concrete work. At the time, concrete surfaces often showed gravel pockets, since the compacting of the material was done by manual puddling rather than by the present mechanical compacting with an immersion vibrator.

[12] Sanatorium "Zonnestraal" had an intended life span of 30 to 50 years [7, pp. 20, 21].

[13] The electric power drill was patented in 1914 in the USA by Black & Decker, but it only came on the market around 1923. In Europe, the first power drills were manufactured by Bosch in Germany in 1928 [14].

Fig. 6. The St. Jobsveem warehouse (1914) in the Rotterdam docklands after conversion into a condominium with 109 apartments in 2007. Due to the ample loadbearing capacity of the huge reinforced concrete loading platforms these could be transformed into hanging gardens. (photo: © WDJArchitecten, 2012)

Il. 6. Magazyn St. Jobsveem (1914) w dokach Rotterdamu po przekształceniu w kondominium ze 109 mieszkaniami w 2007. Dzięki dużej nośności ogromnych żelbetowych platform ładunkowych można je było przekształcić w wiszące ogrody (fot. © WDJArchitecten, 2012)

Fig. 7. Former St. Jobsveem warehouse. The installment of a model apartment included trial repairs of the concrete decks that were to serve as terraces. The underside of the platform above still shows the damage to the plaster finish that was originally dressed to mimic natural stone (photo: © WDJArchitecten, 2007)

Il. 7. Dawny magazyn St. Jobsveem. Realizacja wzorcowego mieszkania obejmowała próbne naprawy betonowych podestów, które miały pełnić funkcję tarasów. Spód platformy powyżej nadal ukazuje uszkodzenia tynku, który pierwotnie imitował naturalny kamień (fot. © WDJArchitecten, 2007)

Before World War II concrete for architectural purposes was therefore mostly rendered and plastered, or clad. This had to do with the aesthetical ideas of the period, that did not allow the face of raw concrete to be exposed. Cladding is mostly found in case of a purely structural use of reinforced concrete, with the concrete parts completely concealed by masonry or stone. When conservation is in hand, one may question to what extent the retention of a concrete surface texture is essential to the heritage value of the object – apart from those rare cases where the concrete itself represents a historic value, being exemplary for certain innovations in concrete technology for instance.

The same may be true when concrete is covered with other materials like render and plaster. In eclectic buildings we often find plastered surfaces that are dressed so as to remind natural stone – which was rare and therefore expensive in the Netherlands. A case in point may be the Sint Jobsveem, a 1914 warehouse in the Rotterdam docklands, which was converted into apartments in 2007[14] (Figs. 6, 7).

[14] The project was carried out by WDJArchitecten in cooperation with Mei architecten en stedebouwers.

Fig. 8. Former St. Jobsveem warehouse.
The underside of the concrete platforms before restoration.
The plaster finish of the tapered bracket (bottom) combines a spatter dashed field with a combed trim. The surface textures of the ceilings show severe damage and colour variation. The reinforcement steel of the secondary beam appeared severely corroded
(photo: © M. van Hunen, 2006, WDJArchitecten Archives)

Il. 8. Dawny magazyn St. Jobsveem.
Spód podestów betonowych przed renowacją.
Dwie faktury tynku wspornika (dolnego) – nakrapiany i czesany. Powierzchnie sufitu wykazują poważne uszkodzenia i różnice kolorystyczne. Stal zbrojeniowa belki wydawała się poważnie skorodowana
(fot. © M. van Hunen, 2006, Archiwum WDJArchitecten)

Fig. 9. Former St. Jobsveem warehouse.
A similar area after concrete repair and partial restoration of the dressed plaster finishes,
including the combed finish of the secondary beams and around the smoothly finished ceiling.
The colour is touched up with a stain
(photo: © M. van Hunen, 2006, WDJArchitecten Archives)

Il. 9. Dawny magazyn St. Jobsveem.
Spód podestów betonowych po częściowej renowacji betonu i tynku z odtworzeniem oryginalnych faktur.
Kolor jest retuszowany farbą
(fot. © M. van Hunen, 2006, Archiwum WDJArchitecten)

Designed by J.J. Kanters (1869–1920), the building is constructed with cast iron columns and steel primary beams, while the secondary beams and floor slabs are constructed in timber. The volume is enclosed by a brickwork façade. Yet the end façade, the cantilevering loading platforms and the tapered beams that support the platforms are constructed of reinforced concrete with a plaster finish.

The plaster consists of natural, slightly buff-coloured cement with a very fine grain aggregate of black and white gravel, lending the surface a nice warm tone reminding of sandstone. The surface has further been combed and partially spatter dashed to mimic the charred and bush-hammered surface of natural stone (Fig. 7). Due to weathering, considerable differences in the articulation of the surface textures and even more in the tones of the plasterwork have resulted over time (Fig. 8).

The material qualities of these finishes were valued as significant. However, the warehouse is regarded as an example of a heritage building involving the use of (concealed) concrete components that are part of a larger scheme and do not represent a high degree of heritage value themselves.

Restoration

The plaster finishes of the concrete work at Sint Jobsveem (Saint Job's Warehouse) have been carefully repaired. First, both brick work and concrete have been cleaned with low-pressure steam. Detached parts of the plaster have been removed and underlying concrete failure has been mitigated in the classic way. Deteriorated concrete has been cut out, then depassivated with epoxy-based products, and repaired with appropriate mortars, in this case Sika Monotop 615. Parts where accelerated curing was expected were pre-treated with Sika Guard 552W Aquaprimer.

For the plaster finish special mortars have been composed by Remmers Building Chemicals, toned with various pigments into a palette for repair on the spot. Finding the right colour for the mortar was a minor challenge as compared to the choice of the proper aggregates and the proportion between them, which required several series of trials. On the basis of the results, a small palette of repair mortars has been selected, in slightly different shades, allowing the craftsmen on the scaffolding to select a tone from spot to spot, depending on the adjacent material. The 1914 combs have been remade in order to give the renewed patches the same surface texture (Fig. 9).

Another discussion arose about the spatter-dashed fields on the ceilings under the platforms. Because the damage occurred in relatively large areas and we had to economise, we initially proposed the application of shotcrete. However, we could not get a guarantee on the bonding of the shotcrete mortars to the original concrete substrate. Also, even if the total surfaces that showed damage were extensive, the actual spots that required repair were limited and the application of shotcrete on relatively small patches does not suit this type of technique, where the mortar is gunned against the substrate. Finally, it appeared to be hardly possible to mimic the original texture and we had to abandon shotcrete as an option. An alternative idea to create a completely new and flush finish of these sections did not meet great enthusiasm with the heritage authorities, since large quantities of original fabric that were still intact would have gone lost.

Eventually, we could convince the client that a more restorative approach would be a better choice. The major part of the plaster finishes has been retained and repaired with the same type of repair mortars as elsewhere. The differences in colour and brilliance between old and new have been touched up with a stain, Keim Restaura Lazur, that has been toned with a dash of pigment (Fig. 9).

Van Nelle Factory

The Van Nelle Factory as well as sanatorium "Zonnestraal" have been completed twelve years later. Both can be regarded as examples of heritage buildings where the use of concrete – as a material and in its particular components – represents an architecture-historical and heritage value in itself.

During the first phase of construction of the Van Nelle Factory, the exterior façades have been finished with a coarse plaster, a "Kratz Putz" based on natural white cement. However, the substrate of the façades is pumice-concrete block, and not reinforced concrete.

The actual concrete work in both buildings had been plastered as well, creating a smooth surface that was then whitewashed. This choice matched the ideas of the Modern Movement about smooth and jointless surfaces, and clear lines. In the interior of the factories a problem arose within a few years as the plaster at the ceilings started to detach from the concrete substrate and particles fell into the produce. Director Van der Leeuw ordered the plaster to be completely removed from the ceilings. The traces of chisels and hammers is still found throughout the building.

Between 1999–2004 the building was converted into a hub for the creative industry of Rotterdam. Replastering the concrete surfaces was prohibitive due to the cost. For reasons of hygiene it would have been unacceptable to merely clean the surfaces. We decided to finish the concrete surfaces with a matte paint in a chalk-white tone, that does not leave a surface film. The dents of the hammering still show as part of the building's history.

"Zonnestraal" main building

The damage of the slender concrete frame of the sanatorium's main building was massive. Still, some parts remained in a fair condition and we have considered to use electro-chemical re-alkalisation in areas where concrete failure was still latent. This was the case for instance beneath the overhanging floor slabs of the first floor that once covered open drive ways that were later closed-off. We had to drop the idea when the reinforcement bars appeared not to form a continuous electrical circuit inside the concrete because the steel bars were not sufficiently connected to each other. Another setback was that the electrolytical paste that was to be applied to the surface for the re-alkalisation process was feared to leave a residue and a guarantee for the proper bonding of new plasters and coats could not be provided. In any case, the cost for re-alkalisation would have remained a challenge too[15].

For the restoration contract we decided to have all concrete surfaces blasted as very little of the original plaster remained (Fig. 2). The concrete was then repaired in the classic way with epoxy-based repair products. The presence of a layer of plaster in the original state appeared to be an advantage as it could be replaced by shotcrete to obtain sufficient strength and as an additional alkaline cover on the reinforcement of the concrete itself. By applying a thin film of plaster of a composition similar to the original, the appearance and the dimensions of the concrete work are virtually identical to the original. In practice, the shotcrete application appeared to be technically required only locally.

The carbonation risk was particularly high for the overhangs of the first floor (Fig. 1). After the drive ways beneath them had been closed-off in the 1970s these concrete surfaces had been in a protected interior climate for decades, leaving all the pores in the concrete completely dry and open. Now that the driveways would be reopened, the open pores would make these surfaces very susceptible to CO_2 when exposed again to open air, and hence particularly prone to carbonation.

The underside of the floor slabs themselves was covered with thermal insulation and plastered. The insulation layer is virtually gas-tight, preventing future carbonation. The exposed beams in these areas have been preventively treated with shotcrete. To this end a PCC mortar has been chosen, which is purely cement-based, and not modified with synthetic admixtures, in order to avoid differences in thermal expansion with the old substrate.

For local in-depth repairs the classic approach was used, taking the same PCC mortar as a repair product. All external surfaces, regardless of the prior treatment, were finished with a mineral plaster. The planned surface treatment with Decadex, an anti-CO_2 coating to avoid future carbonation of the concrete, was rejected because of its rubber-like, synthetic appearance. Instead, all surfaces are treated with a Keim paint, which has a slight CO_2-repellent effect as well. This is a matte, mineral paint that does not leave a surface film, which was chosen in a chalk-white tone for the inside, and bright white for the exterior, closely matching the original appearance[16].

(Almost) horizontal parts have been treated with a special, very durable Montenovo Sockelputz with a smooth finish. Of course. such solutions require a considerable amount of maintenance in the future, so special arrangements had to be made with the client.

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15 At the first DOCOMOMO Technology Seminar on concrete conservation in 1997 electro-chemical concrete conservation seemed very promising, which has been the reason for trying it at the sanatorium. Today, electro-chemical concrete conservation is not used very often for architectural structures in the Netherlands.

16 Duiker used an extremely bright white tone for the exterior containing quite a strong blue hue, whereas the interior of the building had a much milder palette [15].

Sanatorium pavilion

Meanwhile a second phase of the restoration has been completed in 2013, responding to new challenges. At the Dresselhuys Pavilion, the connection of the tapered beams and the columns supporting them, appeared insufficiently resistant to sheer forces. In addition, we found compression strengths similar to those of wet sand in some of the columns. In fact, rather than the columns, the light separation walls inside the building were actually carrying the beams.

In order to master the static problems with the beams, we have tested the use of "Carbon Shear", a thin carbon-fibre fabric, that was attached to the sides of the beams after removal of the plaster. It worked well, although it appeared rather expensive. Again, the original layers of render and plaster were helpful, as it allowed to conceal the carbon fabric later within the replacement finish (Fig. 10).

However, this did not resolve the problem of the weak columns themselves. We have considered to insert steel columns at every intersection of the separation walls, 3.00 m centre to centre. This would have required additional foundations as well, which was complicated and expensive. Also, we would have had to cut sections out of the original walls in order to install the columns. We therefore chose a simpler solution, by assuming that each T-section of the separation walls could be considered as a stable column, as long as 1 m of each wall was to be retained. This allowed for some flexibility in any plan for a new use, and would save a lot of money as well as original substance.

Still, in addition, the worst columns had to be completely replaced, as were all the balconies and the roof slab, which showed persistent damage of pit corrosion as a result of chlorine salts – probably originally added as a curing agent – and had eventually collapsed (Fig. 11).

Future challenges

With the example of the sanatorium we have shown that, technically speaking, even concrete work in a very bad condition can be repaired and restored although it may be hard to retain its material authenticity. Whether we decide to do this or not, depends on the will to do it, the acceptance of a limited lifespan of such repairs and, hence, a lot of maintenance, as well as the availability of sufficient budget to make such a choice. As mentioned before, it is questionable whether material authenticity of concrete work that is principally rendered and plastered, is much of an issue here. This may not be the case for original plasters and finishes that may have to be sacrificed in order to repair the concrete beneath it.

One of the principle challenges of concrete conservation is rather to determine whether we are dealing with a conceptual application of concrete, for instance as a load bearing material as is the case at Van Nelle, where the material expression of the substrate was originally not relevant as it was to be covered, or a building where the conceptual meaning of the use of concrete was visually supported by leaving it exposed. In such cases, it is evident that much more attention must be given to the aesthetical qualities of colour, texture, aggregates, and brilliance of the repair materials to be applied, as well as the retention of remaining original material as far as possible.

As we are increasingly dealing with the youngest generation of modern heritage we are running into these issues more and more. In these buildings we often see an extensive use of architectural exposed concrete, featuring

Fig. 10. Sample tests of strengthening the bearings of the longitudinal beams with carbon fabric, after removal of the render and plaster finishes. The method proved effective but could not resolve the lack of load-bearing capacity of the columns themselves (photo: © WDJArchitecten, 2006)

Il. 10. Przykładowe wzmocnienia belek tkaniną węglową, po usunięciu tynków. Metoda okazała się skuteczna, ale nie rozwiązała problemu braku nośności samych słupów (fot. © WDJArchitecten, 2006)

Fig. 11. “Zonnestraal”, Dresselhuys Pavilion (1931) after the collapse of the chloride-infused reinforced concrete roof slab. The exterior restoration of this structure was completed in 2013 (photo: © R. Wielinga, 2001, WDJArchitecten Archives)

Il. 11. „Zonnestraal”, Pawilon Dresselhuys (1931) po zawaleniu się żelbetowej płyty dachowej poddanej procesowi korozji chlorkowej. Renowację budynku od zewnątrz zakończono w 2013 r. (fot. © R. Wielinga, 2001, Archiwum WDJArchitecten)

particularities regarding cement tone, colour and grain of the aggregates and the dressing of the surface: washed, etched, chiselled, bush-hammered, and so on.

Many of these techniques and colour effects seem to have been borrowed from the architecture of Auguste Perret, who tried to have concrete look like a natural material. In the Netherlands the Groothandelsgebouw, or *Wholesale Centre*, in Rotterdam (W. van Tijen en H. Maaskant, 1947–1953) [16] and the “Patrimonium” Technical School in Amsterdam (J.B. Ingwersen, 1956)[17], are examples of buildings where the very expression of concrete as a material in itself is highly significant. Within the programme of the DOCOMOMO International Specialist Committee on Technology we have started to address some of these issues as early as 1998. But it is clear that still more challenges lie ahead of us.

[17] The extensive concrete conservation and adaptive re-use project for the “Patrimonium” Technical School by WDJArchitecten in 2011–2013 is extensively covered in [17].

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Abstract

Concrete heritage in the Netherlands. Valuation and conservation of concrete and reinforced concrete structures

The article deals with reinforced concrete structures in the Netherlands in the interwar period. The aim of the article was to present the changes in the use of reinforced concrete and the introduction of various light concrete products for the construction of light façades structures such as curtain walls. Reinforced concrete, which appeared in Dutch architecture around 1900, causes conservation problems today, which are discussed in the article on the example of the Sint Jobsveem (Jan J. Kanters), the Zonnestraal Sanatorium in Hilversum (Jan Duiker, Bernard Bijvoet and Jan Gerko Wiebenga) and the Van Nelle Factory in Rotterdam (Johannes Brikman, Leendert van der Vlugt and Jan Gerko Wiebenga), involving the author's own experiences related to renovation works on these buildings. The most serious problem today is the porosity of concrete and the process of its carbonation due to the high level of CO_2 caused by air pollution. In the past, the influence of cement alkalinity and its role in protecting reinforcement against corrosion was not well understood. The damaging effects of curing agents such as calcium chlorides were unknown. The focus was mainly on the relationship between the water-cement ratio and the compressive strength. Today, concrete repair methods are usually selected individually, depending on whether we are dealing with exposed or plastered concrete work, and on the size and scale of the damage. The most effective way to protect concrete against carbonation is to use a special waterproof protective coating – offering the highest possible diffusion resistance to carbon, sulfur and chloride ions and the lowest possible diffusion resistance to water vapor. Such a coating protects concrete against the penetration of CO_2 and acid ions, and at the same time allows free evaporation of moisture from the concrete to the environment. The described experiences show that even heavily damaged concrete can be restored. It is a matter of cost and the challenge of keeping its original appearance.

Key words: concrete, reinforced concrete, the Netherlands, conservation, interwar period

Streszczenie

Betonowe dziedzictwo Holandii. Rodzaje konstrukcji betonowych i żelbetowych oraz proces ich konserwacji

Artykuł dotyczy konstrukcji żelbetowych stosowanych w Holandii w okresie międzywojennym. Jego celem było przedstawienie zmian w użyciu żelbetu oraz różnych wyrobów z betonu lekkiego wykorzystywanych do budowy ścian osłonowych. Żelbet, który pojawił się w architekturze holenderskiej około 1900 r., powoduje dziś problemy konserwatorskie, które omówiono w artykule w oparciu o własne doświadczenia autora związane z renowacją następujących budynków: Sint Jobsveem (Jan J. Kanters), Sanatorium Zonnestraal w Hilversum (Jan Duiker, Bernard Bijvoet i Jan Gerko Wiebenga) oraz Fabryki Van Nelle w Rotterdamie (Johannes Brikman, Leendert van der Vlugt i Jan Gerko Wiebenga). Najpoważniejszym problemem jest dziś porowatość betonu i proces jego karbonatyzacji ze względu na wysoki poziom CO_2 spowodowany zanieczyszczeniem powietrza. W przeszłości wpływ zasadowości cementu na ochronę zbrojenia przed korozją nie był dobrze rozumiany. Szkodliwe działanie środków utwardzających, takich jak chlorki wapnia, nie było znane. Skupiono się głównie na relacji między stosunkiem wodno-cementowym a wytrzymałością na ściskanie. Dziś metody naprawy betonu dobierane są zazwyczaj indywidualnie, w zależności od tego, czy mamy do czynienia z betonem odsłoniętym czy pokrytym tynkiem, a także od wielkości i skali uszkodzeń. Najskuteczniejszym sposobem ochrony betonu przed karbonatyzacją jest zastosowanie specjalnej wodoodpornej powłoki ochronnej – umożliwiającej najwyższą możliwą odporność na wnikanie jonów węgla, siarki i chlorków oraz przepuszczającej parę wodną na zewnątrz. Taka powłoka zabezpiecza beton przed wnikaniem jonów CO_2 i kwasów, a jednocześnie umożliwia swobodne odparowanie wilgoci z betonu do otoczenia. Opisane doświadczenia pokazują, że nawet bardzo zniszczony beton można odtworzyć. To kwestia kosztów i umiejętności zachowania oryginalnego wyglądu.

Słowa kluczowe: beton, żelbet, Holandia, konserwacja, okres międzywojenny