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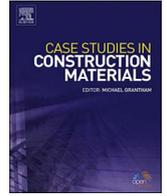
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## Case study

# Colour alterations of historic concrete surfaces during the Dutch Interwar Period



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## ABSTRACT

In the 1920s, the improved concrete technology and growing acceptance of concrete as an aesthetical material resulted in an increased application of coloured concrete. This includes the use of organic and inorganic pigments, ground natural stone, consciously chosen coarse aggregates, and also a new technique: metallisation. This rare, yet internationally applied, technique was patented in the Netherlands in 1917 and allowed a colour change of the hardened concrete by applying metal salts on its surface.

In conservation practice, there are misconceptions with respect to the period of application of exposed concrete and, in particular, of coloured concrete. The application of exposed concrete during the Interwar period (1918–1930s) is often not considered during inspections; this impacts the quality of value assessments, diagnosis of damage causes and choice of conservation strategies.

Besides limited knowledge of the varieties of coloured concrete, the fact that many historic concrete buildings have since been plastered or painted impedes its correct identification. This poses a challenge, as the deviating properties of historic concrete, both due to production methods and use of unproved constituents, can affect the durability of concrete. This paper focuses on the characteristics which can be encountered during visual inspections, an early and influential phase within the conservation process.

## 1. Introduction

In conservation practice, misconceptions exist with respect to the period of application of exposed and in particular of coloured concrete; its use prior to the 1940s/1950s is often not considered during inspections [1]. Instead, these types of concrete are mistaken for natural stone or a more recently applied plaster is considered to be the original surface finish. This impacts the quality of value assessments, diagnosis of damage causes and choice of conservation strategies.

The appearance of monuments, including their surface, influences strongly their heritage values and social acceptance. Concrete heritage still faces prejudices on whether it is entitled to be preserved [2]. Recognition of the spectrum of historic concrete surfaces would positively influence the appreciation of historic concrete buildings. In addition, a correct characterisation of the historic surface is relevant to evaluate the concrete durability. In practice, this would require a sound investigation of how the original surface was achieved, the influence of time on the surface (e.g., erosion, discolouration) and the impact of both damage and repair on the surface (Fig. 1).

The original surface finish of historic concrete is not always described in historical documents. The historic concrete building is often the only source of information. Yet surveys mainly focus on safety and structural aspects [3]; little experience and references

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Fig. 1. Example of an aesthetically incompatible repair of historic concrete. Left: Due to a monochrome, grey layer of paint and local smooth repair, the original colour and textural scheme of brickwork and concrete is impeded. Right: Close up of the surface; where the paint has detached, the original polychrome surface influenced by the gravel and cement is visible (Olympic stadium Amsterdam, architect J. Wils, 1928).

exist with regard to historic concrete surfaces and which aspects of the surface should be investigated – ranging from preliminary visual inspections to in-depth material research. Therefore, it is necessary to create more awareness of surface finishes which can be encountered in historic concrete structures, how they were achieved and the influence of the construction period.

In this paper, a focus will be made on methods applied to alter the colour of concrete during the Dutch Interwar Period (1918–1930s). During this period a wide exploration of finishes took place, overlapping with the advances in concrete technology and availability of new constituents. It is shown that an understanding of the historic context is important as constituents used and periods of application varied nationally. Further, it can help to identify whether a surface finish was consciously chosen or if it represents a then common technical solution, and thereby give information for determining possible heritage values.

Based on a review of historic literature and site visits, an overview is given of techniques and materials used to alter the colour of concrete; some were used only for a short period of time and are hence rare. The role of the technological development and scientific insight is evaluated. This paper focuses on visual inspections, which currently are the basis for a successful survey and conservation.

## 2. The role of visual inspections to identify coloured concrete

A correct identification of the original surface finish of historic concrete buildings is of importance for several reasons. First, the historic surface can be of cultural value and its preservation part of the restoration aim. Second, techniques and constituents used to alter the colour of concrete influence its properties and durability. Some constituents can have deleterious side effects and therefore should be considered during diagnosis.

Visual inspections are part of a condition survey, analysing the context and building, and identifying elements made in concrete, signs of damage and interventions. This requires knowledge of the techniques and materials available when the structure was built. Other relevant factors during inspection are the building typology (e.g., infrastructure, military, industrial, fine architecture), the type of construction (precast or in-situ) and the intention to use concrete (e.g., substitute for natural stone, load bearing material), as these influenced the choice of a surface finish.

However, the original surface cannot always be identified directly. It may have been painted, plastered or otherwise been altered during time. Textural details might have been lost due to erosion, and as a side effect changing the colour of the concrete as more aggregates are exposed. Soiling, efflorescence, washing out and fading of pigments can alter the colour of a concrete. In such cases, investigating the surface in more protected zones, for example under windowsills, might give a better indication of the original surface texture or colour. The present colour and texture of historic concrete should be documented during these inspections; even if only for the sole purpose of documentation in case a safeguarding of the surface is not possible.

## 3. The development of concrete surface finishes

The quality of exposed concrete is strongly influenced by the state-of-the-art of concrete technology and of workmanship. Therefore, all steps in the construction process – from mix design to curing – have to be carried out well. Considering the history of concrete, sufficient time needed to elapse for construction methods to improve. This did not only depend on technological development, but on the entire construction process as blemishes (e.g., voids, segregation, and colour variations) are visible on exposed concrete surfaces.

Too often, the complexity of concrete was underestimated or calculations not carried out. A presumed easy construction of “*simply mixing*” the constituents tempted to carelessness during construction works [4]. The properties of concrete could vary considerably, as the concrete mix was influenced by the type of construction, changing raw materials, and by the preference of the site manager [5]. Segregation due to on-site mixing and transport by wheelbarrows was not uncommon. The relevance of grading curves and of the



Fig. 2. Former head office of the artificial stone company Rotterdamsche Cementsteenfabriek Van Waning & Co (1898). Left: Overview of the main façade with artificial stone elements painted white. Right: Detail of the corner showing the original, tooled concrete surface made with greenish aggregate.

water content was only disseminated on a wider scale in the 1920s; equipment for internal vibration and hence good compaction were introduced a decade later. Many of the tools and skills necessary for a good exposed in-situ concrete were only widely available after the Second World War [6,7], explaining the increased likeliness of, compared to present day standards, fluctuations of quality of historic concrete surfaces.

In the late 19th century, an aesthetical treatment of concrete surfaces was less relevant. (Reinforced) concrete was mainly used for structural elements. Furthermore, it was commonly cladded with bricks or natural stone. Common blemishes caused during construction devaluated the appearance of concrete and impeded the application of exposed concrete. Thus, in order for concrete to be applied as a decorative material, confidence in its potentials and reliability had to be gained first, and concrete had to be accepted as an aesthetical material.

Nevertheless, an exploration of the architectural and aesthetical possibilities of concrete took place. At the beginning of the 20th century, a growing interest to find an appropriate concrete architecture can be observed internationally [8–10]. The grey colour of concrete was an aesthetical problem, it was considered as dull and lifeless [11] and concrete lacked character [12]. To alter the grey colour and remove the imprints of the timber formwork, initially most techniques removed the cement film. This was sometimes combined with the use of coloured cement and specially chosen aggregates. A variety of techniques applied in this period are tooling, brushing, polishing, use of pigments, and metallisation [13]. As the making of coloured concrete was difficult on-site, it was regularly precast.

Experience with precast coloured concrete had been previously gained with natural stone imitations, a variation of precast concrete. By using a variety of coloured constituents and by tooling the surface, the concrete could resemble a variety of natural stone. In Germany, for example, an entire artificial stone industry existed, with several recipes for imitating different natural stones like sandstone, grey wacke, porphyry, tuff, limestone and granite [14]. Dutch examples are the products of the company *Rotterdamsche Cementsteenfabriek Van Waning & Co* (Fig. 2) [15].

In general, the use of reinforced concrete increased in the 1920s. The high prices of bricks and the lack of housing stimulated the experimental use of concrete [16]. By the 1930s, reinforced concrete had become a common construction material. Architectural styles as the Modern Movement took advantage of the structural possibilities of reinforced concrete, and reference is often made to the leading architectural role of the Netherlands [17,18]. These new architectural styles discussed less the aesthetical treatment of the concrete surface; many facades were rendered. Less known is the exploration of different techniques and materials to alter the appearance of concrete in this period, including the increased use of precast decorative elements [19].

#### 4. Historical surface treatments to alter the colour of concrete

In the following sections, an overview will be given of different techniques which were applied to alter the colour of concrete. Painting and metallisation are discussed as methods which were applied on the hardened concrete, and the use of pigments and coloured aggregates as options to modify the mix design.

##### 4.1. Painting

Several historic concrete buildings have been painted or coated during time. Motivations were a change in taste, or the intention to disguise mismatching repairs under a, usually, monochrome layer of paint. In order to evaluate whether a historic concrete was originally painted or not, it has to be understood that a reliable painting of concrete was technically possible from the 1940s onwards, with the introduction of chlorinated rubber paint and plastic paints.

A traditional, yet less durable, method was to lime wash the concrete surface, with the option to add pigments. A variation was to use Portland cement instead of lime. In the 1920s, it was stated that painting of concrete was not possible at all [20]. The underlying

problem was that traditional oil-based paints, such as linseed oil paints, could not be used without any pre-treatment of the surface. The high alkali content of fresh concrete, together with hydrated lime and in presence of humidity, reacted with the fats in the paint, causing saponification. It was advised to wait at least six months before applying an oil-based paint as the alkalinity of the concrete would decrease with time [21].

An option to reduce the alkalinity was to treat the surface with *Kesslersche fluates*, a fluosilicate. It was already used for consolidating stone at the end of the 19th century [22]. For concrete *Fluoziment* was available, which allowed a direct painting of fresh concrete [23]. However these products were expensive yet it was advertised that they additionally increased concrete's resistance against chemical attack [21].

#### 4.2. Metallised concrete

A reaction to the lack of suitable paints for concrete was the invention of metallisation of concrete. In 1915, the Dutch brothers L.A. Sanders and A.J. Sanders applied for a patent for the application of a layer of metal or metal containing coating for artificial stone [24]. After the Dutch patent was issued in 1917, the technique was patented in the United States of America in 1921, where it was classified as a coating process [25–28]. Its use in the Netherlands was limited from the late 1910s to the 1930s [29]. From the 1940s onwards, interest in metallised concrete decreased due to the availability of paints for concrete [30].

The underlying principle of metallisation was to apply a solution of metal salts (sulphates, acetates, chromates, nitrates or chlorides) with a brush on the hardened concrete or cement render [26]. A reaction of the salts with the cement caused a colour change. Unlike other surface finishes, metallisation interacted thus with the Portland cement.

A range of 35 colours could be obtained with metallisation [10]. The possible colours were copper green – using copper salts –, cobalt blue and brown – using iron salts –, yellow, grey, whitish, and dark shades – using tin salts; the texture of the surfaces could be rough, smooth, and have mat-shiny polish [31,32]. For polychromatic finishes, the so-called paper method was advised: a monochrome layer was applied first, which was then covered by a soaked paper; the folds in the paper layer affected the speed of ingress of the second layer of metal salts, creating a random, flame like pattern [20]. The application was quick and cheap, and after a few days, the surface could be waxed or polished [10,33]. Waxing of the surface made the colours warmer and gave a deeper shade; such treated surfaces required no maintenance besides occasionally buffing up with a woollen cloth [20]. Metallisation was applied for walls, which were advised to be plastered beforehand, precast elements, decorative tiles and asbestos-cement panels (brand name Eternit) [20].

Metallisation did not only cause a colour change but was also supposed to waterproof and consolidate the surface and increase its strength [10,26,30,34]. It was said that the treatment was long lasting, even when exposed to the elements and that the colours would not fade. A repair of the surface was possible by treating the area with the same technique again. In practice, no conclusions can be drawn yet whether this proved to be correct as there are not many objects with a metallised surface remaining.

Some buildings have been mentioned in literature where metallisation was applied. A garden house for a fair in the Dutch city of Utrecht in 1917 is said to have been the first metallised concrete building [10,35]; unfortunately, it does not exist anymore. Two water towers designed by Sangster had metallised concrete elements: the water tower in Fijnaart, which was destroyed during the Second World War, had horizontal, black metallised concrete bands; in Zutphen the cupola of the water tower was metallised in a yellow-brown shade and other elements in brown and black [36]. The latter water tower underwent some repair cycles, including a replacement of the concrete cover. Another case of metallised concrete was lost due to a poor quality of the concrete: the reliefs of the *Belgenmonument* in Amersfoort from 1917 by H. Krop were made in metallised concrete but replaced with a French limestone in 1957 [37]. Metallisation was not limited to the Netherlands, an example was the façade of the former Palladium cinema in Birmingham from 1921 [20].

A rare collection of metallised concrete can be found in Amsterdam; the decorative façade elements of a former factory building dating from 1921 are made of precast metallised concrete (Fig. 3). On the bases, the number and year of the patent for metallisation is still visible. It cannot be stated whether the present colours are similar to the original, as the effects of ageing on metallised concrete are not known. Local colour variations influenced by the geometry of the elements indicate that the colour changed during time. For example, the yellow-brown bases and capitals are darker in more protected zones. The green copper colour of the signboard for the entrance to the offices however is still rather homogenous. The green might have been made with a copper salt and the brown colours with an iron salt. This indicates that not all shades of metallised concrete possess the same durability. The concrete itself, however, shows damage which affects the surface. Besides spalling and visible corroded reinforcement, the surface is locally eroded. In these areas, no traces of metallisation can be seen.

## 5. Constituents to colour concrete

Coloured constituents, such as pigments or aggregates influence the colour of the concrete. They are already added to the concrete during the mixing process. Their use was often combined with techniques which would expose the aggregate, such as tooling or sand blasting [1]. In the following sections, a historic overview of pigments and aggregates to alter the colour of concrete will be given.

### 5.1. Pigments used for coloured concrete

The natural colour of Portland cement is grey due to its iron oxide and manganese oxide content. When trying to change the colour of concrete, the grey colour of the cement causes technical problems as lighter colours, such as yellow, are turned into a dirty

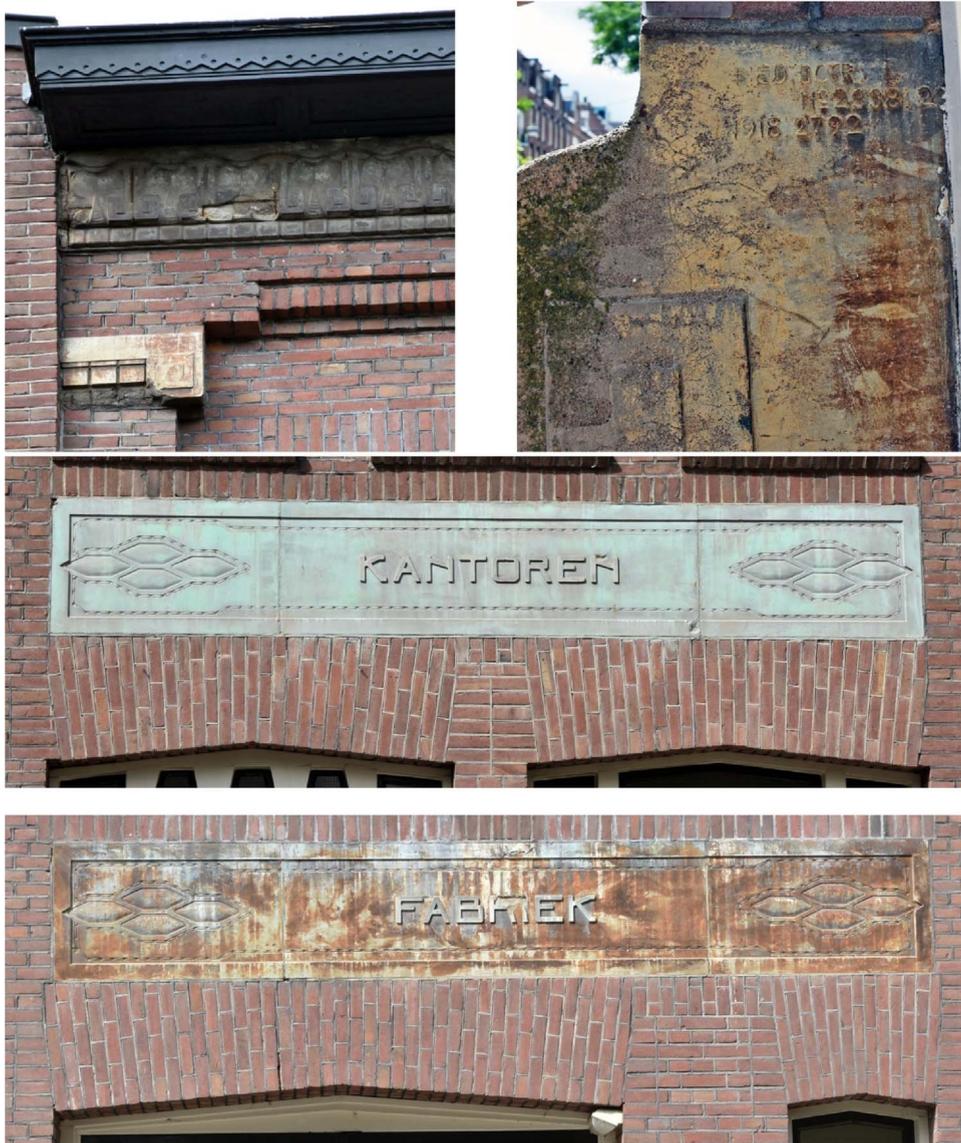


Fig. 3. Overview of precast metallised concrete elements in a former factory (architect C. Tenenti, Amsterdam, 1921). Top left: Cornice made with dark coloured concrete and capital with a sand stone coloured metallised concrete with local darker patches. Top right: detail of a yellow-brown coloured base, with visible inscription of the year and patent number. Middle: Green copper coloured precast metallised concrete sign above entrance for offices. Bottom: Multicolour (green, rust coloured) sign above the entrance to the factory.

colour shade [38]. Therefore, ground granulated blast furnace slag cement is commonly used now when producing coloured concrete, as it becomes lighter in colour after oxidation.

Historically, Portland cement was preferred for concrete. Cements containing slags, such as ground granulated blast furnace slag cement, were considered of inferior quality and only commonly accepted in the 1910s–1920s [1]. Due to the use of Portland cement, the colour range of coloured concrete was initially limited. In the 1890s, possible colours were red, blue, and black [5], whilst it was considered as difficult or impossible to colour concrete white due to the grey colour of the cement [39]. White Portland cement was not available until the beginning of the 20th century. In historic documents, white cement therefore did not always refer to a white Portland cement, but could refer to white cement based on magnesia cement.

The classification of pigments used during the late 19th and first half of the 20th century consisted of the following three groups: natural pigments, with the subgroups mineral pigments and sometimes ground natural stone, synthetic inorganic pigments, and synthetic and natural organic pigments. The variations in terminology pose a challenge when reviewing historic documents. Traditional pigment names can be encountered in the late 19th and early 20th century, replaced by chemical terminology in the middle of the 20th century. An explanation is that this period overlapped with the transition from traditional, natural pigments, to synthetically produced pigments and a naming based on general chemical terms. For example *caput mortuum* [5] which is a synonym

for Venetian red [10,40], was later called red iron oxide [41].

Concerning the correctness of terminology and chemical identification of pigments discussed in historic concrete textbooks, inaccuracy and inconsistencies can be noticed. This might be explained by the engineering background of most authors and the influence of common practice and terminology. A detailed review of the chemistry of pigments used for historic concrete is outside of the scope of this paper, an overview of pigments referred to in historic documents is given in [1].

Different pigments were preferred during time, mainly based on insight into their durability. Some pigments used for historic concrete are not common anymore as experience had shown that they were either not lightproof, had limited resistance towards the alkalis present in the concrete, or that they were harmful to the concrete. Other aspects not reflected in the changing terminology are changes in production, quality (e.g., purity, particle size), and chemical composition. Increasing insight into health hazards at the beginning of the 20th century, led to the prohibition of pigments containing lead, with an exception of yellow chromate of lead [42]. Some durability issues related to pigments are therefore more relevant for historic concrete than for present day concrete.

For example, ultramarine blue was known to be often mixed with gypsum. A contamination with gypsum of the colours red and yellow was possible, as they are made from waste products of the production of sulphuric acid and alum [43]. High gypsum content can cause a degradation of the concrete within a few years (e.g., formation of ettringite), and should be considered if coloured concrete shows damage symptoms related to an internal sulphate attack.

#### 5.1.1. Natural pigments

In the 19th century, mainly mineral pigments, which were understood as finely ground natural stones (e.g., malachite, azurite, or lapis lazuli), were used to colour concrete. However, these were very expensive. A more affordable alternative was ground natural stone such as sandstone, limestone, marble, basalt, porphyry, granite, quartz, diabase and glimmer (mica) [14,39,41,44,45]. Whereas such fine aggregates would be considered as filler nowadays, they were then seen as a pigment. Moreover, they were considered to be the only pigment suitable for achieving a good coloured concrete as they are cement proof (i.e., resistant to alkalis), lightproof and weatherproof, efficient, of intensive colour, easy to mix, and neither affect the strength of the concrete nor the time of setting [14]. Ground natural stone could replace the sand fraction.

A common field of application was for the imitation of natural stone, often without using coarse aggregates. Especially Probst [14] gives detailed mixtures for natural stone imitations using ground natural stone. Its use, together with the use of natural pigments in general, decreased during time, and did not play any major role more in the middle of the 20th century [41].

#### 5.1.2. Inorganic pigments

Inorganic pigments were already early on considered not to be durable in the alkaline environment of concrete, including traditional inorganic blue pigments such as Berlin, Milori, and Prussian blue, cadmium red, chromate yellow, lead and zinc white, chromate and cobalt green [6,14]. This changed during the first half of the 20th century with the increasing research into the chemistry of pigments and their synthetic production, resulting in a wider scope of colours and pigments [46].

Some synthetic inorganic pigments were made from waste products from the growing chemical industry [41]. Inorganic pigments could have been adulterated with aniline or with harmful inorganic components such as clay, gypsum, barium sulphate and chalk, and tests for the purity of pigments were recommended [14,39,43]. Synthetic inorganic pigments were preferred over mineral pigments as they had a better hue [47]. The main types of synthetic inorganic pigments used to colour historic concrete were iron oxides, titanium dioxides, cobalt oxides, and chromium oxides [6,41].

#### 5.1.3. Organic pigments

Cheaper synthetic alternatives to natural organic pigments existed already in the 19th century [40], such as aniline and tar-based pigments. Most, however, were not suitable for concrete as they were neither lightproof nor stable in its alkaline environment, could decrease its strength, lead to an inhomogeneous colour and were strongly affected by weathering [14,45,47,48]. Although the disadvantages of organic pigments were known, they were sometimes added to produce cheaper and (temporarily) more intense colours. An exception is carbon black, which fulfilled the requirements for a good pigment, although this was sometimes doubted [49].

#### 5.1.4. Pigment content

As a high pigment content did not increase the hue but had a negative effect on the concrete a maximum pigment content was discussed [41]. The recommendations for the maximum pigment content varied during time and depended on the pigment type. A commonly recommended maximum content for (oxide) pigments was 10% of the cement weight [10]. For carbon black, the advices for maximum percentage varied from 1% to 3% of the cement weight [6,50].

### 5.2. Coloured aggregates

Coarse aggregates strongly influence the colour of concrete once the cement film is removed. Their colour, texture, shape, grading and distribution determine the appearance of the concrete. A wide range of natural aggregates to modify the colour of concrete were advised over time, including (crushed) gravel, basalt, porphyry, quartzite, quartz, granite, limestone, marble, flint stone, diabase, and ore [10,19,51]. Several artificial materials were used as well: broken ceramic materials (e.g., stone ware, tiles, bricks), broken glass, metallurgical slags, and broken mirror glass [19].

Similar restrictions applied as for normal aggregates: availability, costs, size, and grading. The emphasis on the aesthetical properties however could justify deviations. For example, at the turn of the 20th century, expensive crushed rock was used for



Fig. 4. One of the first Dutch buildings with exposed concrete, yet currently painted (architect A. Moen, 1915). Left: Overview of the rear façade. Right: Detail of a pilaster with spalling, cracking and corrosion, showing the original concrete made with crushed porphyry and with a tooled surface under a layer of paint.

concrete structures with higher demands towards strength. Yet increasing insight into compaction and grading, showed that concrete of equal quality could be achieved with cheaper gravel [1]. As crushed rock was more expensive than gravel, its use for exposed concrete can indicate a conscious aesthetical choice. The former fashion store Gerzon (Fig. 4, 1915) in Amsterdam by A. Moen is such an example where porphyry was used in combination with a tooling of the surface. A different example is the former radio station Kootwijk (1921); try-outs showed that the difference between concrete made with gravel or with crushed stone was not significant when bush-hammered, favouring thus cheaper gravel [52]. However, the building has been covered with shotcrete, and the original surface is not visible anymore.

In the 1930s, an increase use of coloured, precast concrete made with crushed natural stone can be observed. An architectural ensemble – ranging from window frames, sculptures and entire façades – of such precast coloured concrete can be found the Rotterdam Zoo Blijdorp designed by S. van Ravesteyn between 1938 and 1940 (Fig. 5). The elements were produced by the then recently founded Dutch company Schokbeton N.V., which used a patented compaction method.

Some aggregates used for coloured concrete are now considered to be of poorer quality and known to cause deterioration. Porphyry can cause ASR; recycled crushed bricks can be contaminated with gypsum from a possible plaster and, depending on the gypsum content, cause a delayed formation of ettringite. Additionally, some aggregates, although showing no signs of deterioration, might not meet present day standards [53].

### 5.3. Facing concrete

As coloured constituents were more expensive than normal constituents, economic solutions had to be found. A practical solution to reduce costs was to limit the use of coloured concrete to the outer 3–5 cm of a concrete element. Contrary to decorative plaster, which was applied on the concrete afterwards, facing concrete was poured together with the backing concrete. The assumed technical advantage was that both concretes would behave as one material, and not detach as it was known from plasters on concrete. The technique could be applied for reinforced and for plain concrete. The surface of the facing layer could be treated as normal concrete, and was often tooled.

Facing concrete played an important role at the beginning of the 20th century for coloured concrete, and natural stone imitations. It was commonly applied in Germany and the United States of America [9,44,54]. In the Netherlands, the use of facing concrete increased together with the growing use of natural stone imitations [51].

Facing concrete was produced both in-situ and precast. When used in-situ, the coloured concrete was poured simultaneously with the structural concrete. A mixing of the two concretes was prevented by placing a metal shutter between them while pouring. The shutter was slowly pulled upwards during compaction to achieve a good cohesion between the two layers. It required several lifts to achieve a good compaction and to avoid a later mixing of the two concrete species, causing several construction joints. Precast elements could be rotated during production so that first the facing concrete could be poured, compacted and on top the backing concrete applied.

For production, a rich and plastic concrete was advised [9] and even a high cement content of 400 kg/m<sup>3</sup> recommended [21]. Yet, concerns about the durability of such composite constructions were expressed; the two layers would have a different shrinkage,



Fig. 5. Precast concrete elements (window frame and sill, plinth, columns etc.) made by Schokbeton N.V., using different ground aggregates to alter the colour of the concrete (Zoo Blijdorp, architect S. van Ravesteyn, 1939). Left: overview façade. Right: beige-sandstone coloured window frame and a more pink-purple coloured windowsill and column. Partially spalling and cracking has occurred, exposing the reinforcement, and discolouration due to soiling.

causing a detachment of the facing concrete. This was intensified when the surface was tooled as this caused additional impact on the surface. Therefore, a similar shrinkage of the two concretes should be confirmed by tests, to prevent damage. It was considered possible to achieve good results, but it required a careful execution [55,56].

When inspecting historic concrete made with a facing layer, one has to consider the details of design and production. A rather thick, unreinforced facing layer can be exposed to (thermal) stresses and crack. The concrete cover of a reinforced facing concrete can be too little, making the concrete more vulnerable to corrosion. The construction method can be the source of deterioration as well; the sliding shutter could have complicated compaction, and therefore creating voids. The several construction joints can be weak points. During inspections, permanent formwork such as concrete façade panels can be mistaken for facing concrete, requiring an eye for the details of the interface between the two concretes.

## 6. Decorative concrete

Decorative concrete (in Dutch *sierbeton*) is not defined by a special production method, surface finish or material use. It is a concept of the aesthetical perfection of concrete. It was seen as an ennoblement of the prosaic concrete with a surprising variety of “poetic” possibilities [57]. With decorative concrete, the perception of concrete was redefined. It was neither a structural engineering material nor a substitute for natural stone, but a class of its own [58]. However, its proximity to natural stone imitations in terms of material choice and tooling of the surface was criticised, as it was difficult to distinguish between natural stone and decorative concrete [58].

As aesthetics were emphasised and not the structural benefits achievable with reinforced concrete, decorative concrete is characterised by a conscious choice and combination of aggregates, pigments, cement and surface finishes. It was precast in small elements in order to meet the high aesthetical demands. For economic reasons, the technique of facing concrete was commonly applied for elements thicker than 4 cm. The elements were reinforced because of the stresses caused during the finishing of the surface, transport and assembling. The elements were compacted with tamping irons, vibrating tables or in case of products by the Dutch company Schokbeton N.V. with a shocking table. Thereby, a dryer concrete mix could be used. Schokbeton N.V., for example, produced elements with a water/cement ratio (w/c ratio) of only 0.3–0.35 [51], which was then considerably lower than for in-situ concrete.

The production of decorative concrete started in the 1930s. Many producers, for example the Dutch company De Meteor, originated in the making of precast concrete elements such as concrete pavers [57,59]. Decorative concrete was sold under brand names, which distinguished themselves by the aggregates used and the surface finish. For example, the Dutch brand Artlux used crushed Petrosilex, a composite material made from different metallurgical slags; elements were available in several colours, and advertised for their durability. The brands Artistone, Ocraat and Ocraatine used crushed granite [19]. In general, a wide variety of aggregates were used: granite, gravel, quartz, basalt, porphyry, lime stone, and broken ceramic materials (e.g., stone ware, tiles, bricks, glass) [50]. The use of white Portland cement was common, sometimes pigments were added. Popular surface finishes were washing out of the cement film, polishing, and tooling. Widespread decorative concrete elements were balustrades, column bases, claustra, façade decoration, windowsills (Fig. 6), columns, plinths, and tiles [50,59]. Both mass-produced and custom-made elements were available.



Fig. 6. Typical mass-produced precast concrete windowsill dating from the 1930s. Left: Overview of a windowsill with a broken off corner. Right: Close-up of a damaged windowsill showing a coloured facing layer and a grey backing concrete. Due to soiling, the original colour changed from a beige-orange colour to a more dirty shade of green.

## 7. Conclusions

The exploration of possible surface finishes for concrete already commenced at the end of the 19th century. For a wide scale application not only technical problems had to be solved in order to achieve reliable qualities of exposed concrete. Moreover, concrete needed to be accepted as a material with aesthetical qualities. One drawback was that the grey colour of concrete was disliked, requiring techniques to alter its colour.

In this paper, an overview was given of techniques applied to alter the colour of concrete in the Dutch Interwar Period (1918–1930s). In this period, workmanship, mix design, architectural experience and social acceptance were sufficiently sophisticated to enable the use of coloured concrete. A common method was to add pigments to the concrete mix. However, the definition of pigments differed then: ground natural stone was considered as a pigment and not as filler.

Coarse aggregates were often consciously chosen according to aesthetic requirements, deviating from common practice for grading and choice of the aggregate. In order to achieve a good quality, precasting of coloured concrete was common. Elements were often produced with a coloured facing concrete to reduce costs.

A reaction towards the lack of durable paints for concrete was the invention of metallisation for concrete. This Dutch method consisted of the application of metal salts on the hardened concrete, which altered the colour of the concrete. As still existing examples are rare, little reference is available about its properties. As indications exist that this technique was also applied abroad, this surface finish has to be considered in other countries.

Knowledge of historic techniques is not only relevant for historical reasons alone. As stated in this paper, some techniques and materials can affect the durability of concrete. For example, the explorative use of pigments could have affected the quality of concrete, and thereby increasing the risk of degradation. On the other hand, precast elements can have a lower risk of degradation than in-situ concrete, as precasting allowed a better quality control and use of a lower water-cement ratio.

For the conservation of historic concrete a correct characterisation of the surface finish is thus important, for evaluating both its durability and possible heritage values associated to the surface and concrete. By increasing knowledge of surveyors on the varieties of coloured concrete, their periods of application, and of associated risks the quality of conservation can be improved.

Based on better insight into the historic context, detailed material research on the constituents used or on the effects of rare techniques such as metallisation, can be better targeted. Especially for metallisation, little is known of how it was applied and how to identify it in the field; more reference data and objects are needed, including possibilities to repair or reproduce such surfaces. Yet, also more common surface finishes where the main variations lay in the binder and aggregates used, can require detailed material investigation.

In order to increase the knowledge on historic coloured concrete, more scientific research and a collection of findings is necessary; this includes identification of objects, material properties, durability problems, and experience with conservation. Nuances have to be made whether materials and techniques were national or international trends. The example of metallisation showed, that despite being a Dutch product which was applied for a short period, it was used abroad. Although the findings presented are based on the Dutch context, they can give an orientation of what could be encountered in other countries, considering local preference, state of the art of concrete technology, and available constituents.

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