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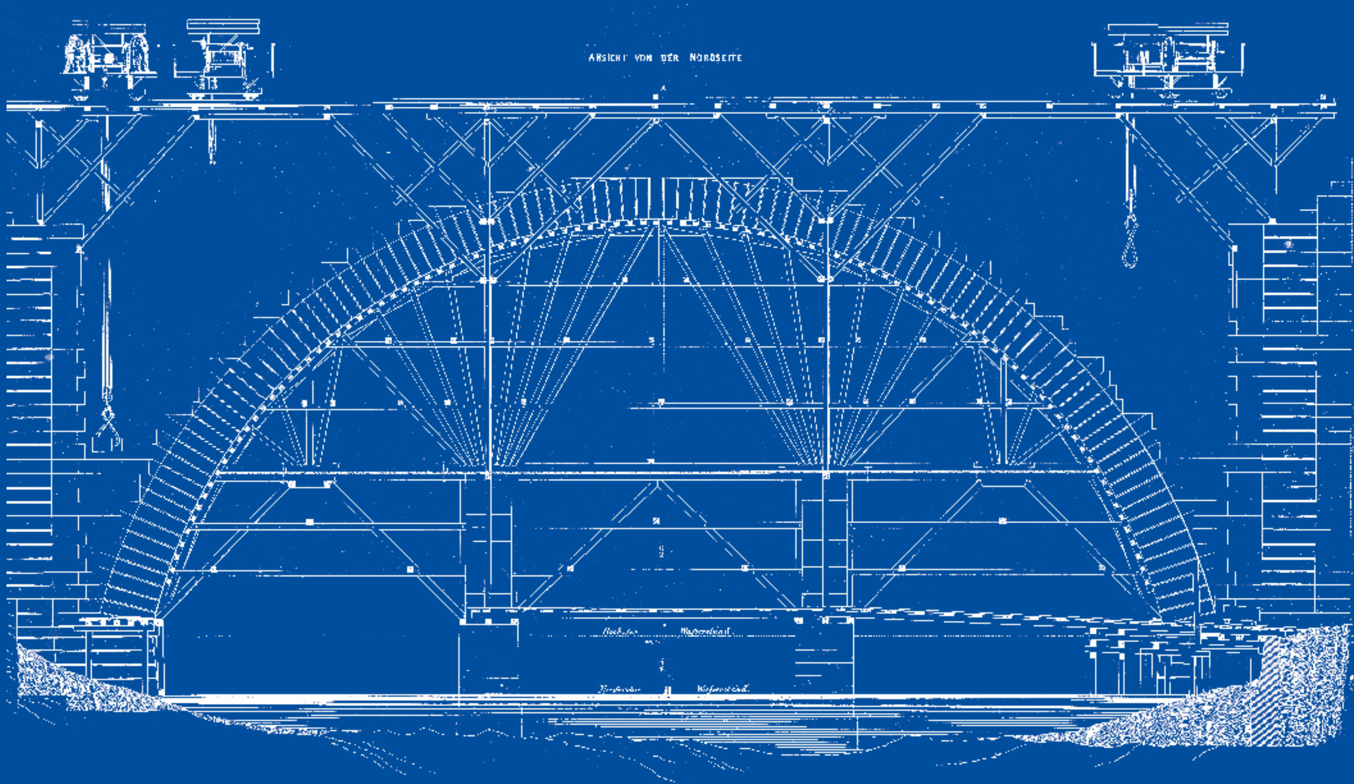

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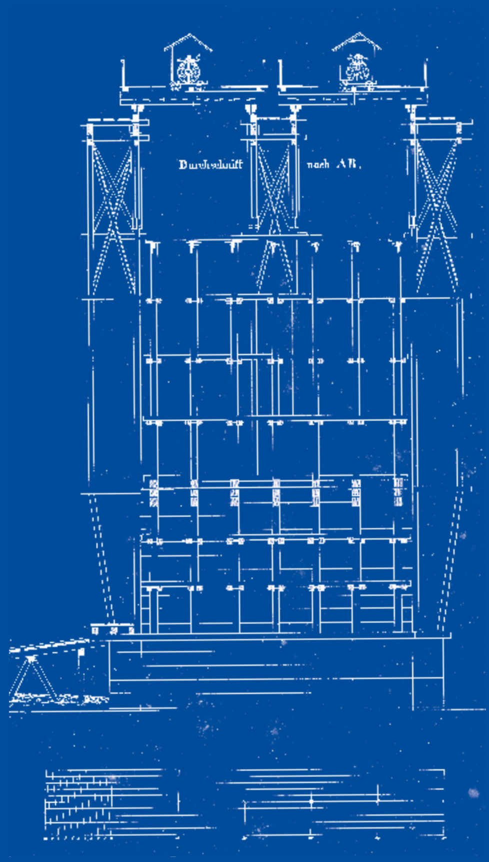

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Between practice and rule: codification, testing and use of plain concrete in Dutch military architecture (1870's–1910's)

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Abstract: From the last decades of the nineteenth century until the dawn of the First World War, plain concrete was the main building material for fortifications in the Netherlands. Although the architecture and typology of those fortifications has been studied, the development of plain concrete itself has received only limited attention. Nevertheless, archival sources, historic handbooks and early construction regulations show plain concrete as a lively material, of which composition and recipes were tested and adjusted to meet the specific standards of military engineering. Over a short period of time, plain concrete underwent rapid evolution, manifesting in year-to-year variations in recipes and concurrent application of diverse concrete types at the same location.

Considering this premise, the paper sheds a light on the development of plain concrete and related construction techniques in Dutch military architecture. Through the crossing of archival sources and on-site observation of case studies (i.e., the fortifications of Naarden), the emerging data show how the development of concrete served the specific military goals. Furthermore, the paper highlights how the work of military engineers was part of a general quest for knowledge in all fields of engineering, showing mutual contributions and collaborative knowledge advancements. Following this historical analysis, the examination extends to contemporary manifestations of damage in concrete constructions, contemplating potential correlations with historical construction techniques. Ultimately, it highlights how this knowledge can promote a better understanding of deterioration processes in relation to experimental construction methods, thus, supporting contemporary preservation practice.

Introduction

The development of plain concrete as a building material for fortifications in the Netherlands must be seen against the background of the fast evolution of weapons and ammunition in the second half of the nineteenth century. An important step in that evolution was the introduction of rifled cannon circa 1860, which amplified the impact of grenades fired with such artillery. The existing, freestanding brick buildings and fortress walls proved vulnerable to these advancements, prompting a shift towards bombproof structures (Werf 2021, 100–102, 107–109; Will 2002, 69–70). Consequently, this led to the redesign of fortifications and the introduction of new construction methods and materials all over Europe. In the Netherlands, this resulted in vaulted, brick constructions concealed under a thick layer of earth and revealing only one façade. This persisted as the dominant construction type for fortifications well into the 1880's.

In the meantime, the Dutch military began considering plain concrete from 1864 onward (National Archive 1864). However, it was not used as a primary building material until 1878 (Koninklijk Instituut 1897, 200). During this initial stage, concrete featured a lime-based mortar with brick as an aggregate, resulting in buildings with a similar appearance to those made of brick and similarly covered in a thick layer of earth.

Subsequently, the introduction of the high-explosive grenade, around 1885, caused a profound transformation in the role and use of concrete in military architecture. This new ammunition rendered the brick buildings with their earth covering useless, just like the buildings made of lime-based plain concrete (Ministerie van Defensie 1988, 114–116; Werf 2021, 110–111, 117). Cement-based plain concrete became the new norm, finding application in the reinforcement of existing fortifications and serving as the primary building material for new constructions. These new fortifications, characterized by compactness and a limited earth covering, reached their zenith in the Netherlands at the dawn of the First World War.

Although the architecture and typology of concrete fortifications have been studied, the development of plain concrete itself has received little attention. Recent studies in the field of fortifications address it only in a brief and general way (Gils 2003/3, 12–18; Gils 2003/4, 3–10; Kant et al. 1988, 116–120; Ministerie van Defensie 1988, 119–120; Schalich 1992, 3–9; Vesters 2003, 156–157). The elaborate study on historic concrete by Heinemann (2013) treats the technical aspects of plain concrete in general and its application in military architecture in some detail, but the accent quickly shifts to more recent, reinforced concrete constructions (Heinemann 2013, 37–43, 110, 114, 116, 318–322). All in all, the state of the art in literature leaves a gap in the knowledge of the technological development of the material that played a pivotal role in fortress construction over several decades.

Figure 1. Map of the Netherlands showing the locations of the towns discussed in this article: Naarden, Schoorl and Oldebroek (Authors).

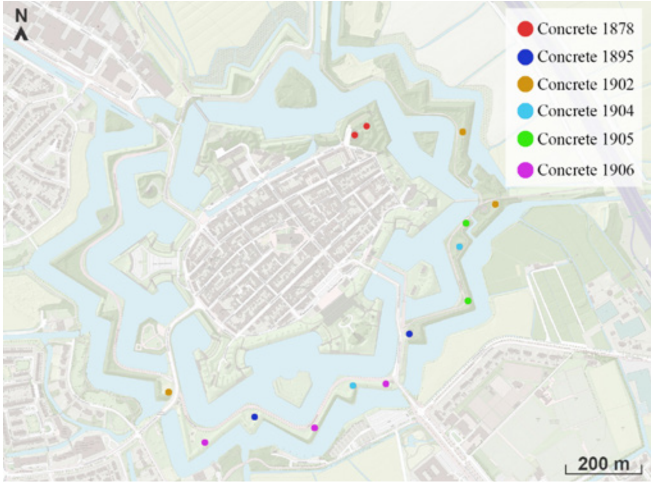

Figure 2. Map of Naarden (NL) showing the locations of the concrete buildings and the concrete type used (Authors).

1. Research methodology and sources

This study delves into the evolution of plain concrete in the Netherlands, spanning from the time of its initial consideration by the Dutch military (1864) to the pinnacle of its development (ca. 1910). In order to gain a comprehensive understanding on this topic, four primary source categories were analyzed.

The first category comprises building specifications and related drawings, which provided detailed descriptions of the construction of each fortification, including prescribed materials, processing methods, and quality standards. They were compiled by military engineers as the base for the work tender.

Given the repetitive nature of military constructions, building specifications resulted in repetitive texts. Therefore, from 1865 onwards, the engineering corps started to explore possible standardization strategies. In 1872, this resulted in the printing of the *Algemeene Voorwaarden voor de uitvoering van werken en leveringen voor den dienst der genie* (General Terms and Conditions for the construction of military buildings; from now on: Terms and Conditions). Subsequently, building specifications had to simply refer to these Terms and Conditions and only describe the work that deviated from them. The Terms and Conditions were reprinted in 1879, 1893 and 1906 (Minister van Oorlog 1872, 1879, 1893 and 1906), and have represented the second main source category of this study.

The third source category encompasses firing tests conducted to assess the resistance of constructions to cannon fire, a practice undertaken widely across Europe. In some cases, these tests were kept secret, in other cases, they were open to foreign observers.

The fourth source category involves the fortifications themselves and their direct observation in situ. For this, the fortifications of Naarden (part of the Dutch Waterlines, UNESCO World heritage since 2021) have been selected as a valuable reference. Spanning the period from 1878 to 1906, the concrete applied in Naarden provides a comprehensive overview of the development of this material. (Figures 1–2) In the following section, the results of this investigation on the evolution of plain concrete are chronologically presented by interweaving insights from these four main source categories, illustrating their interplay.

2. The development of plain concrete in Dutch military architecture

2.1. *First considerations*

In 1861, firing tests were carried out by the Danish military on various materials, including cement-based plain concrete. These tests were observed by the Dutch engineer major Ernst, who reported about them in 1864. After careful consideration, the Dutch military decided not to use this type of concrete, since further testing was still deemed necessary (National Archive 1864). Later tests showed that lime-based plain concrete with a brick aggregate had comparable strength to a brick building of a similar shape and design. Therefore, considering the cost-effectiveness of concrete construction, bombproof buildings in plain concrete started to appear in various fortifications from 1878 onward (Koninklijk Instituut 1897, 200). Notably, no record of the use of cement-based concrete at that time can be reported. In 1864, it was deemed too expensive and unnecessary (National Archive 1864), as alternative constructions were judged sufficiently robust.

2.2. *Setting the rule: lime-based concrete in the first Terms and Conditions of the Dutch Ministry of War*

In 1878, the first edition of the Terms and Conditions had been printed and was in use. In it, concrete is included as part of the chapter on masonry. Four paragraphs are specifically devoted to this material (Minister van Oorlog 1872, 110, 116–117, 130). In particular, the regulations pertaining the composition and preparation of concrete prescribed the use of Belgian Bluestone as an aggregate, alongside brick. The prescribed size for stone pieces was between three and five centimeters large. Brick pieces had to adhere to the minimum standard of *hardgrauw* quality, described as a brick of hard and dense composition. The concrete composition required 10 parts of mortar (as dry as possible) and 18 parts aggregate, the latter thoroughly washed and wet through and through. To achieve this mixture, the mortar had to be lime based and

Figure 3. Naarden (NL), the building made of lime-based concrete dating from 1878 (Authors).

Figure 4. Schoorl (NL), photo of the firing tests from 1892 (Artillery Museum Oldebroek 0476-95).

applied in a 10 cm thick layer. Moreover, it had to be mingled with the aggregate until every part of it was covered in a film of mortar. To make the concrete construction, this mixture had to be tamped into a mold with wooden pestles. This had to be done in layers of 30 to 40 cm. When the concrete had reached sufficient hardness, the facade of the building had to be finished with a plaster, giving it a smooth and even appearance.

In the Terms and Conditions there is no mention of cement to be used in concrete. The following edition of the Terms and Conditions shows the same texts (Minister van Oorlog 1879, 113, 120, 121, 134).

The aforementioned type of concrete was used for two buildings in Naarden, both dating back to 1878. In one case, it was used to cover and strengthen an existing brick building, while in the other, the whole building was made of concrete. (Fig. 3) Notably, in both cases the concrete has an open structure and is relatively soft. Evidently, the tamping did not prevent the formation of many cavities, which can be attributed to the relatively large size of brick fragments incorporated in the mixture. (Fig. 9)

2.3. From Oldebroek to Schoorl: the role of firing tests in the transition towards cement-based concrete

As mentioned above, the introduction of the high-explosive grenade posed a new threat to existing fortifications. Consequently, in July 1887, firing tests on targets made of cement-based plain concrete were conducted in Oldebroek. (Fig. 1) In this context, a diverse array of constructions underwent examination. Unfortunately, the archive material documenting these tests is incomplete, providing no insight into the specific concrete recipes that were used, nor into any of the conclusions drawn from the tests (National Archive 1887).

In the meantime, cement-based concrete started to be applied. An example can be found in the brick vaults of Fort Pannerden, which were strengthened with concrete around 1890. Drawings of this 19th-century fort show the use of various types of concrete (Gelders Archive 1890). Here, the cement-based variation was applied on the parts of the fort that were most likely to be exposed to canon fire.

Another important step in the spread and use of concrete was then marked by the large scale firing tests carried out, in various stages, between June 1891 and October 1892 near the small town of Schoorl, in the northwest part of the Netherlands. (Fig. 1) During this period, five different targets were constructed to test the suitability of concrete for both new buildings and the reinforcement of existing structures (National Archive 1892). (Figures 4–5) The specifications for the construction of these targets prescribed the use of a cement-based concrete for the walls that were exposed to direct cannon fire, to be realized with Belgian Bluestone as aggregate in the composition of one part cement, one part sand and three parts stone. Moreover, the stone particles had to be of a size between 0,5 and 3,0 cm. For the making of the concrete and its application in the mold, a similar process had to be followed as described in the previous paragraph for the lime-based concrete, although with some interesting differences. Instead of adding the stone particles to the mortar as was the case with the lime-based concrete, now it was the mortar that had to be added to the stone. For the application in the mold, the wooden pestles were replaced by iron ones with a prescribed weight of 20 kilos. Ultimately, the layers of

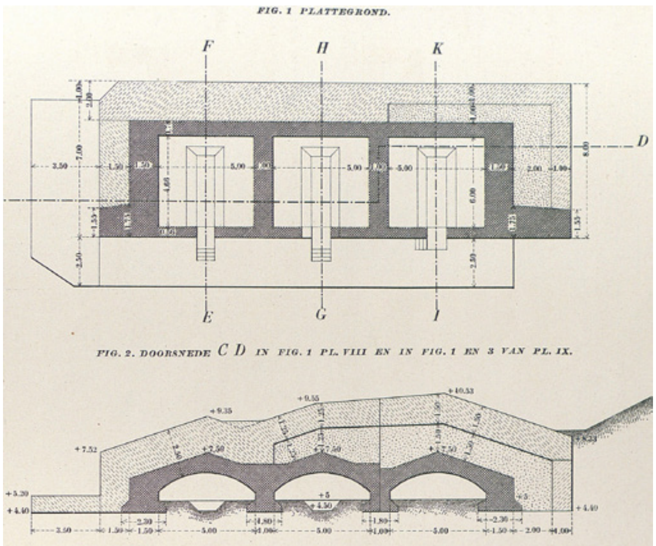

Figure 5. Drawing of one of the targets for the firing tests of Schoorl from 1892 (National Archive, fragment of the booklet in folder 2.13.210-153).

Figure 6. Naarden (NL), concrete shelter on the covered way dating from 1895. The drainpipes were added in a later restoration (Authors).

Figure 7. Naarden (NL), concrete shelter on the covered way dating from 1906. The shelters from 1902, 1904 and 1905 belong to the same architectural typology (Authors).

concrete to be tamped in the mold had to have a maximum thickness of 15 cm instead of 40 cm. (National Archive 1889).

Besides the five targets, four separate blocks of concrete were made, using different aggregates but in a same mix ratio and size of stone particles (National Archive 1892). This was done to assess which concrete gave the best performance and was the most practical to work with. The aggregates used were, besides Belgian Bluestone: gravel, granite, basalt, and baking residues of bricks. This last one was deemed unsuitable, while the others all gave similar results in terms of quality. However, since granite and basalt were deemed too expensive, gravel appeared as the best alternative. It was even cheaper than Belgian Bluestone and could be processed easily. Nevertheless, a downside was that it took gravel too long to get a good cohesion with the mortar. Therefore, the overall conclusion was that cement-based plain concrete, with Belgian Bluestone as aggregate, had to become the new standard for both the construction of new buildings and the reinforcement of existing structures (National Archive 1892).

2.4. Plain concrete in Naarden 1895–1906: a testing ground in the refinement of the standard

Since this new standard was not included in the 1893's edition of the Terms and Conditions, which still showed the same texts as in 1872 and 1879, building specifications related to works realized in Naarden have represented a relevant source of information about the evolution of concrete after the tests in Schoorl. In particular, reference is made to the specifications concerning the construction of the twelve bombproof concrete shelters in Naarden between 1895 and 1906, built according to two main typologies. While the first two buildings dating from 1895 have oblique walls and curved roofs, (Fig. 6) the ten younger ones—built in 1902, 1904, 1905 and 1906—are rectangular, lower and with a flat roof. (Fig. 7)

Excluding the two buildings from 1904, the specifications for the construction of these shelters are all kept in the Dutch National Archive of The Hague. Noteworthy differences emerge from the comparison between these specifications and the 1893's Terms and Conditions. In the latter, concrete is described as still based on lime and brick, resembling masonry. Instead, the concrete prescribed in the aforementioned specifications is a distinct building material, with detailed and much more advanced specifications. Every component, including sand, cement, and aggregate, is subject to specific standards and testing. Also, the processing and production of the concrete is described in detail. This was already the case in the specifications for the targets in Schoorl, but the specifications of 1895, 1902 and 1905 show an evolution of all these regulations and standards (National Archive 1895, 1902, 1905).

For instance, the 1895 specifications state that sand must be coarse, but any gravel exceeding five millimeters must be sieved out. Moreover, the sand must be of such a state that 25% of its weight is left behind on a sieve with 60 meshes per cm2. In 1902, the latter is changed to a minimum of 20% and a maximum of 40%. In 1905, these numbers stay the same, but the measurements of the threads of the sieve are specified to 0,38 mm. Similar details are mentioned for the sieving of cement. The specifications also state that the cement should set slowly. In 1895, the prescribed time the cement should need to set ranged from two to eight hours. In 1902, this has changed to three to ten hours. Regarding the aggregate, the specifications give the choice between Belgian Bluestone, granite, and porphyry. The regulations for the size of the aggregate and the mix ratio between the concrete components differ throughout the years as well. (Fig. 8) Just as in 1878, the facades of the shelters were finished with a plaster.

By 1906, plain concrete had reached a new stage. Samples of cement-based concrete taken in Naarden show a very hard and dense material, completely different from the concrete with brick aggregates dating from 1878. (Fig. 9) Significantly, the 1906 edition of the Terms and Conditions (Minister van Oorlog 1906, 122, 123, 127, 135–139, 152–156) shows no differences from the specifications from 1905 and 1906 (National Archive 1905, 1906). This highlights the crucial role played by practical experimentations on the field—like the ones carried out in Naarden between 1895 and 1906—in the evolution and refinement of the standard.

Place, Date	Application	Concrete components and composition	Source
Naarden, 1878	New concrete building; vault reinforcement of masonry building	Aggregate: brick Aggregate size (width): 3–5 cm Concrete composition: 10 lime mortar, 18 aggregate	Minister van Oorlog 1872
Schoorl, 1892	Firing test target	Aggregate: Belgian Bluestone Aggregate size (width): 0.5–3 cm Concrete composition: 1 cement, 1 sand, 3 aggregate	National Archive 1889
Naarden, 1895	Concrete shelter	Aggregate: porphyry Aggregate size (width): < 0,5–3 cm Concrete composition (roof): 1 cement, 1 sand, 3 aggregate Concrete composition (walls): 1 cement, 2 sand, 5 aggregate	National Archive 1895
Naarden, 1902	Concrete shelter	Aggregate: porphyry Aggregate size (width): < 4 cm; 40% > 2cm; 90% > 1cm Concrete composition: 1 cement, 1.25 sand, 3 aggregate	National Archive 1902
Naarden, 1904	Concrete shelter	No data available	
Naarden, 1905	Concrete shelter	Aggregate: porphyry Aggregate size (width): < 4 cm; 25% > 2cm; 70% > 1cm Concrete composition: 1 cement, 1.25 sand, 3 aggregate	National Archive 1905
Naarden, 1906	Concrete shelter	Aggregate: porphyry Aggregate size (width): < 4 cm; 25% > 2cm; 70% > 1cm Concrete composition: 1 cement, 1.25 sand, 3 aggregate	National Archive 1906
Oldebroek, 1909	Firing test target	Aggregate: gravel Aggregate size: no data available Concrete composition (target 2 m thick): 1 cement, 1.25 sand, 3.5 aggregate Concrete composition (target 2.5 m thick): 1 cement, 2 sand, 4.5 aggregate	National Archive 1909

Figure 8. Table 1 showing the concrete components and compositions presented in this paper (Authors).

2.5. Plain concrete makes way for reinforced concrete

In 1909, new firing tests conducted in Oldebroek led to the formulation of updated concrete recipes, favoring gravel over stone pieces. Moreover, a new standard was established for the finishing of the forts in the Defense Line of Amsterdam, prescribing plain concrete with a mix ratio of 1,0 part cement, 1,5 parts sand, and 3,5 parts gravel (National Archive 1909). Notably, besides plain concrete structures, a reinforced concrete construction was tested for the first time, yielding promising results. Indeed, this period marked the onset of grenades with a higher caliber, rendering plain concrete insufficient. Consequently, from around 1912 onwards, reinforcement became imperative to enhance resistance. As a result, the use of plain concrete in military constructions decreased considerably, giving way to reinforced concrete after the First World War.

3. Exchanges between military and civil engineering

Beside military applications, concrete was broadly used in civil engineering. Within this field, plain concrete was applied for the first time around 1825. In contrast, the first reinforced concrete construction occurred in 1892 (Schippers 1995, 7 and 14), approximately two decades earlier than in military engineering. This discrepancy can be attributed to the different goals of construction in the military and civil domains. Civil engineers sought to develop slender constructions to optimize space and material, for which the use of reinforcement was vital. Conversely, military buildings were designed to withstand the impact of a grenade, encompassing the shock upon contact, its penetration into the construction and the shock of the explosion (Schalich 1992, 4). Consequently, military engineers prioritized the construction of robust and massive structures, initially deeming reinforcement unnecessary.

Although the purpose of military and civil constructions was different, there was significant knowledge exchange among the disciplines in the field of concrete research. In the second half of the nineteenth century, a general quest for scientific knowledge of building materials emerged. In 1847, the establishment of *het Koninklijk Instituut voor Ingenieurs* (the Royal Institute for Engineers) in the Netherlands served as a collaboration platform for both military and civil engineers. Within this institute, a dynamic exchange of knowledge and dissemination of research results took place. Moreover, detailed research on building materials took place at the Polytechnical School in Delft from the 1880's onward. Here, professor J.A. van der Kloes (1845–1935) published his first overview of Dutch building materials in 1893. Many of the observations, tests and regulations described in this seminal work reveal substantial parallels with the building specifications referring to the concrete shelters in Naarden, as well as with the Terms and Conditions of 1906. Notably, van der Kloes refers to fortifications in his book (Kloes 1893, 392–393).

This interdisciplinarity is further exemplified by a Dutch military engineer's visit to Delft in 1888, where he observed pressure tests on various types of cement-based concrete, then documented in a subsequent report (National Archive 1888). This collaboration and knowledge exchange is also evidenced by the appearance, several years before the first

Figure 9. Three samples of the plain concrete in Naarden (NL): concrete from 1878 (right); concrete from 1895 (center); concrete from 1906 (left) (Authors).

Figure 10. Photo of the firing tests in Schoorl from 1892, showing the horizontal crack caused by the pouring of the concrete in different layers (Artillery Museum Oldebroek 0481–48).

publication of the Terms and Conditions for military buildings, of a similar document for civil engineering (Departement van Binnenlandsche Zaken 1866). Remarkably, significant analogies emerge between these documents, reflecting the reciprocal advancement brought about by contact and exchange between the two engineering fields.

4. Hardness, density, and mass

As mentioned above, the primary objective of Dutch military engineers was to make a construction capable of withstanding the impact of high-explosive grenades, with mass, hardness, and density serving as crucial parameters in achieving this goal. The changes implemented in the concrete recipes over the years were integral to the search for an optimal hardness and density. The observations made by van der Kloes in his books can help to better elucidate those changes. Through various tests, he demonstrated that a high ratio of cement and sand would have resulted in a harder and denser concrete (Kloes 1893, 389–393). Additionally, he established that the use of a cement with a slow-setting property results in an enhanced concrete hardness (Kloes 1908, 60). Furthermore, the use of a hard aggregate, like granite or porphyry, was found to augment construction hardness. When this aggregate gets a size ratio that enables the mortar to fill all cavities between the stone pieces, the result is a very dense concrete (Kloes 1893, 389).

The overview of the studied concrete recipes that is presented in table 1, shows an interplay between ingredients, hardness, and mass. In 1895, the roofs of the shelters in Naarden were made of concrete with a higher amount of cement than the walls. This adjustment aimed to achieve greater hardness, given the higher exposure of the roof to gunfire. Because cement was an expensive product, efforts were made to reduce its usage. The increment in the amount of sand from 1902 onward led to a higher sand/cement ratio, resulting in a harder concrete. Parallel to this, enhancements in the size ratio of the aggregate were made, contributing to higher density. The recipes for Oldebroek in 1909 show that an increase of mass could mean a decrease of cement. Concrete samples taken in Naarden further illustrate these principles (Fig. 9):

- The sample of 1878 concrete (right) shows lime-based mortar with bricks, featuring soft mortar and aggregates. The relatively large pieces of brick cause numerous cavities. The mix ratio is 10 parts mortar to 18 parts aggregate.
- The sample of 1895 concrete (middle) shows cement-based mortar with porphyry. The sample is taken from the wall of the shelter and has a mix ratio of one part cement, two parts sand and five parts aggregate. There are many, small pieces of stone visible. Despite its hardness and density, the concrete still shows several small cavities.
- The sample of 1906 concrete (left) shows cement-based mortar with porphyry in a mix ratio of one part cement, 1,25 parts sand and three parts aggregate. The higher content of mortar and the better size ratio of the aggregate has led to effective filling of cavities, resulting in a dense and hard concrete.

5. The concrete buildings in Naarden: current state of conservation and preservation issues

As for the current state of the concrete buildings in Naarden, the concrete building from 1878 is in a good condition, thanks to an intervention carried out in the 1990's. At that time, the facade faced significant deterioration, characterized by the detachment of plaster due to infiltrating water and frost. The relatively soft concrete underneath showed signs of cracking and crumbling. In response, the outer 10 to 12 cm of the facade were removed and replaced by a brick cladding, protecting the rest of the concrete from further deterioration. Although the historic concrete is no longer visible, this measure has ensured its preservation.

Similarly, the concrete used to cover an existing brick building, also dating from 1878, has been consistently protected by a layer of bricks with earth on top. A recent inspection confirmed the enduring condition of this concrete, which has positively stood the test of time.

For the twelve concrete shelters on the covered way (1895–1906), an overall good condition can be observed, albeit with shared patterns of damage. The analysis of the building specifications has shown that part of this damage could be traced back to the construction process. As previously explained, the concrete of the shelters was tamped layer by layer into a mold. Today, long horizontal cracks appear at the interface of some of these layers, where the cohesion of the material is weaker. The risk that the construction could crack at these points already showed in the firing tests in Schoorl. (Fig. 10) While most cracks are thin and pose minimal deterioration risk, some wider cracks necessitate restoration in the coming years. (Fig. 11)

Another weak spot arises at junctures where different concretes meet, such as at the eaves of the shelters of 1895. According to the specifications, they were added later and were made with a concrete holding a large quantity of aggregate. Field observations indicate that little attention was paid to the mixture of the ingredients at the time of construction, leading to inadequate connections between the walls and the eaves. Consequently, the eaves cracked and detached from the rest of the construction, prompting restorations in the early 2000's.

The two concrete shelters from 1895 also display a distinctive vertical cracking pattern. One of them shows one vertical crack in the middle of the longitudinal facade, while the other shows two cracks evenly distributed over the length of the facade. (Fig. 12) Given their volume, this cracking pattern could be indicative of multiple casting rounds during the construction, creating both horizontal and vertical seams between casting rounds. Later movement in the underground or thermal expansion caused them to crack at these weaker points. At present, these cracks are thin and stable, and are carefully monitored for any progression.

Figure 11. The horizontal cracking pattern on one of the shelters. The wide crack needs to be restored in the near future to prevent further damage (Authors).

Figure 12. The cracking pattern in the longitudinal facade of the shelters from 1895. This one, shows two cracks, indicated by the arrows. The other shelter shows one crack in the middle of the façade (Autors).

Conclusion

In conclusion, while this paper provides a concise and therefore limited insight in the development of plain concrete in Dutch military architecture, it underscores the material's diverse and intriguing nature. The rapid and dynamic transformations observed at the end of the nineteenth century characterize plain concrete as a "living" material, deserving in-depth exploration. Beyond contributing to the material's historical evolution, this study offers insights into testing methodologies, regulatory frameworks, and the scientific approaches employed in construction during the late nineteenth century. The great variety in concrete recipes highlights a conscientious search to optimize fortress constructions.

This nuanced understanding of concrete holds practical significance for preservation and maintenance practice. Recognizing the swift changes in concrete recipes and acknowledging the potential coexistence of various concrete types within a single fortress are crucial aspects. This knowledge proves helpful in determining the most appropriate mortars for restoration purposes. Furthermore, awareness of damage patterns stemming from construction techniques is crucial in drafting effective restoration plans.

Ultimately, the results of the research presented in this paper call for further detailed explorations of plain concrete in military architecture, encompassing a broader array of fortifications and on-site observations. A more comprehensive investigation is essential to deepen our understanding of this material and its historical applications, paving the way for informed preservation practices and contributing to the broader discourse on construction history in the late nineteenth century.

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Drawing with sections of fort Pannerden, showing reinforcements with various types of concrete dating from 1890. Gelders Archive, Arnhem, archive number 2.1.2.2, inv. number 631-0015.

Letter with drawings about the firing tests that took place in Oldebroek in 1887. National Archive, The Hague, archive number 4.OGT, inv. number 197.

Letter with the conclusions and recommendations after firing tests in Oldebroek in 1909. National Archive, The Hague, archive number 3.09.23, inv. number 23.

Report on the firing test in Copenhagen that took place in 1861, written in 1864 by major Ernst and the reactions to it. National Archive, The Hague, archive number 2.13.01, inv. number 3523-39A.

Report on the pressure tests on concrete taken at the Technical School in Delft, written in 1888. National Archive, The Hague, archive number 2.13.01, inv. number 3859-49.

Printed booklet with drawings of the five targets in Schoorl and a handwritten report about the results of the tests from 1892. National Archive, The Hague, archive number 2.13.210, inv. number 153.

Specifications for the construction of the targets in Schoorl, in 1889. Including drawings. National Archive, The Hague, archive number 2.13.45, inv. number 961.

Specifications for the construction of the two concrete shelters on the covered way in Naarden in 1895. National Archive, The Hague, archive number 2.13.02, inv. number 162.

Specifications for the construction of the three concrete shelters on the covered way in Naarden in 1902. National Archive, The Hague, archive number 2.13.02, inv. number 185.

Specifications for the construction of the two concrete shelters on the covered way in Naarden in 1905. National Archive, The Hague, archive number 2.13.02, inv. number 196.

Specifications for the construction of the three concrete shelters on the covered way in Naarden in 1906. National Archive, The Hague, archive number 2.13.02, inv. number 200.

Construction History is still a fairly new and small but quickly evolving field. The current trends in Construction History are well reflected in the papers of the present conference. Construction History has strong roots in the historiography of the 19th century and the evolution of industrialization, but the focus of our research field has meanwhile shifted notably to include more recent and also more distant histories as well. This is reflected in these conference proceedings, where 65 out of 148 contributed papers deal with the built heritage or building actors of the 20th or 21st century. The conference also mirrors the wide spectrum of documentary and analytical approaches comprised within the discipline of Construction History. Papers dealing with the technical and functional analysis of specific buildings or building types are complemented by other studies focusing on the lives and formation of building actors, from laborers to architects and engineers, from economical aspects to social and political implications, on legal aspects and the strong ties between the history of construction and the history of engineering sciences.

The conference integrates perfectly into the daily work at the Institute for Preservation and Construction History at ETH Zurich. Its two chairs – the Chair for Building Archaeology and Construction History and the Chair for Construction Heritage and Preservation – endeavor to cover the entire field and to bridge the gaps between the different approaches, methodologies and disciplines, between various centuries as well as technologies – learning together and from each other. The proceedings of 8ICCH give a representative picture of the state of the art in the field, and will serve as a reference point for future studies.

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