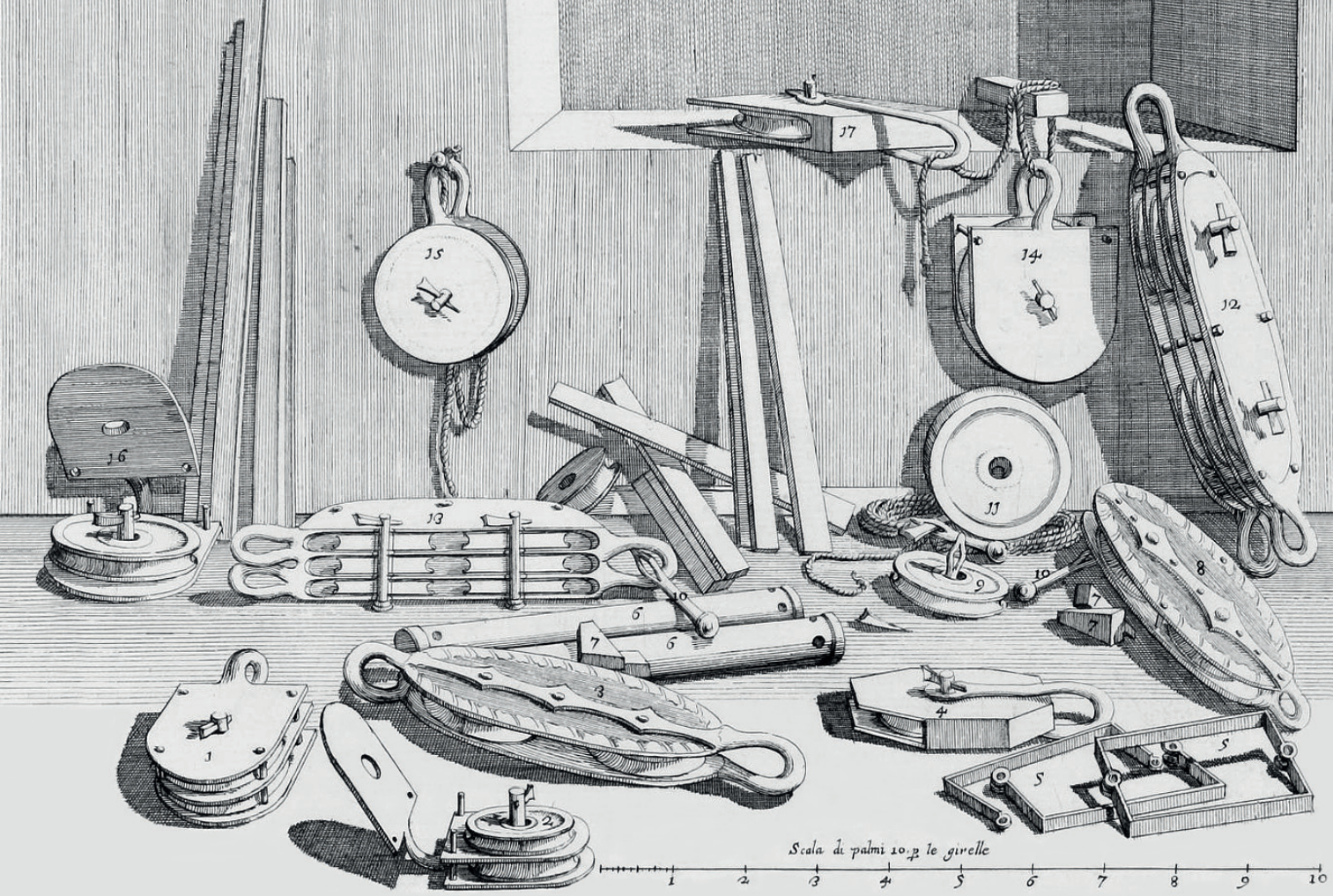
Hennebique Moves North: The First Applications of Reinforced Concrete in Iceland (1907–10)



Quaderni di Storia della Costruzione
Vol. 1

Storia della costruzione: percorsi politecnici

a cura di Edoardo Piccoli, Mauro Volpiano, Valentina Burgassi
Construction History Group - Politecnico di Torino DAD

Il presente volume raccoglie gli studi in corso di docenti e ricercatori del Centro di Ricerca Construction History (CHG) del Politecnico di Torino, Dipartimento di Architettura e Design. All'interno delle varie sezioni, tra età moderna e contemporanea, si affrontano temi di natura interdisciplinare, come l'analisi dei profili di docenti - parte della tradizione di studi sulla Storia della Costruzione dell'Ateneo ("percorsi politecnici") -, proseguendo con un approfondimento sulla cultura costruttiva di età moderna anche attraverso un glossario di termini tecnici e tratti dall'esperienza di maestranze di diversa provenienza geografica, all'interno di due cantieri barocchi coevi, quello sabaudo e quello romano. Nel volume si affrontano anche ricerche sulla cultura costruttiva in età contemporanea relativamente alle applicazioni del cemento armato (Hennebique) nei cantieri fuori dall'Europa e in Islanda tra la fine dell'Ottocento e il Primo Novecento ("Per una storia del cemento armato"). Infine, nell'ultima sezione "Sconfinamenti di metodi e tecniche", si riportano le ricerche in corso, che si avvalgono della tecnologia (modelli numerici, rilievi geometrici e tecniche a infrarosso), finalizzate ad una migliore comprensione delle fabbriche storiche.

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Quaderni di Storia della Costruzione è una collana di ricerche promosse dal Construction History Group PoliTo DAD con l'obiettivo di diffondere studi riguardanti la storia della costruzione in età moderna e contemporanea, fondata nel 2021.
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Hennebique Moves North: The First Applications of Reinforced Concrete in Iceland (1907–10)

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Introduction

Concrete construction in Iceland has quite a long history that dates back to the first application of Portland cement in 1847 and the early experiments with lime conglomerate and concrete since the 1880s.[1] On the one hand, Icelandic builders soon accepted concrete as a material to experiment with in regards to rural constructions.[2] At the same time, however, the growing use of concrete, first in the countryside and then in Reykjavík, did not necessarily include the use of reinforcement bars. This clearly depended on the difficulty in purchasing and importing iron bars in sufficient quantities, on top of the basic need for timber formworks and cement. The first structures in which reinforced concrete was employed were a bridge, a wool factory, the national library and a sanatorium; their construction was condensed in a very short time frame that followed the establishment of the country's Home Rule in 1904. Behind these buildings and infrastructures was the work of Iceland's first generation of engineers, who acted as a bridge of technical knowledge from the continent to the island. Graduated from the Polytechnic School in Copenhagen [Den Polytekniske Læreanstalt, founded in 1829], their expertise was linked to the important accomplishments of the Danish engineering school, the Danish cement industry and the concessionaires of the Hennebique patent in Denmark. This essay will retrace the construction of the first reinforced concrete structures of Iceland and it will try to understand to what extent the Hennebique patent was adopted. Furthermore, this paper will highlight the key role played by these buildings in the definition of Iceland as an autonomous country. As they hosted important cultural, infrastructural, social and industrial activities, they embodied the new needs and aims of a growing country and allowed it to take one step forward into its political independence.

[1] This essay is a modified and updated excerpt of the second chapter in my Ph.D. dissertation: S. Nannini, *The Icelandic Concrete Saga: Architecture and Construction (1857–1958)*, Ph.D. dissertation, Politecnico di Torino, 2021. Abbreviation: ÞÍ = Þjóðskjalasafn Íslands [National Archives of Iceland]

[2] Lýður Björnsson, *Steypa lögð og steinsmíð rís. Sagt frá mannvirkjum úr steini og steypu*, Reykjavík: Hið íslenska bókmenntafélag, 1990, pp. 61–70.

Reinforced concrete knowledge from Denmark to Iceland

As cement made its slow entrance into the Icelandic stage, Europe was experiencing its hectic era of reinforced concrete patents and methods for calculating new, daring structures. In this dynamic moment, the patents that mostly influenced European construction in reinforced concrete were those filed by the French enterpreneur François Hennebique (1842–1921) in 1892 and 1898,[3] and the German version of Monier's patent, published in 1887 by German engineer Gustav Adolf Wayss (1851–1917) in a very successful pamphlet.[4] At the beginning of the twentieth century, however, the understanding of the behaviour of reinforced concrete was breaching the boundaries of private patents and companies, thanks to the publication of internationally distributed handbooks such as *Les béton armé et ses applications* by Paul Cristophe (1902) and *Der Betoneisenbau: seine Anwendung und Theorie* by Emil Mörsch (1903).[5] At the same time, new international journals were being printed, with the aim of collecting opinions and experiences on this building method. In the German-speaking world and in the Nordic countries the most influential journal was *Beton und Eisen*, published since 1902 in Vienna by Austrian engineer Fritz von Emperger (1862–1942).[6] Despite the fortunate and quick success of some of these patents – in particular the worlwide monopoly of Hennebique's complex network of agents and concessionaires – their continental fame slowly came to an end when each country started framing the use of reinforced concrete within its national regulations. First in Switzerland and the German Empire (1904), then in France (1906), Italy (1907), and the UK (1911), reinforced concrete became a matter of national policies. Once privately pioneered innovations ruled by patents, reinforced concrete building techniques became regulated by national committees.[7]

Ironically, Icelandic building history embraced the European reinforced concrete patents – especially Hennebique's – only at the end of the patent era, when some European countries had already drafted their own regulations. Some episodes show the employment of the Hennebique patent in Iceland: the bridge over the Fnjóská river (1906–08); the reconstruction of a wool factory in Reykjavík, after a fire destroyed its first headquarters (1907); the slabs of the National Library of Iceland (1906–09) and the sanatorium at Vífilsstaðir (1908–10). However delayed, the surge of reinforced concrete patents in the country was a clear consequence of the working pres-

[3] G. Delhumeau, *L'invention du béton armé: Hennebique, 1890–1914*, Paris: Norma, 1999.

[4] G.A. Wayss, *Das System Monier in seiner Anwendung auf das gesamte Bauwesen*, Berlin: Seydel, 1887.

[5] T. Iori, *Il cemento armato in Italia. Dalle origini alla Seconda Guerra Mondiale*, Roma: Edilstampa, 2001, pp. 60–61.

[6] K.E. Kurrer, *Geschichte der Baustatik*, Berlin: Ernst, 2002, pp. 358–66.

[7] S. Van de Voorde, S. Kuban, D. Yeomans, "Early Regulations and Guidelines on Reinforced Concrete in Europe (1900–1950). Towards an International Comparison", in J. Campbell (Eds), *Building Histories*, Proceedings of the conference, Cambridge, 7 april 2017, Cambridge: The Construction History Society, 2017, pp. 345–56; S. Kuban, "Konstruieren in einer regellosen Zeit. Eisenbetonbemessung zwischen Monier-Broschüre und den ersten behördlichen Vorschriften (1887–1904)," in W. Lorenz (Ed.), *Alltag und Veränderung. Praktiken des Bauens und Konstruierens*, Dresden: Thelem, 2017, pp. 205–20.

ence of its first generation of building engineers, their international connections with continental building firms and their knowledge of the scientific literature on construction topics. The trigger of these building adventures were two State engineers active in the Icelandic context: Jón Þorláksson (1877–1935) and Thorvald H. Krabbe (1876–1953). Behind these two names was the great expertise on reinforced concrete that had developed in Denmark since the last decade of the nineteenth century.

The Danish school: A brief excursion on the history of reinforced concrete in Denmark

Located at the northern edge of central Europe, Denmark was not included in the fertile network of relations which prompted the development of reinforced concrete in the second half of the nineteenth century. Since the early twentieth century, however, Denmark played an important role in the technical progress of reinforced concrete, which evolved from being an amateurish and still mysterious technique, to a precise, scientifically-calculated building method. Two may be the reasons behind Denmark's growing importance in the debate. First was the presence of many cement plants, which exploited the country's reserves of chalk and limestone. Second, the active academic environment of the Polytechnic School in Copenhagen became a key center for debating on and experimenting with reinforced concrete (Fig. 1).[8] It is no coincidence if the first issue of the *Beton und Eisen* journal boasted two corresponding authors from Copenhagen; this number grew bigger in the following years.[9] The vitality of the Danish engineering debate may also be detected in the pages of some national journals, such as *Den tekniske Forenings Tidsskrift* (1847–1941) and *Ingeniøren* (1892–2006), the latter being the journal of the Danish Engineers' Society, founded in 1892 [Dansk Ingeniørforening]. Despite its central role in the international debate, a part from a few contributions a comprehensive history of reinforced concrete in Denmark is still missing.[10]

In 1906, in the pages of *Beton und Eisen*, engineer and Polytechnic professor Eduard Suenson (1877–1958) outlined a short history of reinforced concrete in Denmark, showing the journal's readers how quickly the material had developed in his country, and what was the current debate at that time.[11] Suenson reported that reinforced concrete was first used in Denmark in 1891, when the German company

[8] J. T. Lundbye, *Den polytekniske Læreanstalt 1829–1929*, Copenhagen: Gad, 1929; M. F. Wagner, "Danish Polytechnical Education Between Handicraft and Science", in D.C. Christensen (Ed.), *European Historiography of Technology. TISC-Conference*, Proceedings of the conference, Roskilde, 1993, Odense: Odense University Press, 1993, pp. 146–63.

[9] Kurrer (Note 6), p. 363.

[10] J. Cederberg, 'De første bygninger og bygværker af beton og jernbeton i Danmark,' *Fabrik og Bolig* vol. 2, 1999, pp. 3–27; G.M. Idorn, *Concrete Progress: From Antiquity to the Third Millennium*, London: Thomas Telford, 1997, pp. 24–26.

[11] E. Suenson, "Zur Geschichte des Eisenbetons in Dänemark", *Beton und Eisen*, 5, 6, 1906, pp. 137–38.

Fig. 1. *The Polytechnic School*, Copenhagen, ca. 1904–06. [courtesy of Danmarks Tekniske Højskoles Billedsamling/DTU Photographic Archives].

[1.]

Aktiengesellschaft für Beton- und Monierbau opened a branch in Copenhagen, directed by architect Emanuel Jensen. The first works were the walls and slabs of a laundry; then the slabs of the Copenhagen Art Museum, and the roof of a glass factory in Hellerup. Soon after, the enterprise Schöller & Rothe was founded, which coordinated the construction of the first reinforced concrete bridge – a gangway located in Copenhagen and engineered by Polytechnic professor Asger Ostenfeld (1866–1931). More infrastructures followed and, at the same time, an in-depth discussion on the physical behaviour of reinforced concrete began, thanks to elasticity tests carried on by engineer and military captain Torben Grut (1865–1952), and to Ostenfeld's pioneering research on calculations of reinforced concrete beams.[12] Beyond the scientific debate on structural calculation, the building industry was populated by a countless number of patents, among which the Monier was the most successful and undoubtedly the most discussed until the 1900s.[13]

The Hennebique patent in Denmark: The success of Christiani & Nielsen

In 1900 another fortunate reinforced concrete patent entered the Danish construction environment. With engineer Grut as agent, and mastermason Carl Schiötz as concessionaire, the worldwide famous Hennebique method had made its way to Copenhagen.[14] Its results were soon published in Hennebique's journal *Le Béton Armé*, which in October 1900 already listed a project for the slabs of the Copenhagen Telephone Society under the heading "Bureau de Copenhague".[15] The Hennebique patent was triumphantly welcomed in Denmark thanks to an article signed by agent Grut and published in *Ingeniøren*.[16] The first Hennebique agent in the country was very keen on presenting the patent and its applications. He was particularly proud of Hennebique's slabs, which usually resulted in flat ceilings, in contrast to Monier's vaulted ones; furthermore, he

[12] T. Grut, "Om Beregningen af Monierkostrukioner", *Ingeniøren*, 5, 9, 1896, pp. 39–40; A. Ostenfeld, "Om Bøjning ved Brudgrænsen", *Ingeniøren*, 5, 13, 1896, p. 71; A. Ostenfeld, "Om Beregning af Monierkonstruktioner", *Ingeniøren*, 6, 1, 1897, pp. 1–4.

[13] S. Wessel, "Brandsikre Gulvkonstruktioner", *Arkitekten. Tidsskrift for Bygningsvæsen og Byggeindustri*, 5, 230, 1899, pp. 147–52.

[14] Suenson (Note 11), p. 138.

[15] *Le Béton Armé*, 13, 29, 1900, p. 16.

[16] T. Grut, "Om Konstruktioner af armeret Beton (Hennebique-Konstruktioner)", *Ingeniøren*, 9, 22, 1900, pp. 179–83.

described in great details the position of reinforcement bars within the concrete beams, which was one of the characteristics that helped towards the renowned monolithic properties of the Hennebique's structural skeleton. In early 1904 a new Hennebique concessionaire appeared on the Danish scene: the firm Christiani and Nielsen. The history of Christiani and Nielsen's worldwide success is well known: the firm was founded in 1904 by civil engineer Rudolf Christiani (1877–1960) and captain Aage Nielsen (1873–1945).[17] Their first office was located in Copenhagen; soon they opened branches in Aarhus (1906), Hamburg (1908), St. Petersburg (1910), attaining worldwide expansion with offices in South America, Africa, and Asia by the 1940s.

As concessionaire of the Hennebique patent, the firm Christiani & Nielsen entered the Danish construction environment with a pressing advertising campaign, which was published in each issue of *Ingeniøren* between 1904 and 1906. They quickly created a strong business revolving around reinforced concrete structures, particularly specializing in bridges. The number of concrete bridges designed by Christiani and Nielsen under the Hennebique patent increased each year and it can be seen in the pages of *Le Béton Armé*. By 1908, the total number reached up to 45 projects: the Icelandic bridge over the Fnjóská river was one of them.[18] The greater part of the Danish and European scientific debate over construction issues scarcely reached Iceland, where the majority of its inhabitants were still struggling with the intrinsic weakness of vernacular architecture and a handful of engineers were trying to modernize the country's architectural traditions. However, those very engineers acted as discreet ambassadors of the continent's building technology, bringing the Hennebique patent to Europe's northernmost geographical limits.

A bridge by Christiani and Nielsen (1907–08)

The construction of the bridge over the river Fnjóská in northern Iceland was only a piece in the monumental task of establishing the country's road network, particularly embodied by the construction of the national road connecting the whole island in one, continuous ring. The daunting project of building and maintening a proper road system had been a key priority of the Icelandic Parliament since the last decades of the nineteenth century, and by the beginning of the

[17] C. Ostenfeld, *Christiani & Nielsen: jernbetonens danske pionerer*, Lyngby: Polyteknisk Forlag, 1976; *Christiani & Nielsen. Twenty Five Years of Civil Engineering*. 1904–1929, Copenhagen: Krohns Bogtrykkeri, 1929.
[18] Ostenfeld (Note 17), p. 71.

twentieth century a suitable transportation network was thought to be at the core of the country's future development. By 1905, the task of planning the construction of roads was assigned to engineer Jón Þorláksson.[19] The building of Iceland's road network was a true national and collective enterprise, which went hand in hand with the improvement of local building traditions. Suitable roads meant adequate transportation, thus easier distribution of construction supplies around the country. If Iceland was in need of roads, its roads needed bridges over the copious and powerful rivers that divided the valleys. The presence of dynamic glacial rivers had always interfered with the movement of people and goods, especially during the summer months, when waterways carry the highest volume. The construction and maintainance of the country's bridges was a source of pride and a promise for a better and quicker economic development. It probably represented the biggest chapter in the Icelanders' history of struggle against the natural elements.[20]

A bridge connecting the east and the west bank of the Fnjóská river, near a forest known as Skógar, had been a pressing need for years, and since the late nineteenth century some possibilities had been debated. This bridge was pivotal to allow a direct link between the village of Akureyri and the Mývatn lake, both populated farming areas in northern Iceland. Eventually, this project became Iceland's first reinforced concrete bridge, designed by Christiani & Nielsen. The bridge was completed in 1908, and despite having been followed by a number of other daring reinforced concrete bridges built all over the country, it still represents the beginning of the Icelandic "age of concrete" for bridge construction (Fig. 2).

This small but elegant piece of infrastructural engineering was described in detail in the local newspapers, and the bridge has also been internationally published several times. One year after the works, the project was published in the journal *Beton und Eisen*, which did not hide the difficulties experienced by the Danish workers during the construction. Because of a late river flood, in June 1908, part of the timber formwork was destroyed and this event caused some delay in the construction. Moreover, the remoteness of the building site forced the workers to use horses for the transportation of building materials such as timber planks, reinforcement bars, and cement.[21] In 1933, a picture of the bridge was included by British architectural critic Philip Morton Shand in the pages of the British journal *The Concrete Way*.[22] This "very elegant" bridge was mentioned in later publications by the Danish firm, remembered as

[19] T.H. Krabbe, *Island og dets tekniske udvikling gennem tiderne*, Copenhagen: Dansk-islandsk samfund, 1946, pp. 13–34.
[20] Sveinn Þórðarson, *Brýr að baki. Brýr á Íslandi í 1100 ár*, Reykjavík: Verkfræðingafélag Íslands, 2006; Krabbe (Note 19), pp. 35–66.
[21] L. Hess, "Fnjóská-Brücke auf Island – Landungssteg im Hafen von Hundested", *Beton und Eisen*, 8, 8, 1909, pp.188–89.
[22] P.M. Shand, "In Concrete. Third Series-IV", *The Concrete Way*, 5, 4, 1933, p. 200.

[2.]

Fig. 2. *The bridge over the Fnjóská river* [photo by the author, 2019].

one of the first results of the building enterprise.[23] The bridge is now considered as the starting point for a number of reinforced concrete arch bridges built around Iceland.[24] Recently, Icelandic author Sveinn Þórðarson has retraced the bridge's construction history thanks to extensive archival research.[25] Here a few arguments will be added to stress the importance of this project, not only within Iceland's epic of road construction, but also in the wider picture of the modernization of the country's building traditions.

As Jón Þorláksson took control over planning of the road network, he strongly insisted to the Ministry of Iceland that the bridge had to be made of reinforced concrete, and suggested the names of his Danish colleagues Christiani & Nielsen. The engineer stressed this opinion even against his own evaluation regarding the final price: according to his documentation, he attested that a suspended steel bridge would have costed 30'000kr., while a reinforced concrete one at least 33'000kr.[26] A few sentences written by Jón Þorláksson to the Ministry of Iceland are striking for their clarity and they explain why the Icelandic government had to build such an avant-garde bridge in a remote area of the country. First, he claimed that the chosen spot for the bridge offered enough aggregates for the mak-

[23] Ostenfeld (Note 17), pp. 71–72.

[24] Pétur H Ármannsson, "Concrete's Furthest North", *Docomomo Journal: Bridges and Infrastructures*, 45, 2, 2011, pp. 87–89.

[25] Sveinn Þórðarson (Note 20), pp. 173–78.

[26] ÞÍ, *Stjórnarráð Íslands* II. *Skrifstofa* B/63, Db. 2, nr. 698 (1909). Jón Þorláksson, "Áætlun um kostnað við brúargerð á Fnjóská hjá Vothamri", 26 January 1907.

Fig. 3. *Group photo of the workers after the bridge was completed. The third figure from the left is Knud Reffstrup, director of the works*, 1908. [courtesy of National Museum of Iceland / Þjóðminjasafn Íslands].

[3.]

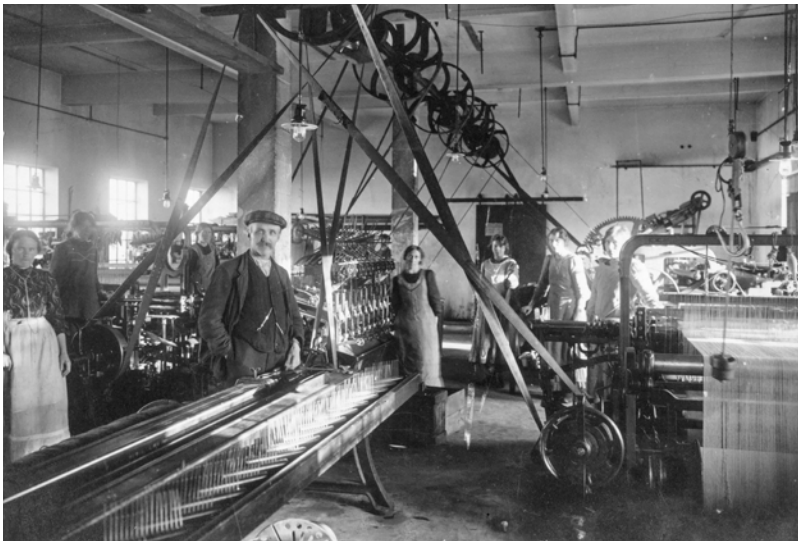

Fig. 4. *The wool factory Iðunn*, ca. 1906–15 [courtesy of: National Museum of Iceland / Þjóðminjasafn Íslands].

[4.]

ing of concrete. By so doing, Jón Þorláksson highlighted the strong link between natural resources and man-made construction, which he had been researching for years. Second, he admitted that a reinforced concrete structure would have been more expensive. He added, however, that the only way of having cheaper reinforced concrete bridges around the island was to train the local builders on how to build them. This knowledge necessarily had to come from abroad, and specifically from Denmark.[27]

The engineer's suggestions to the Icelandic government did play a pivotal role. After a call for tender, published in the Danish journal *Ingeniøren*, in January 1908 the task was assigned to Christiani & Nielsen.[28] Jón Þorláksson had received their project one year earlier, and those drawings attest that the firm was still proudly boasting its status as Hennebique concessionaire. Yet, by 1908 the name of Christiani & Nielsen did not appear in the pages of *Le Beton Armé*

[27] ÞÍ, *Stjórnarráð Íslands* II. *Skrifstofa* B/63, Db. 2, nr. 698 (1909). Letter by Jón Þorláksson to the Cabinet of Iceland, 26 January 1907.

[28] ÞÍ, *Stjórnarráð Íslands* II. *Skrifstofa* B/63, Db. 2, nr. 698 (1909). Letter by the Copenhagen office to the Cabinet of Iceland, 18 January 1908.

anymore, thus the construction was not even mentioned as a Hennebique product. The director of the works was engineer Knud Reffstrup, employed by Christiani and Nielsen – of whom, however, no archival records can be found, with the exception of a photograph of the bridge on which the workers' names were added.[29] In 1908, in a remote corner of the Icelandic landscape, over a powerful river and between wild mountains, the already mature European tradition of reinforced concrete patents was embraced for the first time in the history of the country (Fig. 3).

A wool factory and the national library (1907–09)

In 1906, the headquarters of the Reykjavík-based wool factory Iðunn burned down. Open since December 1903, production had taken place in a large timber building on the eastern outskirts of Reykjavík. Soon after the fire, local newspapers wrote about a forthcoming building in concrete.[30] The factory had to be rebuilt quickly, and with a guarantee of better resistance to fire. Reinforced concrete patents had already conquered Europe with their gospel of fireproof qualities and enduring resistance to earthquakes: the reconstruction of Iðunn was the perfect opportunity to demonstrate these properties to the Icelandic audience.

The new factory was built on the same spot as the old one, in what is today's Skúlagata 42. Wool production stopped in 1914, and the building was transformed into a paint and varnish factory.[31] The structure was destroyed in 1989, and the absence of the original drawings makes it difficult to analyze and evaluate the actual contribution of the Hennebique patent. A few photographs and some later drawings attest, however, the presence of what could have been a Hennebique system of pillars, beams, and ribbed slabs (Fig. 4).

The news of the reconstruction of Iðunn spread through the Icelandic newspapers. A short article published in June 1907 mentioned a "novelty in architecture", and claimed that the new factory was going to be rebuilt in reinforced concrete, following the "Hennebique method". The article asserted the fireproof qualities and the resistance to eartquakes of such structures. Moreover, the text declared that "the construction will be handled by Danish experts", and this will be a chance for the Icelanders who will take part in the process "to learn from them, and bring this knowledge into the country". Eventually, it claimed that the "moving spirit" of this method was engineer Thorvald Krabbe.[32]

[29] Pétur Ingólfsson, "Bogabrúin á Fnjóská", *Lesbók Morgunblaðsins*, 3 July 1993, pp. 6–7.

[30] Klæðaverksmiðjan "Iðunn", *Óðinn*, 1, 1, 1905, pp. 4–6; "Mikill húsbruni enn", *Ísafold*, 33, 50, 1906, p. 199; Klæðaverksmiðjan ,"Iðunn", *Þjóðólfur*, 58, 49, 1906, p. 188.

[31] Lýður Björnsson (Note 2), p. 73.

[32] Nýung in húsagerð, *Norðurlandi*, 6, 48, 1907, p. 168.

By summer 1907, Danish-Icelandic engineer Krabbe, graduated from the Polytechnic School of Denmark, had already moved to Reykjavík and was active as State engineer.[33] During his career, Krabbe travelled extensively around the country. His tasks were mainly related to infrastructures: he supervised the construction of several harbours, lighthouses, and electricity stations.[34] Krabbe's vast network of professional relations emerges from the copies of his letters, collected in a book covering the years 1906–1909.[35] His connections to Denmark's reinforced concrete construction might have stemmed from his use of concrete in the building of piers and breakwaters for Icelandic harbours. In those years, in fact, Krabbe's letters attest that he was working on the harbours of Ísafjörður, Akureyri, and the Westman Islands, among others.

What may truly attest to Krabbe's role as the "moving spirit" behind the use of the Hennebique method at Iðunn are two copies of letters sent by the engineer. The first, dated 10th November 1906 and addressed to a photography atelier in Copenhagen, mentions a drawing to be reproduced in two copies and then to be sent to Christiani & Nielsen, and to the mastermason Carl Schiötz – who, as we have seen, were both Hennebique concessionaires in Denmark.[36] It is therefore likely that Krabbe provided his project for the reconstruction of the wool factory, asked the Hennebique firms to produce the authorized version of the structural design and then accepted the best deal. The second letter is dated 17th April 1907, when probably the "Danish experts" were already working on the reconstruction of the factory in Reykjavík. Krabbe wrote to the commission in charge of the construction of the National Library in Reykjavík and on behalf of the Iðunn factory. The engineer suggested that the commission hire two "workers", who had already been employed by Iðunn, to build the library's reinforced concrete slabs. These workers should not have been paid more than the regular price for a mastermason in Reykjavík; Krabbe attested that for their work at Iðunn they had been paid 500kr.[37] If the former letter confirms some direct connections between Krabbe and Hennebique concessionaires in Denmark, the latter highlights an interesting fact: the Hennebique patent was used, or at least proposed, for the construction of the National Library and Museum, designed by Johannes Magdahl Nielsen (1862–1941) and still today one of Reykjavík's landmarks (Fig. 5).[38] It is also important to consider that in the same year – 1907 – reinforced concrete was first taught in a series of lectures at the Polytechnic School of Copenhagen by Danish engineer Edouard

[33] Sveinn Þórðarson, *Frumherjar í verkfræði á Íslandi*, Reykjavík: Verkfræðingafélag Íslands, 2002, pp. 71–80.

[34] T. Krabbe, *A Few Remarks on Icelandic Lighthouse Practise*, Reykjavík: Iceland Lighthouse Service, 1932.

[35] ÞÍ, Vita- og hafnarmálastofnun, B-BDA 1. *Bréfabók landsverkfræðings* 1906–1909. See also in: ÞÍ, Stjórnarráð Íslands II, *Skrifstofa* 0000 B/59. Örk. 8. Db. 2, nr. 570. *Beiðnir um aðstoðarverkfræðing (fjárlög 1908/1909, 16 grein 10)*. 1636/1910.

[36] ÞÍ, Vita- og hafnarmálastofnun, B-BDA 1. *Bréfabók landsverkfræðings* 1906–1909, 102. 10 November 1906.

[37] ÞÍ, Vita- og hafnarmálastofnun, B-BDA 1. *Bréfabók landsverkfræðings* 1906–1909, 387. 17 April 1907.

[38] Pétur H. Ármannsson, "Veglegasta og vandaðasta steinhús þessa lands, Safnahúsið frá sjónarhóli íslenskrar húsagerðarsögu", in Eggert Þór Bernharðsson (Ed.), *Safnahúsið 1909–2009: Þjóðmenningarhúsið*, Reykjavík: Þjóðmenningarhúsið, 2009, pp. 20–35.


[5.]


[6.]

Fig. 5. *The former National Library, now House of Culture*, ca. 1910–20 [courtesy of: National Museum of Iceland / Þjóðminjasafn Íslands].

Fig. 6. *The sanatorium at Vífilsstaðir, Ársrit Heilsuhælisfélagsins*, vol. 2 (1912).

Suenson. The developments of the technique in Denmark were soon mirrored in its first uses in the remote Icelandic context.[39]
Despite evidence derived from Icelandic sources, the Hennebique archives hold no mention of the rebuilding of Iðunn, nor of the bridge over the Fnjóská river.[40] When it comes to the bridge, the drawings attest that Christiani & Nielsen were operating as concessionaires of the Hennebique patent. The same cannot be said, however, for the rebuilding of Iðunn, as it was not possible to find the original drawings. Although it is impossible to be entirely sure of an official use of the Hennebique patent in the factory, in July 1907 the journal *Le Beton Armé* mentioned a project for a "plancher de filature", under the direction of the concessionaire C. Schiötz in the "bureau de Copenhague". Perhaps it was the factory Iðunn, for the first time pulling Iceland closer to the centre of the European building technology. Perhaps, however, the project was never considered by the Hennebique offices, as it was far too humble compared to what the enterprise had been doing in the continent. However, no matter how small the building was, it represented a huge step ahead for the country's "technical development", as positively portrayed by Thorvald Krabbe in his 1946 book.[41]

Conclusions: The legacy of Icelandic concrete construction

The construction of the bridge over the Fnjóská river, the wool factory and the national library acted as turning points for Icelandic construction, and emerged as crossroads where Icelandic infrastructural and architectural needs met with European engineering tradition. These structures served as a stage where Icelandic engineers and builders could face and learn from the continental construction experience. It's thus no coincidence that already in 1910 the first locally-designed public building emerged near Reykjavík: the sanatorium in Vífilsstaðir, designed by Iceland's first educated architect Rögnvaldur Ólafsson (1874–1917) and supervised by the first generation of Icelandic engineers, including Jón Þorláksson and Thorvald Krabbe (Fig. 6). The building was wholly in concrete, with reinforcement bars in the horizontal slabs and in the staircases. Krabbe himself was in charge of the structural calculations.[42] The sanatorium was the tangible proof that early-twentieth century Icelandic engineers were largely indebted to and saturated with

[39] L. Karlskov Skyggebjerg, "E. Suenson og tidlig materialelære i Danmark", *Historisk Beton* lecture series, *https://www.youtube.com/watch?v=WT-T8Rbf7U_g*, 1:06:41, last accessed 27/04/2021.
[40] As this article is being written, the Hennebique Archives at *La Cité de l'architecture et du patrimoine* in Paris are being reordered, thus the online inventory is only partial. There seems to be no mention to any of the discussed projects, not even in the archival section listing the unidentified projects of Hennebique concessionaires. Refer to the essay by V. Fasoli in this volume.
[41] Krabbe (Note 19).
[42] Rögnvaldur Ólafsson, "Lýsing á hælinu", *Ársrit Heilsuhælisfélagsins*, 2, 1912, p. 19.

Danish and continental scientific building knowledge. From then onwards, the Icelandic engineering profession became increasingly autonomous and played a huge role in the modernization of the country.

This essay tried to explain how scientific and technical knowledge regarding reinforced concrete construction reached Iceland at the beginning of the twentieth century. Expertise on reinforced concrete patents became available in Iceland only when those patents started losing their legal status in the continent. However, the use of these patents, and specifically Hennebique's, was part of a key process of transfer of knowledge from the continent to the island. Furthermore, it also played a pivotal role in the modernization of the country's infrastructures and public services. Due to the scarcity of building experts and the geographical isolation of the country, Icelandic concrete construction remained more or less amateurish until the early 1940s. However, this should not lessen the importance of the first generation of Icelandic engineers. They are often remembered as the true pioneers of Icelandic twentieth-century history, and their contribution was essential in the development of Iceland's "concrete age".[43] The history of Iceland's first reinforced concrete structures allows us to understand their significance as key moments and building ventures that helped the spread of engineering and technical knowledge in such a peripheral and isolated environment at the edge of Europe.

[43] Usually referred to as *steinsteypuöld-din* in Icelandic historiography. Nannini (Note 1).

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Hennebique's Italians in the early days of reinforced concrete construction outside Europe: the Cairo Museums (1894-1903)

The paper examines the presence of Italian professionals at Hennebique's construction sites at the time when the reinforced concrete patent was launched on markets outside Europe. The analysis was conducted between 2012 and 2014 in the Fond Hennebique at IFA (Institut Français d'architecture, Centre d'archives d'architecture du XXe siècle) and studies the relationship between the presence of Italians builders and the diffusion of the patent in Egypt at the time of the construction of the Museum of Egyptian Antiquities and the Arab Art Museum (1894-1903).

Keywords
Construction; History; Reinforced concrete; Cairo; Museum

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Hennebique Moves North: The First Applications of Reinforced Concrete in Iceland (1907–10)

This essay retraces the early uses of reinforced concrete construction in Iceland in the first decade of the twentieth century. Technical knowledge on reinforced concrete structures reached Iceland much later than other European countries and it was deeply connected to the expertise acquired by the first generation of Icelandic engineers at the Polytechnic School of Copenhagen. This study investigates the adoption of the Hennebique patent by Danish and Icelandic professionals, with a case study of the Danish building firm Christiani & Nielsen. The Icelandic buildings where reinforced concrete was first used were not mere technical accomplishments but major cornerstones in the process towards the political and material independence of the country.

Keywords
reinforced concrete; Iceland; Hennebique; Christiani & Nielsen; Den Polytekniske Læreanstalt

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