Structural Innovation and Local Agency in Siam: The Hennebique System in Bangkok's Ananta Samakhom Throne Hall

Pinai Sirikiatikul[1]

Abstract—The adoption of the French Hennebique system in constructing the Ananta Samakhom Throne Hall (1907–1915) introduced advanced reinforced concrete to Siam, but also imposed proprietary constraints, limiting local control over design and contractor selection. Siam's Public Works Department (PWD) engineers were relegated to supervisory roles under Hennebique's patent. Meanwhile, Bangkok's soft soil led to foundation settlement, exposing flaws in the Compressol pile system employed by Hennebique's concessionaire. To resolve this, E.G. Gollo, an Italian engineer employed by the Siamese government, devised a caisson foundation, stabilizing the structure and reducing reliance on Hennebique's specialists. This article examines how Gollo's intervention marked a crucial shift in Siam's modernization, strengthening local agency in architectural development and technological adaptation.

Keywords: Ananta Samakhom Throne Hall; Construction History; Engineering Innovation; Hennebique System; Public Works Department (PWD); Reinforced Concrete

Reinforced Modernity in Siam

King Chulalongkorn's ambition to construct a Western-style throne hall in Bangkok marked a pivotal moment in Siamese architectural history, signaling a bold shift toward modernization. His vision took root in the 1870s when he commissioned British architect John Clunis to design the Chakri Maha Prasat Throne Hall. However, Regent Somdet Chao Phraya Borom Maha Sri Suriyawongse (สมเด็จเจ้าพระยาบรมมหาศรีสุริยวงศ์ ช่วง บุนนาค; 1808–1883) insisted that the king's symbolic throne hall must adhere to ancient royal traditions, particularly the tiered roofs emblematic of a "Prasat" (Damrong 2475: 2; Chulalongkorn 2514: 51; Duangchit 2535: 72), even though the delivery of imported ironwork intended for a Western-style roof had already arrived in Siam at the time.[2] This conflict of ideals resulted in a compromise,

[1] Silpakorn University, Bangkok.
Email: sirikiatikul_p@silpakorn.edu.

[2] This unused ironwork was later repurposed at the request of Prince Chaturonrasmi (สมเด็จฯ เจ้าฟ้าจาตุรนต์รัศมี; 1857–1900) for his residence at Phra Ratcha Wangdoem Palace (พระราชวังเดิม). See letter of King Chulalongkorn to Chao Phraya Phanuwong Maha Kosathibodi (เจ้าพระยาภาณุวงศ์มหาโกษาธิบดี ท้วม บุนนาค), 3 June 1878, in National Archives of Thailand, มร. 5 รล–พศ/2; National Archives of Thailand, มร. 5 นก/12 เรื่อง 317; Chulalongkorn 2477: 302.

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merging Western and Siamese architectural elements. King Chulalongkorn's determination to modernize architecture grew stronger. Three decades later, he commissioned the Ananta Samakhom Throne Hall (พระที่นั่งอนันตสมาคม), a project that fully embraced Western architectural principles and cutting-edge construction techniques, notably reinforced concrete. Although King Chulalongkorn (r. 1868–1910) did not live to see its completion in 1915, the Ananta Samakhom Throne Hall stands as a powerful testament to his visionary leadership, representing Siam's decisive embrace of modern global building technology.

Reinforced concrete, a revolutionary method that transformed global construction practices in the late 19th century, was among the most significant innovations of the era. While a few systems for reinforced concrete emerged during this period, French engineer François Hennebique's (1842–1921) approach stood out as the most flexible and widely used. The Hennebique system integrated structural elements such as columns, beams, and slabs into a unified framework, with steel bars embedded in concrete for reinforcement. By significantly enhancing the strength, durability, and fire resistance of buildings while enabling long-span structures, the system offered a combination of capabilities that were unattainable with traditional materials. These attributes made it popular for constructing long-span buildings such as bridges and ribbed domes worldwide (Curley 2010).

To date, much of the scholarship on King Chulalongkorn's architectural legacy has concentrated on the adoption of Western styles, treating them as symbolic gestures of civilization and modernization. While these interpretations offer valuable cultural and political insights, they often prioritize form, style, and aesthetics over the material realities of construction. By revisiting these propositions and re-centering attention on the process of construction, this article argues that the integration of reinforced concrete was far more central to shaping Siam's architectural modernity than previously acknowledged. This approach highlights the interplay between technological adaptation, power dynamics, and local agency, offering a deeper understanding of Siam's modernization efforts.

The first proposition examines how Siam's architectural modernism responded to Western colonialism. Traditional narratives, shaped by royal nationalism, connect King Chulalongkorn's adoption of Western architecture with efforts to counter Western dominance and preserve Siam's sovereignty. Sumet Jumsai, for instance, argued that emulating Western lifestyles was seen as necessary to avoid colonization, as "Foreigners [ฝรั่ง] measure progress solely by their technology and culture; if any country is not considered advanced in their eyes, it might end up as a colony" (2525: 294; my translation). Similarly, Chot Kalayanamitr (2526: 57–76) noted that the influx of Western architects transformed Bangkok, enhancing its appeal to foreigners and countering perceptions of barbarism. Though this perspective may seem outdated, it reflects the view that modernization was crucial to Siam's independence, a

belief echoed by some hyper-royalists today.

The second proposition examines the consumption practices of Siamese elites, shaped by their Westernized preferences. Maurizio Peleggi (2002) contends that the adoption of Western luxury goods, architecture, and public spectacles was a deliberate strategy to enhance the symbolic capital of the Siamese monarchy, intentionally distancing it from Indian and Chinese cultural spheres. In his analysis of Suan Dusit's development—a royal residential complex purposefully distinct from the traditional Grand Palace—Peleggi calls attention to the pivotal role of European professionals within the Public Works Department (กรมโยธาธิการ) in reshaping Bangkok's royal and urban landscape. The construction of the Ananta Samakhom Throne Hall, other residences within Dusit Palace, and the creation of the Ratchadamnoen Boulevard, which connected the new complex to the Grand Palace, marked a departure from traditional architectural designs. This transformation introduced not only more refined private and public spaces but also a deliberate alignment with a localized conception of "civilization", *siwilai* (Peleggi 2002: 75–88, 95–102). As Thongchai Winichakul (2000: 529–534) argued, *siwilai* (ศิวิไลซ์) encompassed aspirations for progress and modernity that arose from Siamese elites' concern about Siam's standing among modern nations. This concept extended beyond mere Westernization, reflecting a selective adaptation of global influences to assert Siam's sovereign identity on the world stage. By incorporating Western forms and practices, the Siamese monarchy signaled a shift toward these ideals while maintaining an autonomous and uniquely Siamese appropriation of "civilization".

The third proposition emphasizes the concept of hybridity—defined as the fusion or blending of disparate cultural or architectural elements—suggesting that architectural modernization during King Chulalongkorn's reign was not merely a response to colonial pressures but also a selective integration of foreign influences with local traditions. Somchart Chungsiriarak (2553) points up this fusion, particularly in the design of the Ananta Samakhom Throne Hall, which blends Western architectural paradigms with Siamese traditions. As Somchart noted, "This throne hall was designed like a Thai temple, falling into the category of turning a Western building into Thai" (2553: 130; my translation). This focus on hybridity during King Chulalongkorn's reign laid the foundation for subsequent architectural developments, where the interplay between foreign and local elements continued to evolve. Expanding this framework, Chatri Prakitnonthakan (2563) applies the notion of hybridity to his analysis of post-1932 architecture, challenging Eurocentric readings of modernity. He argues that modernity is not a singular, uniform process but one of adaptation, where foreign and local elements coexist and intertwine. In Thailand's case, Chatri asserts that this hybridity—between "modernity" and "Thainess", shaped by the country's socio-political context—forms the key to understanding the trajectory of modern architecture (2563: 6–9). Thus, modernization in Thailand is not a

passive importation of Western ideas but a dynamic and localized reinterpretation.

While these propositions interpret Western architecture in their own terms, they often overlook the critical innovations in construction technologies that made such designs possible. Discussions on the Ananta Samakhom Throne Hall often acknowledge its use of reinforced concrete but rarely explore its broader significance (Somchart 2553: 126–133; Koompong 2013: 71–88). This reflects a common trend in architectural historiography, where construction is treated as secondary to style, symbolism, and political implication. Such an approach diminishes the transformative power of construction technologies, which play crucial roles in reshaping the relationship between design and construction.

Among the scholars of Western architecture in Siam, Francesca B. Filippi stands out for her focus on these often-overlooked construction processes. Her research on the Ananta Samakhom Throne Hall highlights the pivotal role of reinforced concrete in Siam's modernization. Drawing on archival materials from Turin architects and Italian engineers working for Siamese administrations during the Fifth (1868–1910) and Sixth (1910–1925) Reigns, Filippi examines how technological innovations symbolized Siam's attempt to balance the adoption of European technologies with resistance to European political and economic dominance. As Filippi notes, "Relations were ambiguous, vacillating between Siam's need to recruit European technicians and its equally important need to resist the political and economic pressure exerted by European firms" (Filippi & Fasoli 2014: 1). Her work urges a more nuanced view of how technology, power, and autonomy shaped Siam's modern identity. Yet, while she acknowledges this ambiguity, her analysis stops short of examining exactly how Siam actively managed and negotiated these conflicting pressures.

This article builds on Filippi's foundational research, expanding the focus to address these limitations. While her work offers crucial insights regarding the introduction of reinforced concrete in the country's modernization, it remains predominantly in European perspectives—a reflection of the sources she uses—leaving key aspects of Siamese agency underexplored. By incorporating previously unexamined local sources, this article offers a fresh analysis of how reinforced concrete was not merely imported but strategically adapted to local conditions. It highlights the nuanced strategies Siam employed to reconcile its modernizing ambitions with the imperative of maintaining autonomy.

Two observations from existing scholarship on King Chulalongkorn's modernization further support the argument presented here. While these works do not specifically address reinforced concrete, they align with a broader scholarly consensus that this article builds upon. David Wyatt's characterization of "Young Siam" (1969), led by King Chulalongkorn, provides a compelling framework to understand this agency. Comprised of younger royal family members and reform-minded officials, "Young Siam" embraced Western ideas not merely as tools but as values

aligned with Thai principles, using them as foundations for political and institutional reforms (Wyatt 1969: 44–45). In addition, Kullada Kesboonchoo-Mead emphasizes King Chulalongkorn's ability to strategically blend old and new, observing that "the Thai monarch chose to keep old practices when it suited him while also introducing modern practices" (2004: 125). Together, Wyatt's and Kullada's perspectives provide a robust lens for understanding the selective modernization strategies employed by the Siamese elite.

Building on this foundation, this article reexamines the adoption of foreign technologies such as reinforced concrete, shifting the focus from European influences to local agency. It reframes the construction of the Ananta Samakhom Throne Hall as a process of negotiation, in which European advancements were selectively employed to align with Siam's modernization goals and reinforce royal sovereignty. This approach demonstrates that modernization in Siam, through the early use of reinforced concrete, was neither straightforward nor entirely European-driven, but the result of a dynamic interplay between technological advancements, power structure, and local autonomy in the early 20th century.

The Transition to Modern Building Materials

Historically, the Siamese court relied on the *corvée* system, a state-controlled mechanism that ensured a steady supply of materials and labor for construction. However, the 19th century marked a significant shift as capitalism emerged, leading to the decline of the *corvée* system and the increasing reliance on Chinese migrant labor. This transition was pivotal, transforming Siam from a system of state-controlled resource management to a market-driven economy where building materials and labor became commodities. Under King Chulalongkorn's reign from the 1870s onward, this economic shift fueled ambitious modernization projects, spurred growth in the building industry and attracted European contractors to Bangkok.

These contractors, responding to the emerging market-driven economy in Siam, revolutionized the construction industry by introducing general contracting practices that prioritized formal agreements, precise cost estimates, and comprehensive project management. This system allowed clients to anticipate building costs in advance, reflecting the contractors' emphasis on efficiency and profitability. It also provided opportunities for generating profits at various stages of the building process, such as through material procurement or labor management. The Public Works Department (PWD) was inaugurated in 1889 and later became part of the Ministry of Public Works when it was established in 1892, alongside four other departments: Railways, Post and Telegraph, Goldsmith, and the Ten Crafts. Upon its inauguration, Prince Narisara Nuwattiwong (นริศรานุวัดติวงศ์; 1863–1947) served as the first Minister of the PWD, with the English engineer E.F.W. Wilkinson as Engineer-in-Chief. By this time, the contracting system introduced by European firms had

become standard practice—whether through external contractors or by incorporating these procedures directly within the PWD itself (Pinai 2565: 72–90).

As market-driven forces transformed labor and resource management in Siam, they also introduced modern building materials such as iron and cement. While traditional materials such as wood, brick, and stone had long been the backbone of government construction projects, the second half of the 19th century saw the increasing use of imported iron and cement in Siamese construction.[3] European contractors, working with Chinese laborers, played distinct roles in this transformation. Iron, often fabricated by European manufacturers, became the preferred material for larger and more complex structures, particularly in public buildings and infrastructure projects such as bridges, train stations, and government offices, where durability and strength were paramount.[4]

Cement, though imported, was locally mixed with aggregate, sand, and water, and Chinese laborers were key in providing the manual workforce required for tasks such as transporting materials, preparing mixtures, and laying cement under the direction of European supervisors. Initially valued for its resilience, cement was first applied in mass, unreinforced structures such as roads and river embankments, where its durability was indispensable.[5] Its application soon expanded to include roof and floor tiles, as well as serving as a modern alternative to traditional mortar and plaster in decorative work. This steady yet decisive shift towards modern materials and techniques marked a new era in Siamese construction, where foreign innovations were progressively integrated with traditional practices.

Recognizing Siam's growing dependence on cement, John Clunis (1830–1894), a British architect formerly based in Singapore and later Siam's first royal architect,[6] proposed establishing a cement factory in Siam as early as 1885, with the capital and locations to be provided by King Chulalongkorn. This initiative predated the more commonly noted 1908 proposal. Although the King recognized the project's potential to significantly advance Siam's construction industry, his concerns about Clunis's ability to execute it successfully ultimately led to its rejection.[7] Nevertheless, the importance of cement continued to grow, with Siam relying

[3] Evidence indicates that imported cement was in use as early as 1882, for the restoration of Wat Phra Kaew (วัดพระศรีรัตนศาสดาราม), where it was applied to the repairs of the Ordination Hall (พระอุโบสถ) and the surrounding low walls (กำแพงแก้ว). However, its introduction may have occurred even earlier. See National Archives of Thailand, มร. 5 ศ/27 ศ6/46 (พ).

[4] For an early account of metal construction in Siam, see Filippi & Fasoli (2014: 21–28), particularly Vilma Fasoli's discussion in the section "The Società Nazionale Officine Savigliano and the Italian contribution to the introduction of metal construction in Siam".

[5] Concrete was regarded as the ideal material for the embankment, with Prince Narisara recommending its use along the riverfront at Wat Ratchaburana (วัดราชบูรณะ กรุงเทพฯ) in 1889. He acknowledged its superior durability, with an expected 150-year lifespan, despite being the most expensive option compared to cast iron and wood. See National Archives of Thailand, 16 ม.ค.–18 พ.ย. 108, กร. 5 ย/20 ยธ 8.3/1.

[6] During his tenure as royal architect for the Chakri Maha Prasat Throne Hall, Clunis also served as contractor for the pavilions in front of the hall. See National Archives of Thailand, มร. 5 นก/21 เรื่อง ที่ 4.

[7] National Archives of Thailand, 1885 (จุลศักราช 1247), มร. 5 รล พศ/16.

entirely on imports until 1916, when the first locally established cement factory, founded in 1913, began production.

By the late 19th and early 20th centuries, cement had become indispensable to Siamese construction, driving public infrastructure projects such as the expanding railway network (Brown 1988: 151; Porphant 2015: 463) and in supporting developments in the newly cut streets of Bangkok, particularly in Sampheng (Chua 2013: 160).[8] Cement imports rose significantly, from 11,275 casks in 1898 to 25,972 casks in 1901, reflecting the nation's growing reliance on this material during its modernization. Although imports temporarily declined between 1904 and 1905, they rebounded by 1907, coinciding with the commencement of major projects such as the Ananta Samakhom Throne Hall, which marked a renewed surge in building activity. By 1913, Denmark, Cochinchina, and Hong Kong had emerged as Siam's top three cement suppliers, catering to the increasing demand for this essential building material.[9]

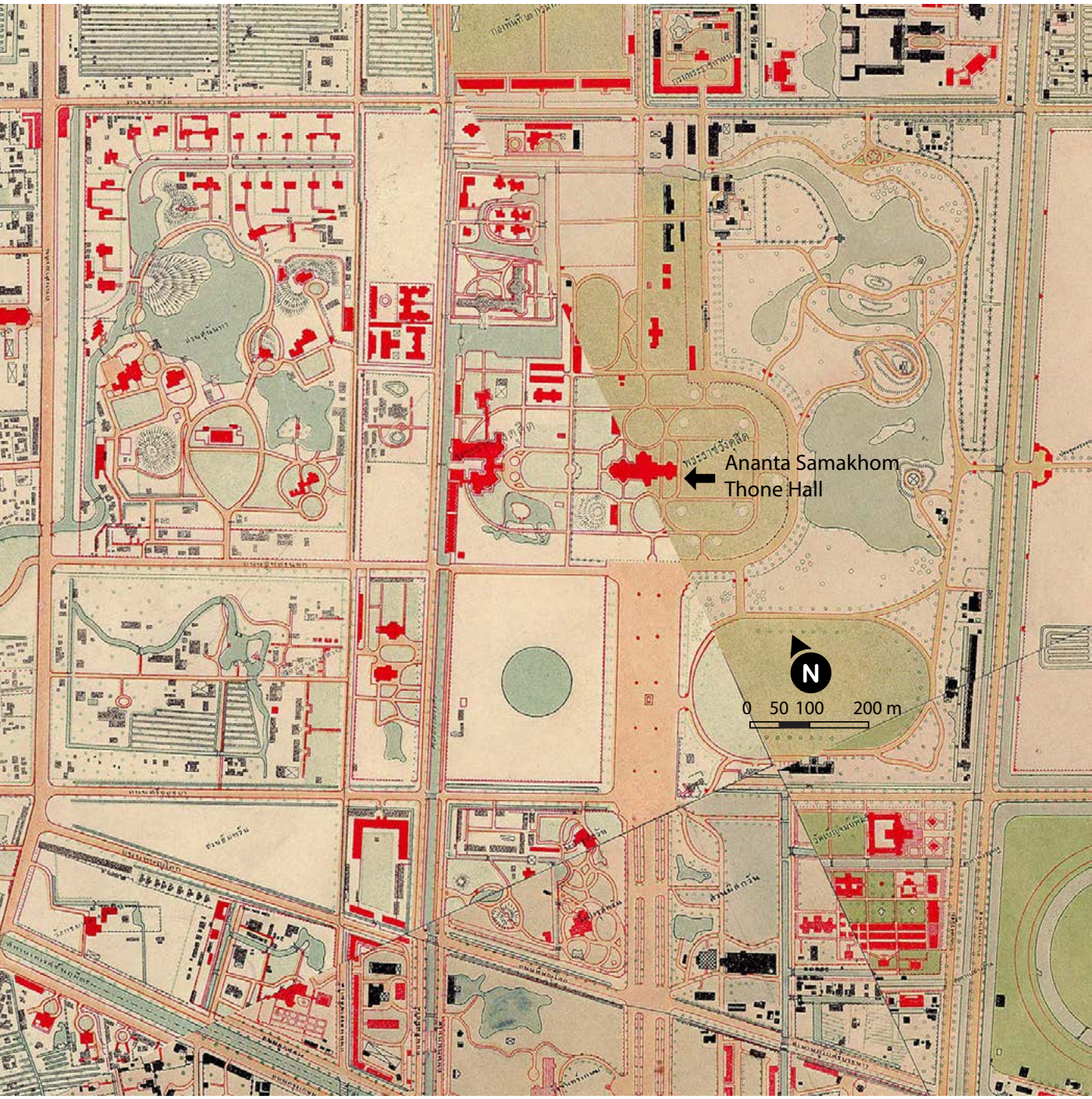
Despite cement's growing prominence in construction, its integration posed significant challenges. European contractors, entrusted with key projects, encountered structural weaknesses that exposed the limitations of contemporary construction. A notable example is the clock tower at the Supreme Court of Bangkok, constructed by Joachim Grassi, (1837–1904), an Austrian-born architect who became a French national in 1883. Within just three years of completion, the tower exhibited alarming cracks and instability, ultimately leading to its demolition in 1892.[10] Such failures highlighted the inadequacies of existing techniques and underscored the urgent need for more reliable and robust construction methods to meet the demand of Siam's modernization.

As the 19th century gave way to the 20th, King Chulalongkorn's architectural ambitions—most notably the creation of the new royal residence at Dusit Park (สวนดุสิต)—sought to redefine the Siamese monarchy's modern identity, distinguishing it from the traditional grandeur of the Grand Palace. Central to this vision was the Ananta Samakhom Throne Hall, conceived not only as a monumental structure but as a symbol of Siam's progress. Positioned at the end of Ratchadamnoen Boulevard—a newly cut thoroughfare linking the Grand Palace with the emerging Dusit Palace—it was intended to embody Chulalongkorn's modernization and realize his long-standing aspiration to erect a Western-style throne hall, a vision he had first pursued unsuccessfully with the Chakri Maha Prasat (พระที่นั่งจักรีมหาปราสาท). However, the failure of its brick and cement foundation (Gallotti 1910: 67) exposed the limitations of traditional construction methods, undermining the broader ideological aspirations tied to the project **[Map 1]**.

[8] By 1931, Sampheng had become the area most densely populated with concrete buildings.

[9] The statistics on cement imports in this paragraph are sourced from the *Diplomatic and Consular Reports* and *The Foreign Trade and Navigation of the Port of Bangkok* for the years 1898 to 1913. These records indicate no documented cement import statistics prior to 1898.

[10] For the building inspection of the Supreme Court conducted by Wilkinson, refer to the National Archives of Thailand, 14 September 1890 (ร.ศ. 109), กร. 5 ยธ/20 ยธ 8.3/2.



Map 1: Dusit Palace, based on 1925 survey, with the Ananta Samakhom Throne Hall at its center, Bangkok © Royal Thai Survey Department (Adapted)

This structural collapse accelerated Siam's interest in reinforced concrete, a European innovation promising greater durability and new structural possibilities. Yet, the adoption of reinforced concrete in any context is not merely a substitution of materials; it carries far-reaching implications, transforming construction practices by reshaping production methods and labor dynamics. In Siam, its introduction must be understood within the global development of reinforced concrete in the late 19th century together with its profound impact on local authority.

The Rise of Reinforced Concrete: The Hennebique System

By the late 19th century, the transformation of concrete into modern reinforced concrete was driven by the integration of steel reinforcement—a groundbreaking development independently pioneered in France, England, and the United States. This innovation allowed a few select firms to establish patented systems, which they zealously guarded and commercially exploited, protecting technical details through litigation to maintain their competitive edge (Cusack 1987: 61). For clients and architects, engaging with these specialized firms became a necessity, as only these firms possessed the expertise to design buildings using their proprietary systems. Relying on these firms became synonymous with ensuring construction reliability and success (Forty 2012: 15, 18).

Among these patented systems, Hennebique's, introduced in 1892, emerged as the most prominent. By 1905, the Hennebique system controlled roughly one-fifth of the global market, achieving this dominance without the firm requiring significant capital investment or maintaining its own dedicated construction workforce, relying instead on a network of agents and concessionary contractors. The cornerstone of this success was Hennebique's Paris-based engineering office, which translated architects' designs into structurally sound reinforced concrete framework. Upon receiving these designs, Hennebique's specialists meticulously adapted them to align with the firm's proprietary system, ensuring all necessary structural details complied with its specifications. This carefully orchestrated operation, supported by agents and contractors selected by Hennebique rather than the architects, cemented the system's widespread adoption (Cusack 1986: 184–185; Forty 2012: 18).

While the Hennebique system ensured precision and reliability, it significantly diminished architects' influence, rendering them increasingly dependent on the specialized expertise and authority of the firm (Cusack 1986: 184–185). This shift in power dynamics reflected a broader transformation within construction practices, as engineering and material expertise began to overshadow traditional architectural authority. This transformation was particularly evident in the construction of the Ananta Samakhom Throne Hall, where the Hennebique system played a crucial role in ensuring its structural integrity. The Throne Hall illustrates how the adoption of Hennebique system not only provided the Siamese government with the advanced building

technology but also curtailed its architectural autonomy, profoundly reshaping palace construction practices.

The Creation of the Ananta Samakhom Throne Hall

The Ananta Samakhom Throne Hall stands as a testament to King Chulalongkorn's ambitious architectural vision, despite facing silent criticism over its perceived extravagance and necessity.[11] On 23 March 1907, just before his second trip to Europe, the King appointed Chao Phraya Yommarat, also known as Pan Sukhum (ปั้น สุขุม; 1862–1938), to oversee the project, instructing him to commence construction without delay.[12] To mitigate potential criticisms, the King brought to the fore the importance of advance cost estimation and proposed using Privy Purse funds, with plans for reimbursement at a later stage.[13] Unlike the Chakri Maha Prasat Throne Hall, where compromises were made, King Chulalongkorn remained resolute in ensuring that the Ananta Samakhom Throne Hall would be completed without compromise.

The monumental scale and height of the Ananta Samakhom Throne Hall—measuring 49.5 meters in width, 112.5 meters in length, and crowned by a central dome rising 49.5 meters above the ground—posed significant challenges for ensuring structural stability. According to *Bangkok Times*, the dome was designed to dominate the skyline, standing "higher than the pagoda of Wat Saket, or the masthead on Phra Maha Chakri" (1908: 5). While this observation is partially misleading, as the pagoda of Wat Saket rises to a height of 59.75 meters, it reflects the prominence the dome was expected to achieve in the reporter's view.

Initial efforts by PWD engineers to use solid brick for the foundation quickly proved inadequate. As Paul Gallotti, a columnist for *Le Béton armé*—Hennebique's monthly journal—noted: "The engineers tried to establish a few meters deep of soil plate made out of strong brick that usually is used within the country. The instability of the base location disallowed the continuation of the construction that has already used up a significant amount of funds" (1910: 67–68). The brick foundation system Gallotti described was likely considered the best available in Siam at the time, as detailed in a *Construction Manual* (Ploy & Ju 1909: 16-17). This method involved a brick layer resting on a mixture of cement and broken brick, used as an aggregate, with driven wooden piles beneath to provide additional support on the region's notoriously unstable soil **[Figure 1]**. However, this early setback created a critical pause in the project, ultimately leading to an inevitable shift toward the more reliable and innovative reinforced concrete system.

Carlo Allegri's Initiative: Partnering with Reinforced Concrete Experts

The transformative shift in Siamese construction practices was heavily influenced by the Italian engineer Carlo Allegri (1862–1938), Chief Engineer of the Public Works Department. Allegri

[11] Letter of Chulalongkorn to Yommarat, dated 25 March 1907, as quoted in Bandit & Pirasri 2550: 837–838.

[12] Ibid., as quoted in Bandit & Pirasri 2550: 836.

[13] Ibid., as quoted in Bandit & Pirasri 2550: 837–838.

Figure 1: A diagram of a foundation considered the most effective and recommended for constructing a stable foundation in 1909 © Ploy & Ju 1909: I, 17

began his career in Siam in 1889 with the contractor firm Grassi Brothers and was appointed as an assistant to PWD Chief Engineer Wilkinson within a year. By 1892, Allegri succeeded Wilkinson as Chief Engineer (Peleggi 2002: 83), marking the start of a career that would redefine Siam's construction practices. While Allegri is celebrated for recruiting European architects and engineers for the Ananta Samakhom Throne Hall, his equally vital but often overlooked contribution was his selection of reinforced concrete firms.

As Filippi noted, Allegri came from a family of general contractors specializing in large-scale construction, particularly bridges. Eusebio Allegri, a key figure in the industry, established important connections, notably with the Italian firm Dominio Borini, renowned for the Dulac system for pressurized caissons (Filippi & Fasoli 2014: 9). These connections proved invaluable as the Siamese government sought cutting-edge expertise for the Ananta Samakhom Throne Hall.

Recognizing Allegri's expertise, Chao Phraya Yommarat entrusted him with the task of studying advanced foundation systems in Europe. Accordingly, Allegri approached two prominent firms: Domenico Borini in Turin and Hennebique in Paris. Although Allegri initially favored Borini due to familial connections, Borini declined the project, citing its complexity, prompting Allegri to turn to Hennebique (Filippi & Fasoli 2014: 9). Allegri's decision to collaborate with Hennebique was likely influenced by the strong ties between PWD staff and Turin, particularly Emilio Giovanni Gollo (1873–1934), an alumnus of Turin's School of Application for Engineers. As a student under Professor Camillo Guidi, Gollo gained hands-on experience with reinforced concrete through projects managed by Porcheddu, an agent and the General Concessionaire of the Hennebique system in Northern Italy (Filippi 2008: 125).

Returning to Bangkok, Allegri outlined his strategy in a *Memorandum* submitted on 30 March 1907. The report estimated a cost of 2 million baht and a five-year timeline, advocating reinforced concrete for both the roofing

and foundations.[14] For the foundations, Allegri proposed using the Compressol apparatus, a cutting-edge system introduced to Siam for the first time. This apparatus created subterranean pylons by perforating the ground and compressing concrete with a sequence of weighted tools. Allegri described the process as follows:

> Foundations to be made of compressed columns of cement concrete, which are to rest on the stratum of clay to be found at 12 meters below the surface of the ground. Such depth will be reached by means of a new apparatus called compressol. This consist of a portable scaffolding (almost like a pile driver) worked by a steam engine and provided with 3 different weights to be applied at the falling extremity of the chain. The first of these weights has the shape of a cone with the pointed end towards the ground, which on being dropped from the scaffolding, perforates the ground and reaches after repeated strocks [*sic*] the depth required. The second weight [...] has the shape of a rifle buffet, while the third one is perfectly flat at the bottom. These two weights are used to compress gradually the stones and the cement concrete, which is thrown into the hole, perforated by the first weight, and thus obtaining subterranean columns of great compression and stability. These columns at ground level will then be connected together by ferro concrete beams on which the building will be erected. This system has been successfully adopted lately in Europe and has given great satisfaction in grounds of the same nature as that of Bangkok (Bandit & Pirasri 2550: 845–846; my translation).

Allegri championed reinforced concrete for its ability to address Bangkok's unstable soil, as well as for its durability, cost efficiency, and time saving potential. He highlighted its benefits: creating a solid foundation with less earth removal, reducing masonry needs, and minimizing labor costs, while ensuring long-term stability (Bandit & Pirasri 2550: 845).

Hennebique's Reinforced Concrete Solutions

By spring 1907, Italian architect Mario Tamagno (1877–1941) of the PWD had finalized the initial design of the Ananta Samakhom Throne Hall, establishing its layout and elevation. However, lacking structural detail, the architectural drawings were sent to Hennebique's Paris office for adaptation to reinforced-concrete methods **[Figure 2]**. Subsequent revisions reduced the hall's scale by eliminating side corridors intended

[14] Carlo Allegri, *Memorandum for the Construction of the New Throne Hall at Suan Dusit, 30 March 1907*, รล. ร 5 ก. 12 กล่อง ที่ 1 แฟ้ม ที่ 4, The Royal Secretariat (สำนักราชเลขาธิการ), as quoted in Bandit & Pirasri 2550: 845–846.

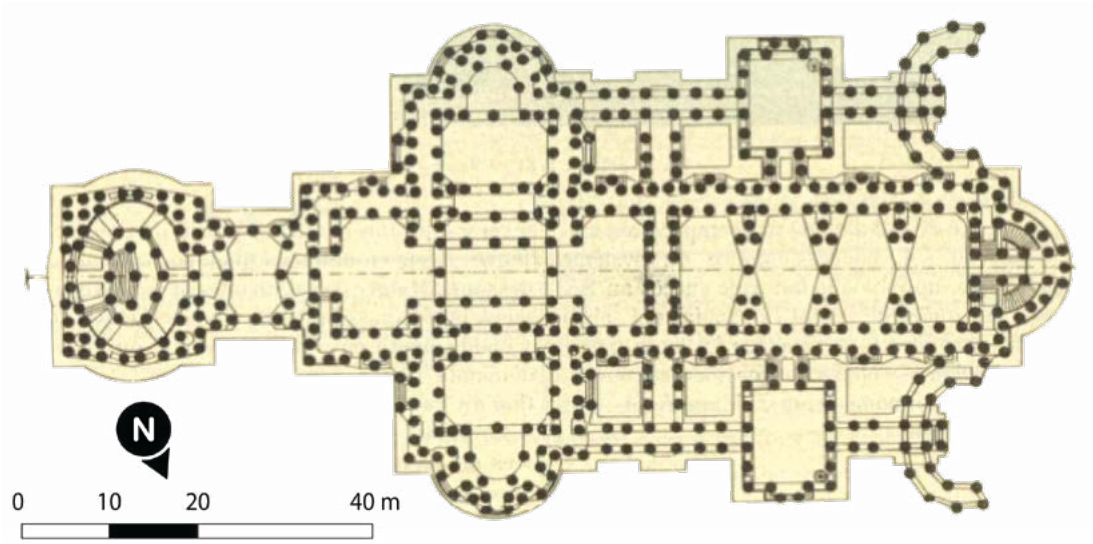


Figure 2: Foundation plan of the Ananta Samakhom Throne Hall, as published in *Le Béton armé* © Gallotti 1910: 67 (Adapted)

for service areas, streamlining the design and enhancing its monumental character (Filippi 2008: 126). Recognizing the project's complexity, Carlo Allegri enlisted Italian architect Annibale Rigotti (1870–1968) in November 1907 to assist with the second phase, incorporating feedback from Paris.[15]

Drawing on the archives of Hennebique in Paris and Allegri in Turin, Filippi recounts key developments during the adaptation process. Hennebique's specialists identified a critical issue early on: the unstable clay bed at Dusit Park. In an August 1907 letter to Allegri, a preliminary solution was proposed, but by February 1908, it was evident that stability could not be ensured without reinforced concrete in critical elements, including the roof, dome and floor slabs. To address these challenges, Hennebique's team designed a double-shelled dome to distribute the load across concrete pillars and marble columns, reducing weight and improving stability (Filippi 2008: 132–135; 2010: 12). By 1910, *Le Béton armé* reported that reinforced concrete had been incorporated into the ceilings, domes, floors, and stairs—an approach that reduced weight while ensuring durability and efficient load distribution for the superstructure (Gallotti 1910: 67–68) **[Figures 3–4]**.

The demand to reduce the building weight of the superstructure considerably was a direct response to the unstable soil conditions identified earlier by Hennebique's team. This likely explained why Allegri and the PWD architectural team scaled down the Throne Hall's design. Initial calculations for a continuous foundation revealed impracticalities, requiring beams over

[15] Rigotti's official tenure as PWD architect ended on 30 September 1909, after he completed essential drawings, leaving the remaining tasks to draftsmen. Despite this, he continued supporting the Siamese government from Turin as a consulting architect, ensuring that elements fabricated in Italy adhered to the original designs. See National Archives of Thailand, มร. 5 บ/32, ร. 5 บ. 9/64.

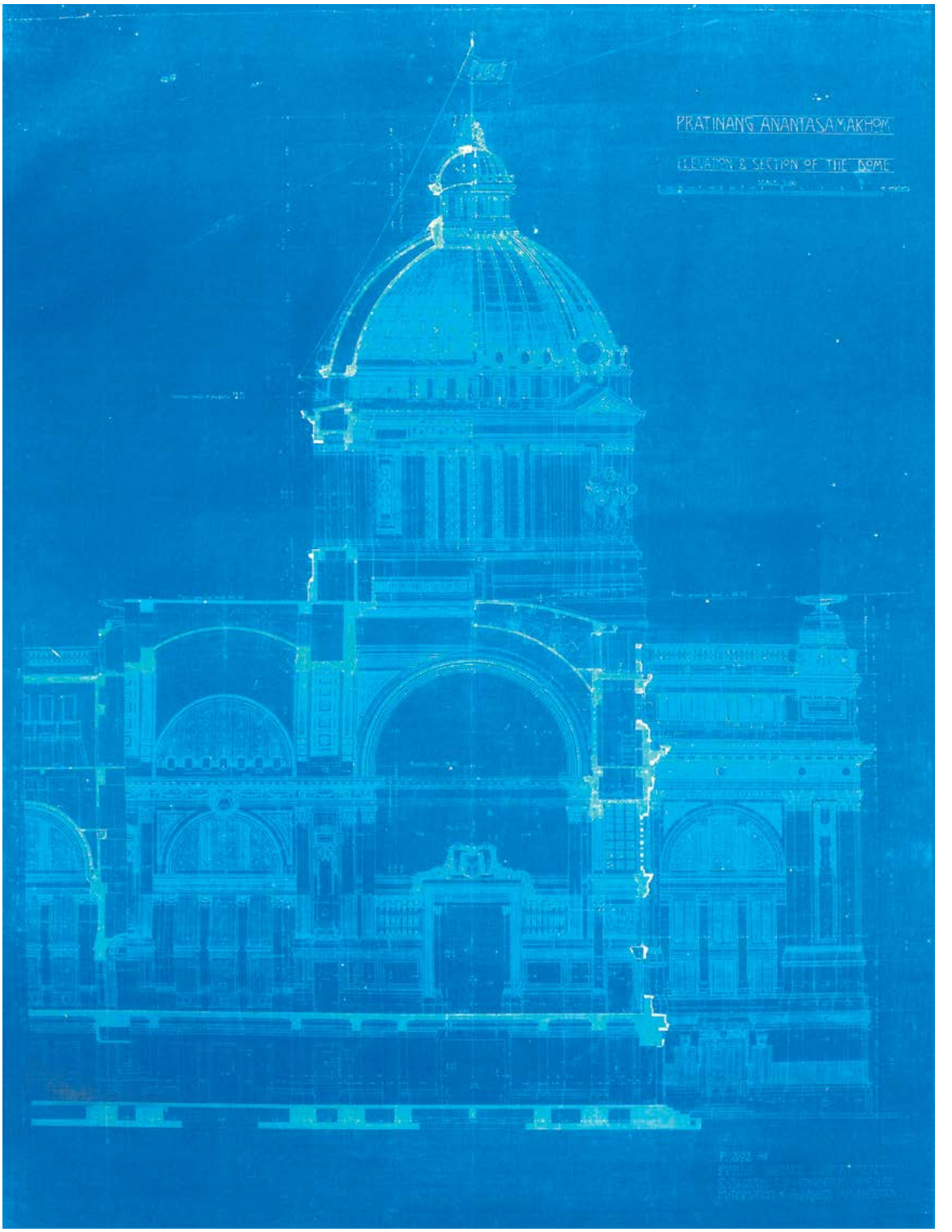


Figure 3: Section of the Ananta Samakhom Throne Hall, revised after Hennebique's feedback, showing a double-shell dome by Tamagno and Rigotti © Nithi 2551: 51

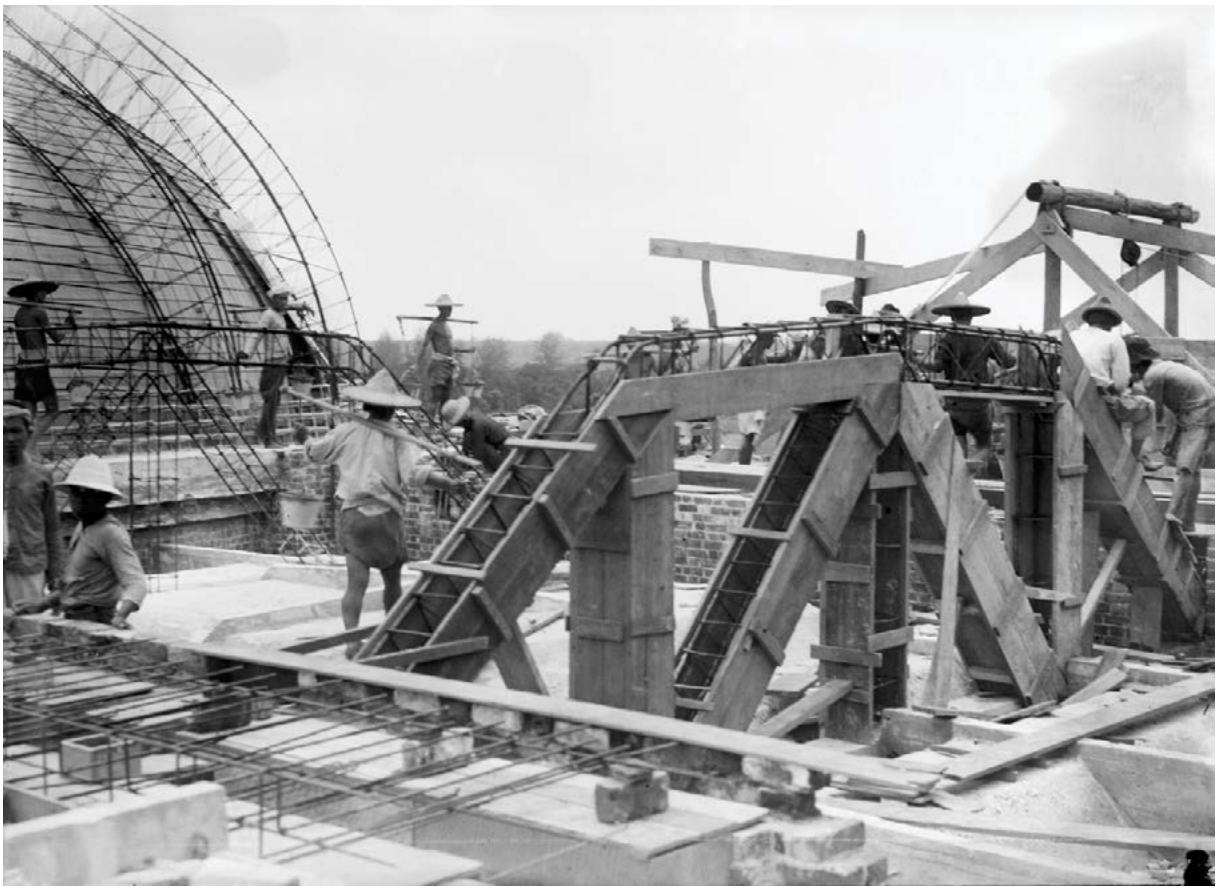


Figure 4: Reinforced concrete work at the Ananta Samakhom Throne Hall, 1910. Photo by Kurt Beyer showing Chinese workers preparing formwork and steel for the roof © Deutsche Fotothek

three meters thick, which still could not guarantee stability. As an alternative, Hennebique's specialists considered a reinforced concrete slab for the foundation. However, concerns over costs, terrain unpredictability and material availability led to its abandonment (Filippi 2008: 132–133). To address foundational challenges, Hennebique proposed the patented "Compressol" deep pile-driving system, which Allegri detailed in his 1907 *Memorandum* as a solution specifically designed to stabilize unstable soil. Patented in 1902 and executed by the "Société Anonyme de fondations par compression mécanique du sol", this technology had proven effective in other challenging projects, such as the bridges of Saint-Louis in Senegal (Gallotti 1910: 68). Beginning in March 1908, 501 subterranean pylons were driven beneath the throne hall's perimeter to stabilize the foundation **[Figure 5]**. The significance of the Compressol system was further acknowledged in King Chulalongkorn's royal command, likely influenced by Allegri's 1907 report, and engraved in the foundation stone laid on 11 November 1908, underscoring its importance in the throne hall's construction (NAT 2527: 100) **[Figure 6]**.

Figure 5: Compressol piling system from France, begun in March 1908, using a 2-ton steel pendulum to drive piles to the required depth © NAT

Figure 6: Key foreign personnel at the Ananta Samakhom foundation ceremony, 11 Nov. 1908, included Allegri, Gollo, Tamagno, Rigotti, Shaw (PWD), and Bénabang (Compressol) © NAT

Hennebique's Foreign Network of Concessionaire Contractors

Hennebique's network mobilized personnel from French Indochina to manage the implementation of both systems. Among them were J. Bénabang, a French Engineer of Arts and Manufactures, who served as Director of the Société Anonyme de fondations par compression mécanique du sol, played a pivotal role in overseeing the foundation work. As reported by *Bangkok Times*, Bénabang represented the firm "engaged for many months sinking the foundations" (1908: 5). He was assisted by compatriot François de Fornel, an experienced site manager, who, after completing his work on the concrete construction of the Ananta Samakhom Throne Hall, applied for a position with the Siamese Government's Sanitary Department (กรมศุขาภิบาล) in November 1909, ultimately serving as a concrete specialist.[16] In May 1908, contractors affiliated with Hennebique's concessionaire network arrived to supervise the brickwork, using locally sourced "pressed bricks" alongside reinforced concrete (Gallotti 1910: 69; Filippi 2008: 128–129) **[Figures 7–8]**.

While many workers remain unnamed, their contributions were indispensable to the project's progress. Despite material supply challenges and the complexity of coordinating skilled labor, early construction phases advanced rapidly,

[16] Recommendation letters written in French for De Fornel by J. Bénabang, A. Fraysse, and A. Stemmer, dated 8 November 1910, detailing his responsibilities as a site manager, can be found in the National Archives of Thailand, กต 35. 8/9.

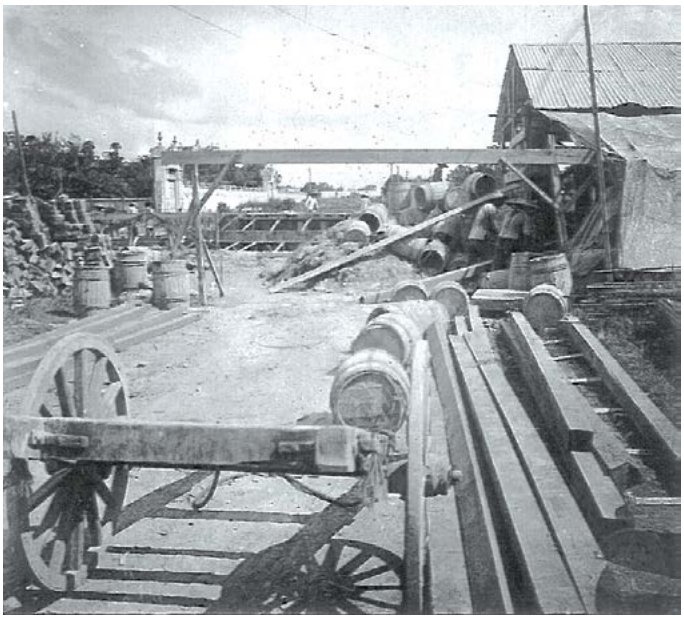


Figure 7: Construction site of Ananta Samakhom Throne Hall, January 1909, showing foundation work with imported cement stored in wooden barrels © NAT

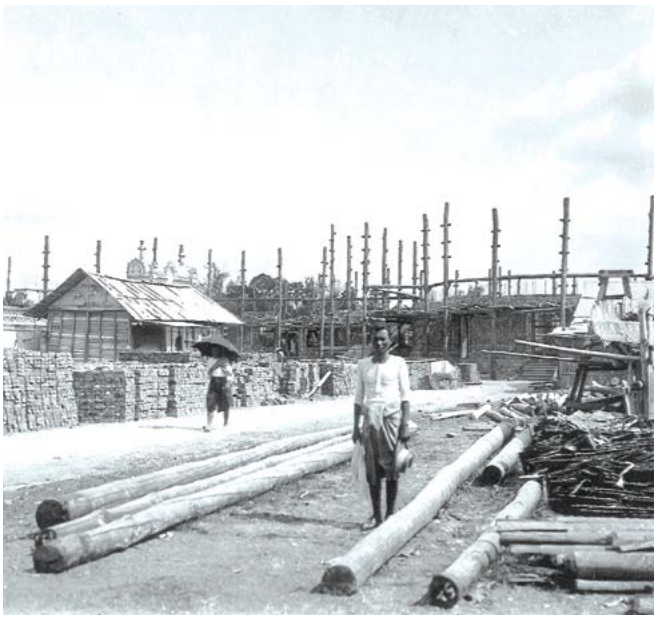


Figure 8: Brickwork at the Ananta Samakhom Throne Hall under construction, 1909, with scaffolding and stocked pressed bricks © NAT

with each stage completed in less than three months (Gallotti 1910: 68). King Chulalongkorn, observing this progress, praised the dedication of foreign workers on 24 April 1909:

> The foreigners truly deserve praise for their work on the construction of the Ananta Samakhom Throne Hall. Unlike some of our supervisors who stand around pointing fingers, they worked diligently, often late into the evening until it was completely dark—just as they would in Italy. Upon seeing their efforts, it was highly satisfying (Chulalongkorn 2482 134; my translation).

However, even with their innovative methods and tireless efforts, building on unstable soil remained a precarious endeavor, and the project faced ongoing risks.

The Role of Local PWD Engineers in the Hennebique System

During the construction of the Ananta Samakhom Throne Hall, local PWD engineers—who were often foreign professionals, primarily Italian—found their roles largely confined to supervisory tasks. Hennebique's French proprietary control over its reinforced concrete patent placed all structural calculations and detailed drawings under the purview of its specialists, leaving the PWD engineers without the expertise or authority to address critical construction issues. This lack of control is evident

in a letter from Italian PWD engineer G. Kluzer to his compatriot Edmondo Roberti di Castelvero, dated 28 March 1908, in which Kluzer expressed concerns about the reinforced concrete system:

> The French team is working on the foundations of the Hall, but we still do not know whether the famous posts will remain stable or whether they will sink into the deep, [...] the engineer Moreschi is supervising the works in reinforced concrete being built by the French (Filippi & Fasoli 2014: 10).

Kluzer's remarks underscore the uncertainty surrounding the project and emphasize the limited influence of local PWD engineers, such as the Italian Bernardo Moreschi, who were tasked with overseeing construction without the authority or technical knowledge to intervene in Hennebique's foreign procedures.

The integration of Hennebique's reinforced concrete system was meticulously managed, with the process divided into distinct stages that extended its influence far beyond the initial architectural design. While local PWD architects initiated the project, Hennebique's specialists in Paris translated the design into reinforced concrete, ensuring every structural detail conformed to the firm's patented system. The execution of the concrete work was entrusted to the Société Anonyme de fondations par compression mécanique du sol, a concessionaire chosen by Hennebique. Skilled French personnel, drawn from the firm's French Indochina network, were deployed to supervise construction in Bangkok. PWD engineers, though formally responsible for overseeing the project, were required to strictly adhere to Hennebique's exact specifications. This separation of design and execution allowed Hennebique to retain effective control over international projects like the Ananta Samakhom Throne Hall, ensuing its monopoly on its proprietary system, while delegating implementation to local and regional teams. This approach exemplified Hennebique's broader strategy of international expansion, maintaining control over complex projects without direct involvement in on-site concrete work.

King Chulalongkorn's Struggles with the French Hennebique System

The infringement of Hennebique's patents was a significant concern that shaped the French firm's strict control measures. While this approach enabled Hennebique to maintain commercial advantage, it also introduced challenges for the Siamese government in exercising oversight. Initially, King Chulalongkorn supported the use of the Hennebique system for the Ananta Samakhom Throne Hall and, on 4 September 1907, praised Chao Phraya Yommarat's decision to adopt reinforced concrete, remarking, "I would like to compliment you on your very good conscience" (Chulalongkorn 2482: 166–167; my translation). However, problems soon emerged. The autonomy granted to concessionaire contractors, who were carefully selected by Hennebique rather than by PWD's architects or engineers, created a shift in control that bypassed

traditional processes. This dynamic, emblematic of a broader transformation in the construction industry globally, undermined the discipline and standards King Chulalongkorn sought to uphold within palace construction, replacing centralized authority with an increasing reliance on external expertise and management.

In a personal letter to Chao Phraya Yommarat dated 26 November 1907—during the period of active construction by Hennebique's concessionaire contractors—the King expressed his concerns and called for immediate corrective measures:

> There is a protocol for the palace's public works: all tasks fall under their responsibility, except for those specific commanded by His Majesty. Anyone undertaking such work must collaborate closely with the palace's Public Works Department as though they were part of it.
>
> In the construction of this throne hall, there are obstructions because it is outside the control of the palace's public works. How can we address this situation? We need a solution that is both suitable and orderly. Please take some time to consider this matter (Chulalongkorn 2482: 67; my translation).

This letter underscored the tension between the palace's PWD and the growing influence of external contractors operating under the proprietary Hennebique system. The King's frustration arose from the diminished control over the Ananta Samakhom Throne Hall project, which disrupted established protocols and revealed gaps in governance. These tensions reflect the broader organizational reforms initiated by the Minister of Public Works, Phraya Suriyanuwat (พระยาสุริยานุวัตร; 1862–1936), a few years earlier. These reforms sought to consolidate authority under the Engineer-in-Chief, who was tasked with assessing structural possibilities, inspecting construction, supervising contractors, and managing financial approvals:

> The Engineer Division and the Architect Division, overseen by an Engineer-in-Chief. The Engineer-in-Chief is responsible for assessing structural possibilities, inspecting building work, and supervising all contracting based on the designs created by the architects and engineers. This role includes comprehensive control over the project, down to approving daily employee wages and contractor fees.[17]

King Chulalongkorn's call for corrective action can be seen as a response to the incomplete implementation of these reforms. External contractors, particularly those affiliated with Hennebique's concessionaire network, operated with a level of independence that clashed with the

[17] Letter of Phraya Suriyanuwat to King Chulalongkorn, National Archives of Thailand, 8 February 1906 (ร.ศ. 124), กร. 5 ยธ/1 ยธ. 1/32 (my translation).

King's vision for centralized oversight and governance of palace construction. The proprietary nature of the Hennebique system further complicated matters, as it circumvented the traditional oversight mechanisms of the palace's PWD. This tension between innovation and governance reflects the broader challenges faced by the Siamese government in integrating modern techniques into traditional frameworks of control.

These struggles became particularly acute during the crisis of the sinking foundations of the Ananta Samakhom Throne Hall. A central figure in addressing this crisis was E.G. Gollo, whose expertise, developed in Turin, played a crucial role in stabilizing the structure. As Francesca B. Filippi notes, Gollo's relentless efforts were vital to addressing the crisis and ensuring the project's continuation (Filippi & Fasoli 2014: 10). While Filippi's research has illuminated the contributions of Italian engineers like Gollo, this article argues that his success in resolving the foundation crisis extended far beyond technical problem-solving. It demonstrated the complex interplay of foreign innovation and the Siamese government's aspiration for autonomy in the broader context of Siam's modernization.

Gollo's intervention and subsequent involvement in Siam's building activities, therefore, merit re-evaluation within this broader historical framework, showcasing King Chulalongkorn's efforts to reassert control over processes that had, at times, been dominated by foreign entities such as the French owned Hennebique company.

Gollo's Heroic Rescue of the Ananta Samakhom Throne Hall

Despite the use of advanced foundation technology and meticulous preparation for Bangkok's notoriously soft soil, the Ananta Samakhom Throne Hall project encountered significant setbacks. Two years into construction, as the subterranean foundation was completed and brickwork commenced, the building began to sink—most critically beneath the massive dome, which weighed approximately 1,500 tons. This alarming subsidence accentuated the complexity and unpredictability of the project, prompting Gollo to intervene.

Drawing on Allegri's notebook, Filippi reveals that by late 1910, local PWD engineers determined the cause of the subsidence as the failure of Compressol posts to reach bedrock. Confronted with this urgent crisis, Gollo devised an innovative foundation system to address structural instability. Despite significant challenges such as water infiltration and the need to demolish newly installed posts, Gollo implemented a network of tall, waterproof caissons made of reinforced concrete beneath the entire structure. These interconnected caissons effectively stabilized the Hall, enabling it to "float" on the unstable soil (Filippi & Fasoli 2014: 10).

Gollo's expertise in caisson foundations, cultivated through his education in Turin and his practical experience with the Porcheddu company, proved critical in resolving the foundation crisis (Filippi & Fasoli 2014: 9–10). His ingenious solution not only stabilized the structure but also garnered wide-

spread acclaim. Chao Phraya Yommarat praised Gollo's unwavering dedication: "From May 1911 to September 1911, E.G. Gollo oversaw the work tirelessly, day and night, until the second part of the foundation was completed, effectively halting further sinking" (Neungreudee 2543: 60; my translation). Independent accounts, such as Erik Seidenfaden's *Guide to Bangkok with Note on Siam*, further attest to Gollo's ingenuity. Seidenfaden (1928: 252–253) observed that while Bangkok's subsoil could not support the immense weight of the building, Gollo's air-filled concrete pontoons allowed the structure to "float" on the soft river mud. Apart from being celebrated in his time, Gollo's achievements were substantiated in official records from the 1970s and 1980s, which further validate his pivotal role in stabilizing the project through the use of caisson foundations.

Post-Construction Challenges

In 1975, severe flooding in Bangkok caused significant damage to the Ananta Samakhom Throne Hall, particularly its foundation. In response, the Committee of Construction and Repair (คณะกรรมการสร้างและซ่อมแซมปรับปรุงพระที่นั่งอนันตสมาคม) was established. This committee oversaw two sub-committees: First, the Sub-committee on Structural and Architectural Restoration, which included the Engineering Division (ฝ่ายวิศวกรรม), and the Architecture and Mural Painting Division (ฝ่ายสถาปัตยกรรมและจิตรกรรมฝาผนัง); Second the Sub-committee on Public Relations and Event Documentation (ฝ่ายประชาสัมพันธ์และบันทึกเหตุการณ์). These sub-committees convened intermittently between 1979 and 1984 to address the issues. The most pressing concerns were subsidence and leakage, particularly around the western staircase, which necessitated a comprehensive investigation.

In December 1979, the Sub-committee on Public Relations and Event Documentation uncovered 48 photographs documenting the original foundation construction and Gollo's critical interventions **[Figure 9]**.[18] Engineer Dr Rachot Kanjanavanich (รชฎ กาญจนะวณิชย์; 1924–1996) drew attention to the significance of these images, noting that they provided a rare and detailed insight into the construction process:

> Photographs retrieved from the National Archives vividly depict the foundation's construction process, which involved the utilization of a steel pendulum to drill into the ground and pour concrete, reaching a maximum depth of 7–8 meters. The addition of the basement likely ensued by excavating the soil between the piles to alleviate weight, a common practice following the initial construction phase. Despite the antiquity of the technique, exceeding 80 years,

[18] These photographs are likely the same ones featured in Allegri's 1911 report at the International Exhibition in Turin, where Allegri commended Gollo for his ingenious application of reinforced concrete. See Filippi 2008: 132.

Figure 9: Photograph of the original foundation of the Ananta Samakhom Throne Hall during its conversion into caissons designed by Gollo, *circa* 1911 © NAT

> its efficacy remains commendable. The structural integrity of the Throne Hall, evidenced by its reinforced concrete composition, is notably robust and stable.[19]

After 810 days of monitoring, the investigation revealed that the building was sinking at a rate of 1.5 centimeters per year, with uneven subsidence on the eastern side. Proposed solutions included full underpinning at an estimated cost of 50 million baht or a targeted underpinning of the western staircase for 5 million baht. By January 1984, the Engineering Division of the Sub-committee concluded that subsidence was primarily due to natural factors and groundwater pumping, posing no immediate threat to the building's overall integrity. Consequently, the decision was made to underpin only the western staircase.[20]

Furthermore, Thai engineer Arun Chaiseri's (อรุณ ชัยเสรี; b. 1934) 1980 investigation into leaks prompted a thorough assessment of the underground chamber, which revealed leaks at the ceiling and wall joints.[21] His survey also detailed the sophisticated network of cellar walls, which divided the basement into functional spaces

[19] Rachot Kanjanavanich, National Archives of Thailand, 9 January 1980, (4) ศธ 2.3.15/12 (my translation).

[20] National Archives of Thailand, 10 January 1984, (4) ศธ 2.3.15/12.

[21] National Archives of Thailand, September 1980, (4) ศธ 2.3.15/12.

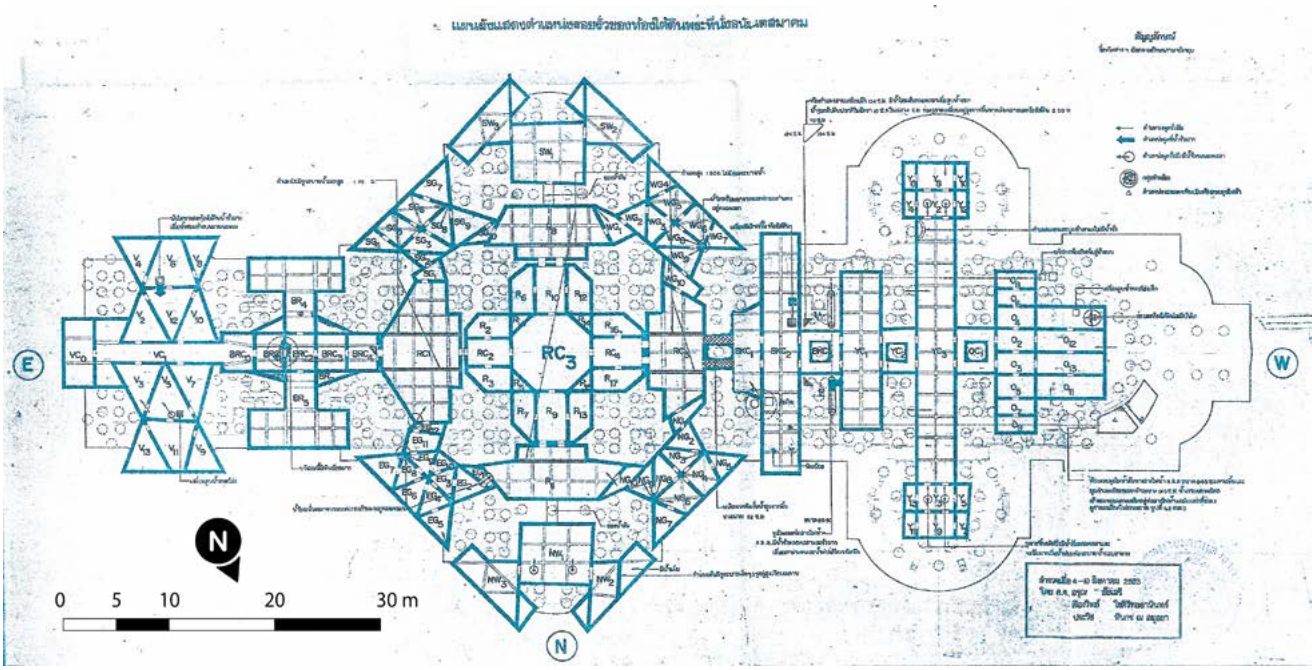


Figure 10: Map from the 1980 leak detection surveys, showing Compressol piles superimposed with Gollo's cellar walls of caisson foundations © NAT

designed for ease of maintenance. These walls, positioned perpendicular and diagonal to the building's axis, played a crucial role in integrating Gollo's caisson foundations with the Compressol piles, effectively halting further sinking.[22] The foundation of the Ananta Samakhom Throne Hall thus represents a successful synthesis of the Compressol pile system and Gollo's caisson foundations, showcasing a remarkable engineering achievement that continues to stabilize the structure **[Figures 10–11]**.

****

E.G. Gollo's intervention in constructing the second foundation of the Ananta Samakhom Throne Hall to rescue the failed Compressol piles surpassed the original plan set by the Hennebique company, addressing the anticipated challenges of Bangkok's soft soil with unparalleled ingenuity. His approach redefined reinforced concrete technology, demonstrating the necessity for flexibility and innovation beyond the rigid constraints of patented systems such as French Hennebique's. From the perspective of the Siamese government, Gollo's expertise offered a superior alternative, enabling the local PWD to regain control over the reinforced concrete process—

[22] National Archives of Thailand. September 1980, น (4) ศธ 2/12.

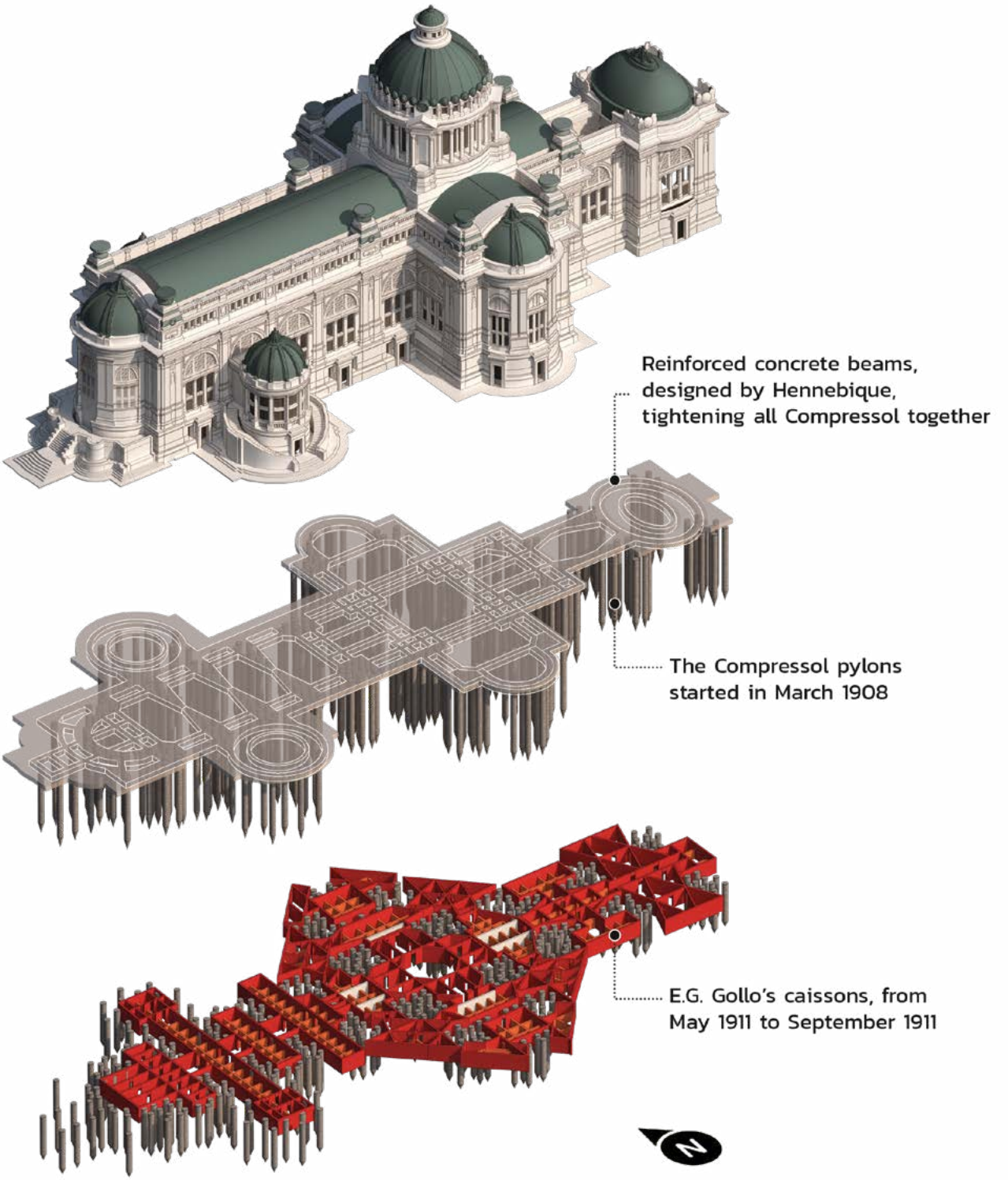


Figure 11: Isometric drawing demonstrates the Gollo's caissons insertion into the Compressol piles, just underneath the reinforced beams designed by Hennebique
© Pinai Sirikiatikul & Patcharapong Kulkanchanachewin

something previously impossible under the Hennebique system. Consequently, Hennebique's influence in Siam waned after the completion of the Ananta Samakhom Throne Hall, while Gollo's prominence steadily rose, owing to his proven success with caisson foundations tailored to Bangkok's unique conditions. This distinguished Siam's case from other Southeast Asian countries such as Cambodia, Laos, and Vietnam, where the Hennebique system maintained a strong presence under French colonial rule.

Gollo's contribution to the Throne Hall set a precedent for future projects, demonstrating to the Siamese government that technological innovation could support, rather than undermine, its authority. His involvement in subsequent high-profile projects across the public and private sectors—such as Phaya Thai Palace (พระราชวังพญาไท), Villa Norasingh (บ้านนรสิงห์), and Chulalongkorn University (จุฬาลงกรณ์มหาวิทยาลัย)—cemented his reputation as an indispensable figure. Remarkably, Gollo often served as both engineer and reinforced concrete contractor, an unusual role for a government official at the time. The exception, which allowed him to work in the private sector, underlined his unique importance to the Siamese government. His expertise in reinforced concrete became an asset independent of the patented system, liberating Siam from the constraints that had previously limited its agency.

Most notably, Gollo played a crucial role in the establishment of the Siam Cement Company (บริษัทปูนซิเมนต์ไทย) in 1913. By 1915, the company was producing cement domestically, significantly reducing the nation's reliance on imports (Brown 1988: 151–155). In recognition of his unparalleled contributions, his contract with the Siamese government was extended and, in 1923, he was honored with the prestigious title Phraya Sinlapasat Sopit (พระยาศิลปศาสตร์โสภิต)—an accolade not even his fellow Italians, Allegri and Tamagno, received. This distinction underscores Gollo's exceptional value as a reinforced-concrete expert to the Siamese government and highlights his enduring impact on Siamese construction.

In summary, the early adoption of reinforced concrete initially limited Siamese control over construction practices, as foreign expertise and patented systems dominated the process. However, Gollo's unplanned intervention to stabilize the sinking foundation marked a turning point, demonstrating how local agency could regain influence over imported technologies. His expertise bridged the gap between tradition and modernity, aligning with the broader political strategy of King Chulalongkorn's reign. As Wyatt and Kullada observe, King Chulalongkorn's modernization reforms carefully balanced Western ideas with Thai values, selectively integrating modern innovations while maintaining royal authority. Within this context, the adoption of reinforced concrete under Gollo's guidance was not just a technical advancement but also part of a larger effort to navigate the influence of competing foreign powers—particularly the French firm and Italian engineering expertise—ensuring that no single foreign power dominated Siam's modernization efforts. Far from

being a straightforward importation of Western technologies, the process exemplifies how Siam strategically managed modernization on its own terms, using technological advancements to reinforce, rather than undermine, its sovereignty. Gollo's contributions to reinforced concrete stand as a critical moment in Siam's history, where the interplay of local agency and foreign expertise redefined both its architectural and political trajectory.

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Abbreviations

FAD	Fine Arts Department (กรมศิลปากร)
NAT	National Archive of Thailand (สำนักหอจดหมายเหตุแห่งชาติ)
PWD	Public Works Department (กรมโยธาธิการ)

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