CONCRETE AT THE FRONT
THE BRUGES SUBMARINE SHELTER (1917-1918)

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Abstract

Starting in August 1917, a large submarine shelter was erected in the port of Bruges. Its construction completed a transition from mixed wood-and-steel structures to all-concrete bunkers in this area. The new *Gruppenunterstand* prefigured many of the typological and technical key features of the iconic submarine pens from World War II. An early application of reinforced concrete, the bunker in Bruges illustrates how the Great War serves as a breeding ground for experiment. Moreover, it exemplifies the underexposure of military pioneering work in the field of construction.

Key words: bunker, submarine pens, First World War, reinforced concrete, Bruges

Introduction

In his book *Concrete and culture: a material history*, Adrian Forty acknowledges the transition of reinforced concrete from the realm of vernacular experiment to that of industrialized building and engineering as being instrumental in concrete's association with modernity.[1] This transition from 'mud' to 'modernity' takes places around the turn of the 20th century, when calculation methods, building codes and standards for reinforced concrete are developed, after decades of trial-and-error construction in different fields. While most attention in this respect goes to the pioneering work of civil entrepreneurs, the influence of the military remains underexposed. However, military courses on concrete calculation were organized and experimental laboratories had been installed well before the start of the war, for instance in the Belgian Royal Military Academy.[2] By 1914, after half a century of constructing fortifications in unreinforced concrete, military engineers had realized that only reinforced concrete would offer protection to contemporary siege artillery. The upcoming war would accelerate the implementation of these insights. At the same time, it established a firm association between reinforced concrete and warfare in people's minds.[3] An early but advanced example of such experiments is the large group shelter or *Gruppenunterstand* for submarines in the northern port of Bruges, erected in 1917-1918. This paper highlights its importance, both as a typology and construction paradigm.

The need for new typologies

The stalemate of the First World War marks the transition to a full three-dimensional battlefield, characterized by overhead, underground and submerged warfare.[4] The introduction of those new tactical

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[1] (Forty, 2012), 13-42.
[2] (Van De Voorde, 2011), 134-153.
[3] (Forty, 2012), 169-170.
[4] (von Busch, 2011), 2-3.

layers radically disrupted the traditional spatiotemporal experience of conflict space and paved the way for new building typologies. For instance, the confrontation between the new weapons of strategic aerial bombing and submarine warfare, is condensed in the construction of bombproof shelters in the German occupied Belgian ports, together forming the *Kaiserliche Marinewerft Brügge*.[5] The inland harbor of Bruges, linked by canals to the coastal ports of Zeebrugge and Ostend, housed the headquarters of the *Unterseeboots Flotille Flandern*, operating around the British Isles. This flotilla's successes turned the *Marinewerft* into an important objective for strategic aerial bombing. To keep pace with the rapidly increasing intensity and destructivity of aerial attacks, successive submarine shelter designs were developed throughout the war. Apart from some isolated particular designs, most shelters predating the *Gruppenunterstand* can be divided in two main types.[6]

Cantilevering canopies (*Kragunterstände*) attached to the existing quaysides constitute a first type. They come in a variety of construction methods, mostly using steel beams or trusses as a primary structure and corrugated steel as a secondary structure. These cantilevers are counterbalanced by containers filled with concrete or sand, or they are anchored to the quay. In some cases, the roof is doubled to create a hollow explosion chamber or to integrate an impact-absorbing layer of clay bags. Sometimes the upper roof is covered with steel plating, in other cases a thin slab of reinforced concrete is used (Fig. 1).

The second type, the so-called *Ubootsstall* (U-boat shack), is a small covered dock, excavated between metal sheet pile walls. Part of the excavated earth is used to create a protective dike. The dock itself is covered by a roof composed of wooden supports, steel girders and corrugated steel plates. Bomb proofing is attained by absorbing sand layers separated by a slab of reinforced concrete (Fig. 2).

Such proliferation of typologies and construction methods indicates an empirical approach towards shelter design at this point in the war. Often, pragmatic reasons or local conditions, such as the load bearing capacity of existing quay walls, or the increasing lack of steel as a construction material can explain particular design decisions.

Constructing the *Gruppenunterstand* in the northern port[7]

Following a peak in aerial bombing activity in the summer of 1917, the German navy command planned a new bombproof shelter for the submarines of the *Flandern* flotilla. Realizing the flaws in earlier shelter designs, the engineers of the *Hafenbauabteilung I* conceived a new typology of juxtaposed covered wet docks that relied almost entirely on the use of reinforced concrete.[8] The choice for concrete added the potential of maximum protection to the advantage of reduced steel consumption, at a time when this had become scarce as a building material.

The new bunker was planned in the northern port, at the end of a partially excavated dock, whose construction had been commenced before the outbreak of the war. From the initially planned 11 covered docks, only 8 bays were completed by the end of the war, each measuring 8.80 by 62 meter. The bunker was built on the water to save time-consuming excavation works, a solution that at the same time would overcome the lack of steel sheet piles needed for retaining walls. A total number of 1,200 wooden piles measuring over 10 meter of length were driven in the bottom of the dock using floating steam pile drivers.[9] The overall layout of the bunker followed the outline of the dock, resulting in the stepped floorplan that characterizes the building. The main structure was executed as a framework of piers, columns and beams in reinforced cast-in-place concrete. To avoid extensive scaffolding and formwork over the water, the roof was composed of lined-up U-shaped precast concrete elements. Concrete ties,

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[5] The *Kaiserliche Marinewerft Brügge* (KMW) comprised the ports of Bruges (principal seat), Zeebrugge and Ostend (dependencies) and disposed of shipyard facilities in the ports of Ghent and Antwerp.

[6] (BA-MA RM 120/97) summarizes aerial bombing and different shelter typologies in the KMW.

[7] This draws upon ongoing and unpublished research of archival sources from BA-MA, KLM, WLB and NCAP.

[8] (BA-MA RM 104/234) describes explosion tests in March 1915 to assess he resilience of different construction methods.

[9] (Journal de Bruges, 10 October 1951), 3.

placed at regular intervals in between those elements, further ensured the horizontal stability. Similarly to the *Ubootsställe*, this supporting structure was then topped with a blast roof, here a double reinforced concrete slab, followed by an elastic layer of gravel and on top an impact layer of double reinforced concrete. To protect the base of the facades from bomb damage, protruding eaves were cast along the contours of the roof. For similar reasons, the voids between the columns in the facades were filled with blast walls in brick masonry, leaving only small openings for access and natural lighting (Fig. 3 and 4).
The size of the *Gruppenunterstand* allowed for a semi-industrialized construction process. Materials were delivered directly on site by train or via the dock, where a jetty provided direct access to a purpose-built concrete plant. The mixed concrete was raised to a casting tower and from there gravitationally distributed over the building site through a rotatable casting arm.[10] Additional narrow-gauge tracks on the roof and on the ground complemented this system. The stretch of land behind dock No.7 housed a production line for the precast roof elements, sufficiently large to cast the roof elements for an entire bay. Wooden gantry cranes displaced the finished elements to the end of this line, where they were hoisted by an identical roof-mounted crane. In turn, this crane would run on tracks over the columns to place the elements on their final position over the dock. This semi-industrialized process reduced the construction time considerably. Work started in August 1917 with the installation of the concrete plant and the pile foundation of the northern bay No.8. By the end of the year, two bays had been completed, followed by six more in the first half of 1918. No building progress was made after the end of July 1918, days before the start of the allied campaign that eventually would end the war (Fig. 5, 6 and 7).[11]
After the Armistice, the bunker in Bruges was recovered by the Belgian army. Initially, it served as a naval base for the short-lived *Corps des Torpilleurs et Marins*.[12] Following the dismantlement of the navy corps in 1927, the city of Bruges attempted in vain to have the bunker demolished for the extension of the port. The civil authorities claimed that the continued lowered water level in the dock had caused the wooden piles to rot to such a degree that the building risked collapsing.[13] Insisting on its strategic importance, the army dismissed the argument. In April 1939 the bunker was converted into a floating fuel depot for the war to come.[14] Somewhere between that time and early 1943, almost half of the building did collapse after all.[15] In 1951 the remainders were finally dynamited to extend the dock.[16]

Design continuity

The March 1942 issue of the periodical *L'Illustration* proudly announced the completion of the concrete submarine pens in Saint-Nazaire.[17] Interestingly, the article also included a picture of the bunker in Bruges and the text identified the *Gruppenunterstand* as the ancestor of the new submarine pens.[18] Even if the interwar evolution of technology had dramatically increased the scale of the new bunkers, the typological resemblance is evident, for instance in the juxtaposition of the covered docks and the protruding eaves. Less visible are other similarities, such as the layered blast roof, the judicious application of precast concrete or the thought-out organization of the building site. But essential differences also exist. The shelter in Bruges, for instance, does not dispose of the workshop facilities that were integrated in later designs. Its primary structure is composed of a concrete framework, while the examples of the 1940s feature solid concrete walls and eliminate the masonry blast walls. Moreover,

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[10] According to (Illingworth, 1972) concrete pumps were patented only later in 1927 by engineers Max Giese and Fritz Hull.
[11] Account based on (KLM aerial photograph database), pictures dating between 30 September 1917 and 19 September 1918.
[12] (KLM 185/311) The navy corps was formed with German ships that were assigned to Belgium by the Treaty of Versailles.
[13] (KLM 185/3294).
[14] (KLM 185/5320).
[15] (WLB); (NCAP 25-524); (NCAP 25-525).
[16] (Journal de Bruges, 14 March 1951), 3.
[17] (L'Illustration, 21 March 1942). By then, German propaganda would supervise the editorial board of *L'Illustration*.
[18] A point of view shared by (Neitzel, 1991), 9-15.

pile foundations, such as in Bruges, would later be dismissed, being too sensitive and unable to take on supplementary loads after construction. Wherever possible, later bunkers would be founded directly on rock soil, for this reason sometimes even away from the waterfront (Keroman I and II). In the 1940s, steel trusses were preferred over precast concrete for the roofs in France, until the increasing lack of steel would favor pre-stressed concrete trusses for the later constructions in Germany and Norway.
The submarine bunker Nordsee III in Helgoland, Germany, is interesting in this respect. Built in 1940-1941, but conceived in the late 1930s, it constitutes a missing link between both wars.[19] It shares some of the trademark features of the bunker in Bruges that were completely abandoned in later projects, such as the skewed plan, the construction on the water, the concrete framework or the beveled eaves. On the other hand some ideas from Bruges were further developed or modified. Examples are: the use of soldier pile walls for the foundations of the piers, the installation of concrete blast walls and most notably the application of an enormous mobile concrete formwork for the roof instead of precast concrete (Fig. 8).
Even if no hard evidence of continuity between bunkers of both wars could be found, the juxtaposition in *L'Illustration* under German supervision is a strong indication that the shelter in Bruges was used at least as a starting point for later designs. This seems to be confirmed by the fact that officials of the Krupp Germania submarine shipyards in Kiel photographed the ruins of Bruges in March 1943, only weeks before the start of the construction work on the Konrad submarine bunker, located next to their premises in Kiel.[20]

Conclusion

Within the timespan of the war, submarine shelters evolved from improvised mixed-material structures to all-concrete pens constructed in a semi-industrialized manner. Rather than being an endpoint of an evolution, the Bruges *Gruppenunterstand* sets a typological example for later submarine bunkers. Moreover, it exhibits certain technical solutions that would be continued, improved or dismissed in later designs. In particular, the experimental use of reinforced concrete in military context raises the question if the bunker in Bruges, in the words of Adrian Forty's *Concrete and Culture,* is 'mud' or 'modern'. If the previous *Kragunterstände* and *Ubootsställe* still tend towards empirical experiment, the later *Gruppenunterstand* displays a certain engineering rationality and mastering of reinforced concrete construction, that undoubtedly would justify the label 'modern'.

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[19] (Neitzel, 1991), 97-99; (BA-MA RM 45-II/471-476).
[20] (WLB); (Neitzel, 1991).