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REMEDIATION TECHNOLOGY OF CLOCHE REPLACEMENT FOR WW2 FORTIFICATION IN THE CZECH REPUBLIC

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ABSTRACT

Nowadays many parts of the Czechoslovak border fortification built in 1935 – 1938 have been sold to the private owners who want to reconstruct it. One of the biggest problems while reconstructing these objects is missing cloches. The aim of this study is to find solution of this problem. Authors wanted to offer the owners (usually clubs of military history) authentic design of the cloche for low cost, high durability and full functionality of the cloche that enables installation of original weapons.

A result of the work was a development of a technical solution of the cloche consisting of a replica of the upper part made of reinforced concrete in combination with lower part made of concrete. This unique technical solution was confirmed as an utility model CZ32920(U1). Remediation measure was approved by the team at the pillbox T-S 20 in Červený Kostelec in 2019.

KEYWORDS

Cloche, WW2, Pillbox, Remediation, Concrete

INTRODUCTION

Cloches were typical elements of the reinforced concrete fortifications built in Europe in the 1930s and 1940s [1,2]. We can find most of them in the objects of Maginot Line (Figure 1) which was built from 1929 till the German´s Nazis troops attacked France in May 1940 [3,4]. Czechoslovak cloches made in 1937 – 1938 were inspired by the French pattern however, their construction was a bit different. While Sudetenland was annexed to Germany (October 1938), there were almost 400 pieces of cloches (mostly types AJ-S-N and AJ-S-D used for light or heavy machine guns) in the objects of the heavy blockhouses built between 1936 and 1938[6]. Most of them were removed and the steel was used for war production of Nazi Germany [7]. The cloches were mostly removed by using explosives so the fortresses were damaged (Figure 2).

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Fig. 1 – Cloche in the object of Maginot Line in France.

Fig. 2 – Damage of the pillbox by the explosive used for cloche removal during occupation by Nazi Germany in 1939-1945 (pillbox N-S 84 „Voda“ in Náchod, Czech Republic)

Motivation

Missing cloches in the objects of the Czechoslovak heavy fortification are one of the biggest problems while reconstructing the objects by their owners, mainly military history clubs. The clubs cannot afford to cast an exact replica in a steel plant, the price of one cloche is 2,5 million CZK. The weight of the steel cloche (AJ-S-N) is 20 tons so its transport and placement to the objects that are usually situated in hardly accessible places would cost a lot of money too.

The clubs usually solve this problem by making replicas from cheap materials as wood with covering upper layer or metal sheet. Such solutions are not long lasting, after 2 or 3 years there are leaks of water to the constructions that cause deformation of the scale model. It is not possible to put original weapons to the loophole of the cloche and demonstrate shooting during excursions (kickback while firing machine gun would damage the replica) which is another disadvantage of the cheap solution.

PRINCIPLE OF REMEDIATION TECHNOLOGY

Based on the problems mentioned above, the team of the project NAKI II DG18P02OVV063 set a goal to find a solution which would offer:

1) authentic design of the cloche (not only form outside but also from the inside)

2) low cost, friendly for the military history clubs

3) long life of the solution

4) full functionality of the cloche construction allowing the installation of the original weapons and demonstration fire for the visitors of the fortress museum.

The result of the work was a development of the technical solution of the cloche consisting of a replica of the upper part made of reinforced concrete in combination with lower part made of concrete. This unique technical solution was confirmed as a utility model CZ32920 (U1) at Czech Industrial Property Office on 4. 6. 2019 [9].

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Replica of the upper part of the cloche is prefabricated reinforced concrete element (Figure 4) imitating upper visible part of the cloche, however it lacks the massive original lower part (Figure 3) which is recessed into the fortress construction. The reinforced concrete element is smaller than the original cloche, thanks to this solution its height is half, but the parts visible from outside are as big as the original element. Due to the fact that the placement of this element will be made together with concreting the damaged part of the fortress, it is possible to prepare the round shaped gap that follows up the element (concreting substitutes the lower part of the cloche).

The original shaft has been preserved in case of the fortress where was no time for installing the cloche in 1938, so the part of the fortress was not damaged by the explosives. In this case the element will be placed on the concrete part of the shaft which replaces the lower part of the cloche.

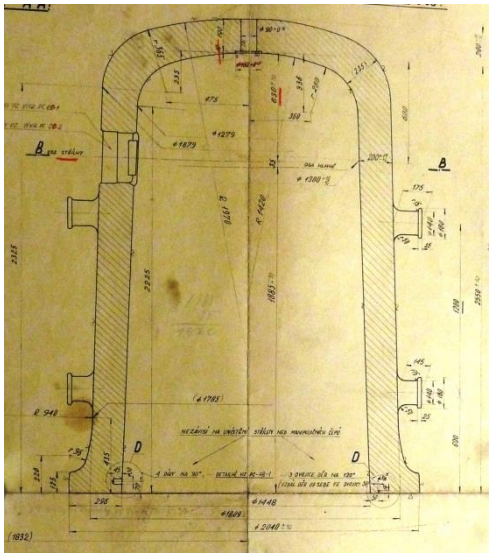

Fig. 3 – Original cloche type AJ-S-D (drawing from 1937 AČR - VÚA/VHA)

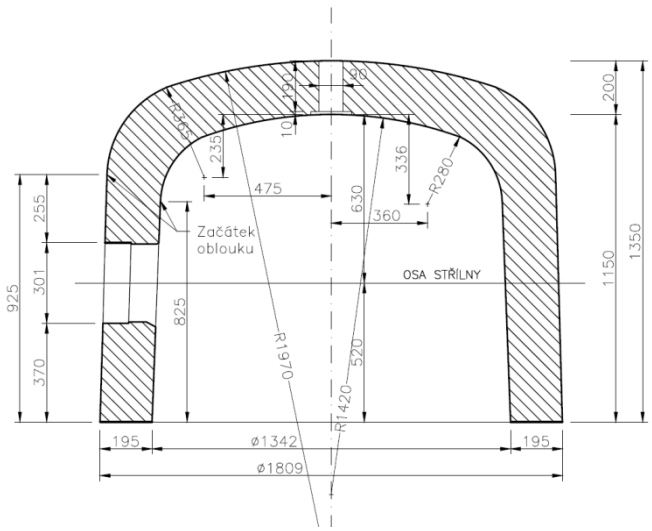

Fig. 4 – Replica of the upper part of the cloche AJ-S-D developed within the project.

It is possible to manipulate with the replica by ordinary lifting tools because its weight is only 2,8 tons in comparison with the original steel cloche of 20 tons. It is due to the fact that the replica represents only upper part of the cloche which is visible from outside and it is not made of steel but concrete. Thanks to the massive construction of the element it looks authentic also from the interior (in contrast with the wooden ones) and it is possible to use original machine gun for demonstration fire for visitors of the fortress museum. The surface of the replica is painted by original colour to ensure full authenticity. The paint continues also to the wall of the circular shaft which is a part of the newly concreted construction and reaches to the edge where the lower part of the original cloche was. The painting makes almost perfect impression of the internal appearance of the original cloche construction. The cloche is also painted by camouflage colour from outside, which makes the original appearance from 1930s.

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EXPERIMETAL APPLICATION

The technical solution of the cloche developed within the project NAKI II DG18P02OVV063 was tested on the pillbox T-S 20 „Pláň“ situated close to Červený Kostelec in Hradec Králové region in the Czech Republic in October 2019. See Figures 5 and 6.

Fig. 5 – Western wing of the pillbox T-S 20. Part for placing the cloche AJ-S-D replica is marked (shaft is covered by wooden construction, which will be removed).

Fig. 6 – Preserved original shaft from 1938 in the western wing of the pillbox T-S 20.

Construction of the pillbox T-S 20 was stopped in September 1938 exactly before placing the cloche (the concrete construction was finished and the cloches were prepared at the railway station in nearby town Náchod). After Munich Agreement, when the Sudetenland was annexed by Germany, the pillbox remained at the German´s part of a new border. As the cloches were never placed to the pillbox, the construction was not damaged by explosives and the original shafts remained preserved. There should have been 3 cloches of different type in this pillbox (1xAJ-S-D for heavy machine gun, 1xAJ-S-N for light machine gun and 1 x observational cloche AJ-P).

Owner of the pillbox, Military History Club TS- 20, decided to reconstruct the AJ-S-D type of the cloche in the western wing of the pillbox so they asked the project team NAKI II DG18P02OVV063 from the Faculty of Civil Engineering for help. Due to this fact the replica of upper part of the cloche was designed as a type AJ-S-D (method could be used also for creating the AJ-S-N cloche type, which differs from AJ-S-D type only in a shape and position of loophole gaps).

MATERIALS AND METHODS

It was necessary to develop a unique manufacturing process for making the upper part of the reinforced concrete cloche replica, because nothing similar has been realized yet.

Molds

Two specially developed molds were a basic for the manufacturing process of the reinforced concrete element. Outer reusable fiberglass mold (Figure 9) was made on the polystyrene backing (cupola) with special surface adjustment allowing lamination. For easier removal after concreting the mold is composed of two parts. Inner mold was made of polystyrene with specially paved surface, there were also two molds for loopholes (Figures 7, 8). This inner mold is disposable (it was damaged after formwork). In the future there is a plan to make a

reusable mold consisting of two parts as well as in the case of the outer mold. Production of the complicated molds was made by external suppliers and was based on the documentation prepared by the project team NAKI II DG18P02OVV063. Size of the reinforced concrete prefabricated element (as well as the size of both molds) is determined exactly according the project documentation of the cloche from 1937. We got the documentation in the Military Historical Archive of the Czech Republic. Production of the reinforced concrete element took place in the laboratories of the CTU in Prague, Faculty of Civil Engineering

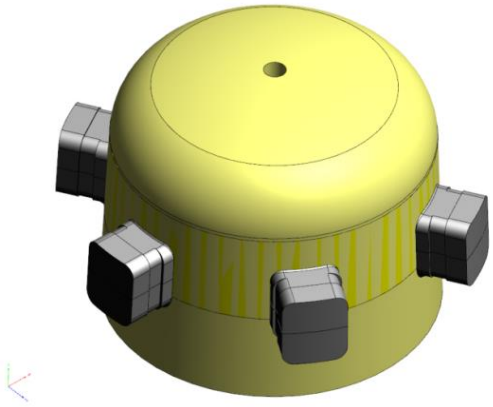

Fig. 7 – 3D model of inner mold

Fig. 8 – Assembly of reinforcement on the inner mold in tle laboratories of the Faculty of Civil Engineering CTU in Prague.

Concrete

Lightweight concrete mixture of specification LC40/44 D2.0 XF2 which well declares required level of compressive strength was designed for the production of the element. The lightweight concrete had to be used due to limited manipulation technique during demoulding and especially during placing under complicated condition. Hence, the maximum weight of an entire element could be 2.0t. The concrete consists 400 kg/m3 of common Portland cement CEM I 52.5 R and addition of milled limestone as a filler for higher dense of concrete. The water-cement ratio was 0.40. The superplasticizer was used to improve the consistency of a fresh mixture. The artificial lightweight aggregate Liapor 2-10mm was used. Total volume of the lightweight aggregate was approximately 20% of the mixture. The mixture was produced in one batch to attain ideal homogeneity; hence the restarting agent was dosed to postpone the setting time.

The lightweight aggregate Liapor 2-10mm was used as a partial replacement of natural aggregate to achieve required level of bulk density, which should be bellow 2000kg/m3. Liapor is a natural clay product. The raw clay is burned in a rotary kiln at a temperature of approximately 1200 ° C. The clay beads expand, resulting in a porous, air-filled Liapor. The water absorption of Liapor aggregate is more than 10 times higher in comparison with a natural aggregate, which negatively influence especially workability of fresh concrete. The freeze-thaw resistance of Liapor aggregate did not decrease with high water absorption due to the specific porous system inside the particles. The properties of natural aggregate were verified in the laboratory to compare with Liapor aggregate. The properties of used aggregate and its comparison – Liapor aggregate [10] and natural aggregate are shown in Table 1.

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Table 1 - The properties of aggregate

Types of aggregate Properties	Natural aggregate	Liapor aggregate
Oven-dried particle density (kg/m^3)	2530	1190
Fines content (%$_{mass}$)	0.1	
Water absorption capacity w_{60} (%$_{mass}$)	0.6	9
Water absorption capacity w_{24h} (%$_{mass}$)	1.7	15
Freezing and thawing resistance (%$_{mass}$)	< 1	< 2

The consistency of fresh mixture was controlled in terms of CSN EN 12350-2. The examination of workability of fresh concrete was measured two times during the concreting, due to the expected decline of workability causing by high water absorption of used lightweight aggregate. In the beginning, the initial consistency was S5, which means slump exceed 210 mm, however, the consistency gradually got worse over time. At the end of the production, approximately after 3 hours, the slump was only 120 mm, what corresponds with the class of S3.

Fig. 9 – Fitting the outer mold part (Laboratory of the Faculty of Civil Engineering, CTU)

Fig. 10 – Concreting of the cloche after turning the completted mold parts (Laboratory of the Faculty of Civil Engineering, CTU)

Mechanical properties were investigated in terms of compressive strength in accordance with EN 12390-3 [11] by using cubic specimens of edge 150 mm. The compressive strength was controlled after 7 and 28 days; the attained values were gradually 49.6 and 54.0 MPa, respectively. The permeability of the hardened concrete was investigated in terms of water penetration test (EN 12390-8 [12]) after 28 days of curing. The achieved penetration was only 7 mm, which confirmed very impermeable structure of the concrete. The results of mechanical properties of lightweight concrete correspond with the results of previous studies [13-15]. The properties of the used concrete mixture are summarized in Table 2.

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Table 2 - The properties of concrete

Properties	Slump (mm)	Density (kg/m^3)	Compressive Strength 7 days (MPa)	Compressive Strength 28 days (MPa)	Permeability (mm)
LC40/44 D2.0 XF2	210	1970	49.6	54.0	7.0

Completed prefabricated reinforced concrete element of the cloche type AJ-S-D was exhibited in front of the Faculty of Civil Engineering from 21. 9. till 11.10. 2019. There were also two posters describing the manufacturing process.

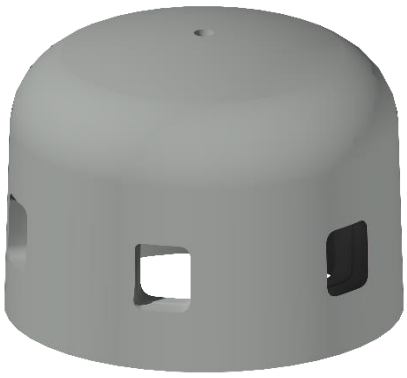

Fig. 11 – 3D model of upper part of the cloche AJ-S-D

Fig. 12 – Completed replica of the upper part of the cloche exhibited in front of the Faculty of Civil Engineering CTU in Prague.

ON –SITE IMPLEMENTATION

In parallel with the production of the upper cloche part described in a previous chapter the lower part of the cloche was concreted directly in the pillbox T-S 20 (Figure 17). Inner surface of concreting was made with the help of a formwork with smooth surface so after the upper part of the cloche will be placed and everything will be finally painted by original colour, it will seem to be as high as the original cloche. Finally, the upper part of the cloche was moved from the faculty to Červený Kostelec and placed to the pillbox T-S 20 (Figures 18 and 19). Cement mortar with crystallization admixture (in 1938 it was only standard cement mortar) was used for connecting of both cloche parts. We used the crystallization admixture because of its ability to ensure the waterproof structure of the mortar, so it prevents leaking to the space between the cloches and the construction of the object. Features of the crystallization materials have been verified by many studies [16-20].

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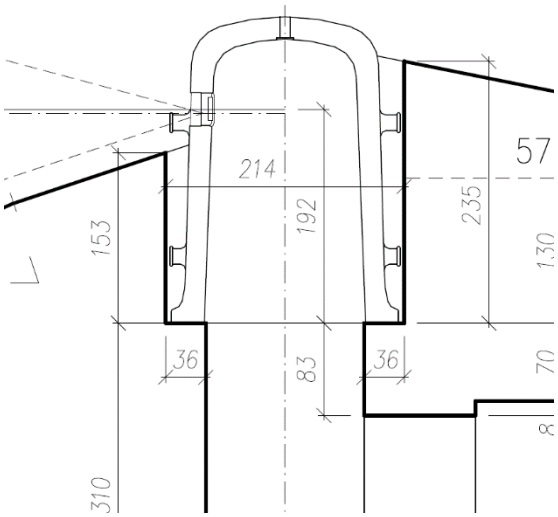

Fig. 13 – Original solution of the cloche type AJ-S-D from 1937 (part of the drawing cut through the pillbox)

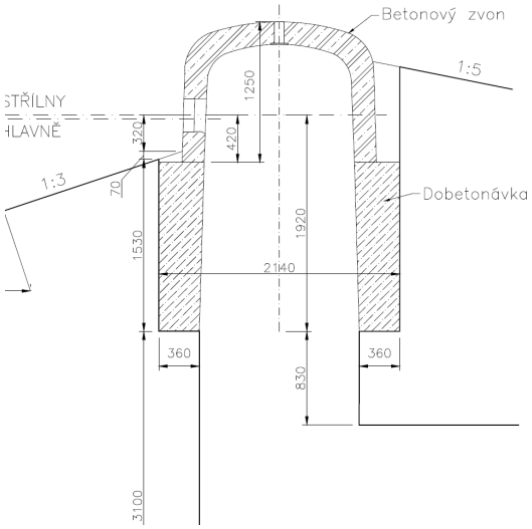

Fig. 14 – Technical solution of the reconstruction developed within the project (used at pillbox T-S 20)

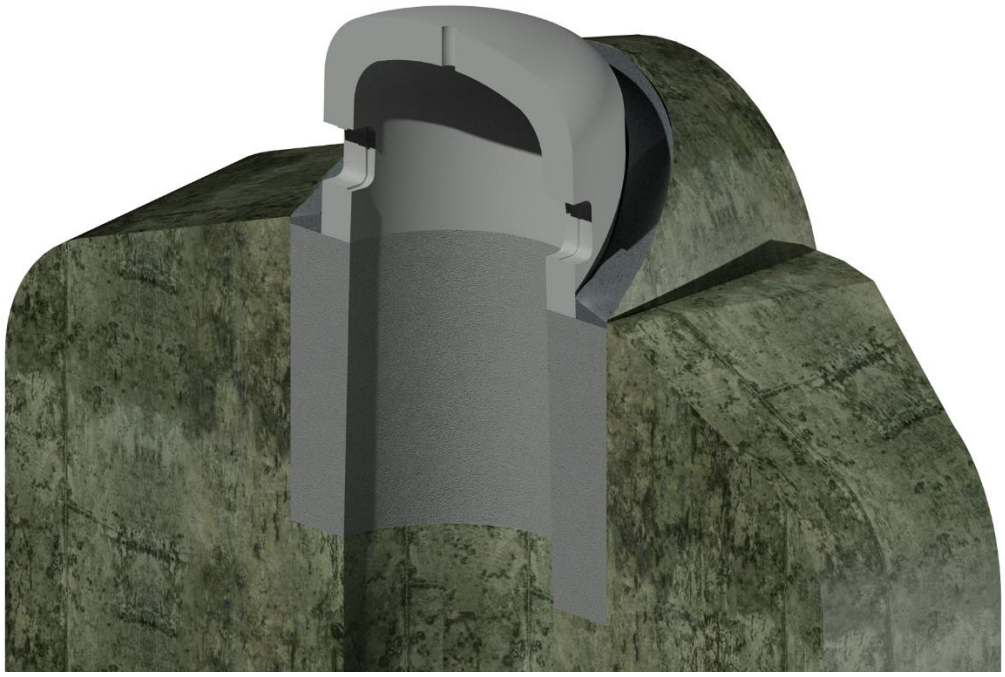

Fig. 15 – 3D model of remediation steps -– fitting the replica of the upper part of the cloche on the concreted part of the shaft and final connection by cement mortar with cristalization admixture.

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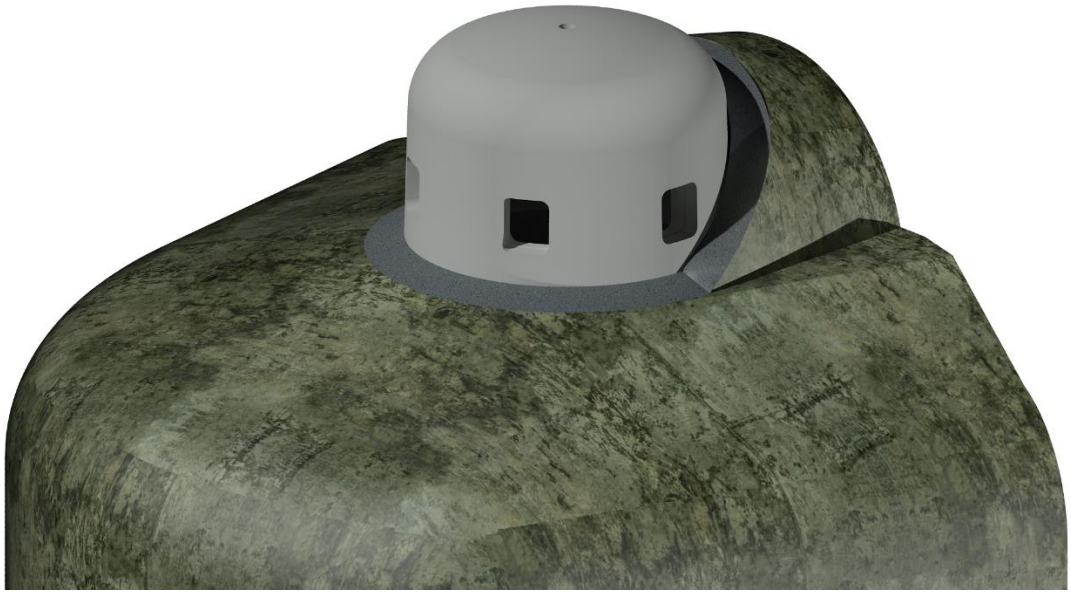

Fig. 16 – 3D model of a final state

Fig. 17 – Realization of the lower monolithic part of the cloche (pillbox T-S 20)

Fig. 18 – Placement of the replica and realization of concreting (pillbox T-S 20)

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Fig. 19 – Current state of the pillbox T-S 20 (April 2020). Replica of the cloche was painted by the colour imitating metal, reconstruction of the surface plasters has not been made yet (due to COVID 19 pandemic)

CONCLUSION

Main phase of the reconstruction of the cloche AJ-S-D at the pillbox T- S 20 was successfully completed by placement of the prefabricated element and its monolithic connection with the construction of the object on 13. 10. 2019. Complete reconstruction is not finished. Following steps are: levelling and painting the inner surface of the shaft and especially overall external reconstruction of the plaster layer of the fortress, including the application of an original masking to the fortress and cloche. Then the replicas of loopholes will be placed as well as the gun carriage for the contemporary machine gun ZB type 37 which is a property of the historical club T-S 20. There will be also a functional shooting platform inside the cloche and a ventilation system. Everything was supposed to be finished in May or June 2020. However, the current crisis caused by the COVID 19 pandemic delayed the remediation measures.

The technical solution of the complete reconstruction of the cloche made at the pillbox T-S 20 in Červený Kostelec, was positively received by the military history clubs as well as the private owners of the fortresses in the Czech Republic. The team of the project NAKI II - DG18P02OVV063 has been already contacted by other owners of fortresses who are interested in the solution.

ACKNOWLEDGEMENT

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