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Case study

Restoration and preservation of the reinforced concrete poles of fence at the former Auschwitz concentration and extermination camp

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ABSTRACT

The objective of this study was to assess the present state of the reinforced concrete poles of fence at the former Auschwitz I and Auschwitz II-Birkenau concentration and extermination camp. The poles were subjected to renovation about 10 years ago. After this time some deficiencies of applied renovation method were noticed. Cracks appeared between fresh and original part of concrete cover. Analysis of the reasons of these failures was performed and a modification of used restoration method was proposed to overcome this deficiency. The modification consists in application of sacrificial anodes mounted outside the pole, in soil and inside the concrete cover.

1. Introduction

Fences, consisting of concrete poles and barbed wire are a visual symbol of death camps created during World War II by Nazi Germany (Fig. 1). KL Auschwitz was the largest of the concentration and extermination camps. This memorial for the tragic events of World War II and a symbol of the Holocaust and Nazi German crimes is a warning to the world and should be preserved as intact as possible for the future generations. This area is now the Auschwitz-Birkenau State Museum, which is visited annually by over 1.5 million people from all over the world [2]. The museum consists of two distinct areas: Auschwitz I (the older part, founded in 1940) and Auschwitz II-Birkenau (founded in 1942), located at a distance of about 3 km from each other and situated in or near the town Oswiecim. The whole area of the former camp Auschwitz is ca. 200 ha. This area was surrounded and divided by a fencing system, which has been connected to the electrical high voltage and guarded by sentries on the watchtowers [13]. After more than 70 years of exposure the former concentration and extermination camps Auschwitz I and Auschwitz II-Birkenau, need assessment of the current state of buildings, ruins and other elements included in order to undertake the necessary comprehensive maintenance. In particular, this applies to the reinforced concrete poles of fences. A comprehensive and systematic approach to their renovation to prevent progressive degradation was undertaken at the end of the twentieth century [13]. As the aim was to restore them using the principles of minimum necessary intervention, they were difficult to perform and required the participation of many people with different specializations. About 3000 poles were renovated. Currently, it has been over 10 years since the completion of this work. It was decided to review the status of these poles to gather experience and possibly correct methods used. There are still poles requiring renovation (Fig. 2).

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Fig. 1. A fragment of fence and barrack in the former Auschwitz II—Birkenau.

2. Mechanism of destruction

The results of conducted study showed that the primary cause of the destruction of the reinforced concrete poles is the process of carbonation and high humidity of environment due to high levels of groundwater. As a result of these phenomena, the environment of the concrete cover becomes close to neutral, which leads to corrosion of steel reinforcement [1,4,10,5]. Because steel corrosion products occupy several times larger volume (up to 6 times [7]) than consumed steel, disintegrating stresses arise which cause cracks and the loosening of concrete cover (Fig. 3). It has been found that the presence of adverse ions (chlorides, sulfates) in the environment was minor and did not affect the degradation process.

3. Used method of restoration and preservation

There is scarcity of the repair methods of historic reinforced concrete structures damaged by carbonation inducted corrosion [8,3,15,9,6,11]. The approach selected for restoration and preservation of the reinforced concrete pillars consisted in cleaning of the exposed bare reinforcement from corrosion products using abrasive methods. Then such prepared rebar was protected with an organic coating and finally the missing concrete layer was substituted with a fresh mortar. Fig. 4 illustrates an exemplary pillar restored using the above technology. Unfortunately, after 10 years of atmospheric exposure

Fig. 2. Some poles need still renovation.

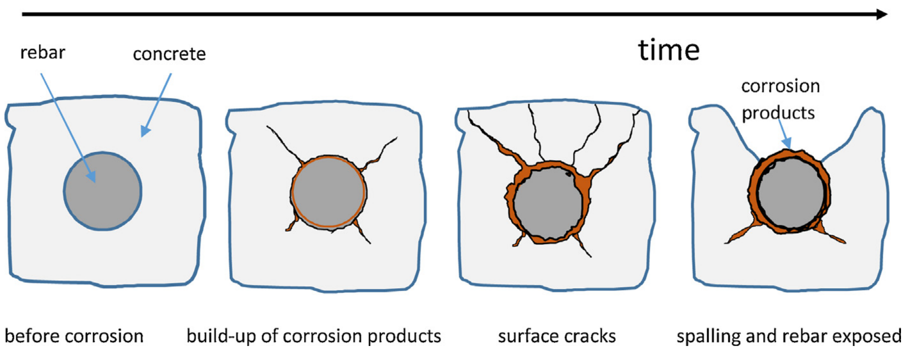

Fig. 3. Mechanism of destruction of reinforcing steel bars embedded in concrete due carbonation process.

most of the renovated pillars have experienced degradation in form of cracks. The cracks run along the interface between original concrete and the part of the mortar applied during the renovation (Figs. 4 and 5). The first suspicion on possible reason of this degradation was disbonding between the original and new part of concrete due to significant shrinkage of fresh mortar. It created the stress, which occurred to be significant enough to overcome interfacial adhesion between old and repaired part of concrete. However, the fact that the cracks had not formed within the period of time directly following restoration did not support this assumption. Thus, the most probable scenario was degradation due to renewed corrosion of steel reinforcement according to the mechanism described in Section 2. The small amount of mortar used for the restoration did not change significantly the environment of concrete cover to passivate bare steel and after about 10 years of service life of coatings applied on steel rebar a protection has finished. Also the mortar used for the restoration suffered from carbonation over time and the organic coating applied on the reinforcement during renovation no longer provided anticorrosion protection. Hence, corrosion products build-up caused concrete cracking due to the formation of corrosion products on a much larger volume than the consumed steel. Probability of this scenario is supported by the fact that in all cases the cracks appear at the side of the pillar where the rebar is located (closer to steel rebar). In the case of shrinkage different location of crack with respect to joints will be justified.

4. Suggested modification of the used methods

In order to help that situation and prevent that type of pillar degradation the authors propose a modification to the applied protection method. The modification involves utilization of cathodic protection system with sacrificial (galvanic) anodes [14,12]. It is an electrochemical approach, in which steel structure to be protected is electrically connected with more active electrode (named sacrificial anode or protector), which exhibits lower electrochemical potential than the protected

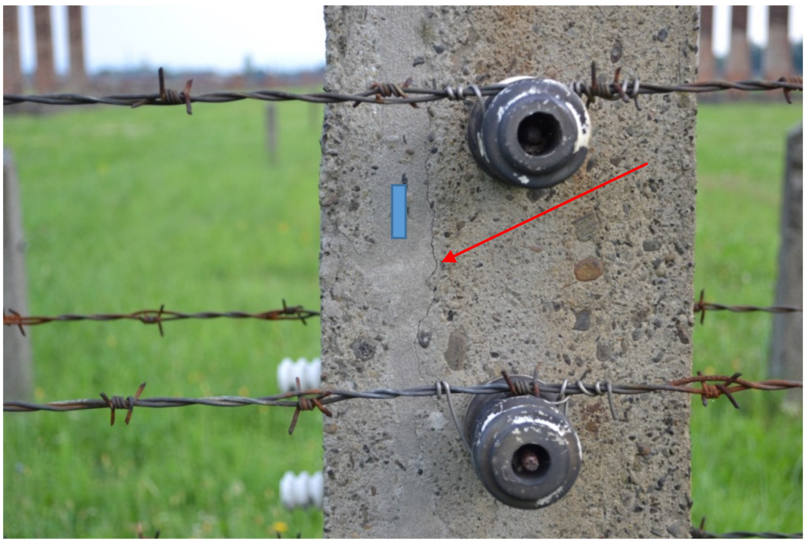

Fig. 4. Reinforced concrete pillar subjected to repair in 2004. The red arrow indicates the crack and the blue rectangle the new mortar.

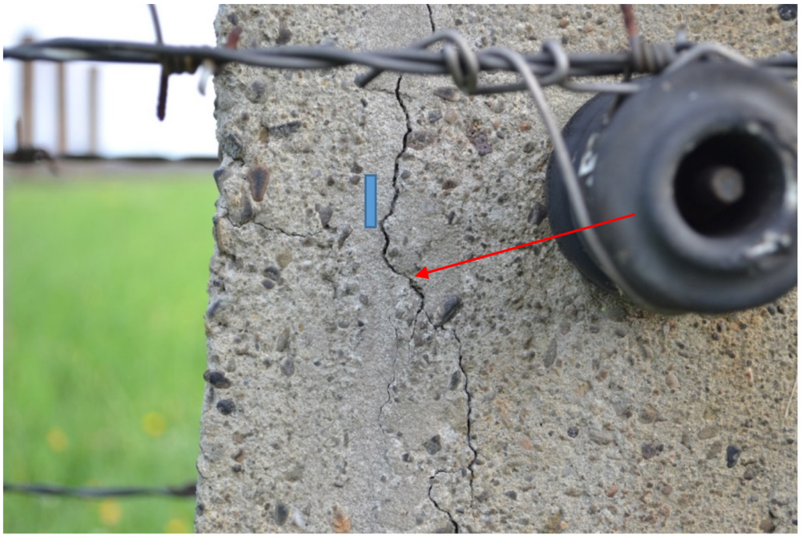

Fig. 5. Examples of cracks on the border between original material and new additions after 10 years of exposure. The red arrow indicates the crack and the blue rectangle the new mortar.

element. In this way an electrochemical cell is formed and it is the protector that corrodes and thus protects the structure. This solution requires periodical replacement of the consumable protector. Magnesium or zinc sacrificial anodes are used in soil environment for steel protection.

In order to ensure effective protection of steel reinforced pillar two variants of protection are suggested. The first one consists in placing the protector in ground in vicinity of the reinforced concrete pillar as illustrated in Fig. 6a . Electrical connection between the protector and the steel reinforcement is accomplished in the underground section of the pillar, so the protection system is not visible for the potential visitors, which fulfills the requirements for conservation of historical heritage objects. The same requirement is fulfilled by the second variant of protection, which predicts positioning of the protector directly on the reinforcement (Fig. 6b). In this case the protector is typically in form of small-dimension zinc disc or wire fixed on and electrically connected with the reinforcement bar. Then missing layer of concrete is applied covering the rebar together with the protector. As long as the concrete layer is not penetrated by water, ions and the front of carbonation is away from the reinforcement, steel does not corrode and the protectors play a waiting role. The moment the aforementioned agents reach the rebar the sacrificial anodes start to provide electrochemical protection. The second variant of protection is ideally suited for the degraded pillars calling for restoration where the reinforcement is revealed and exposed to atmospheric conditions. In case of both approaches the effectiveness of applied protection as well as the time instant when the protector has to be replaced can be monitored and determined by measurements of electrochemical potential of the pillar's reinforcement. Both proposed variants of electrochemical protection have already been implemented at separate pillars present on the area of the former Auschwitz camp (Fig. 7a and b).

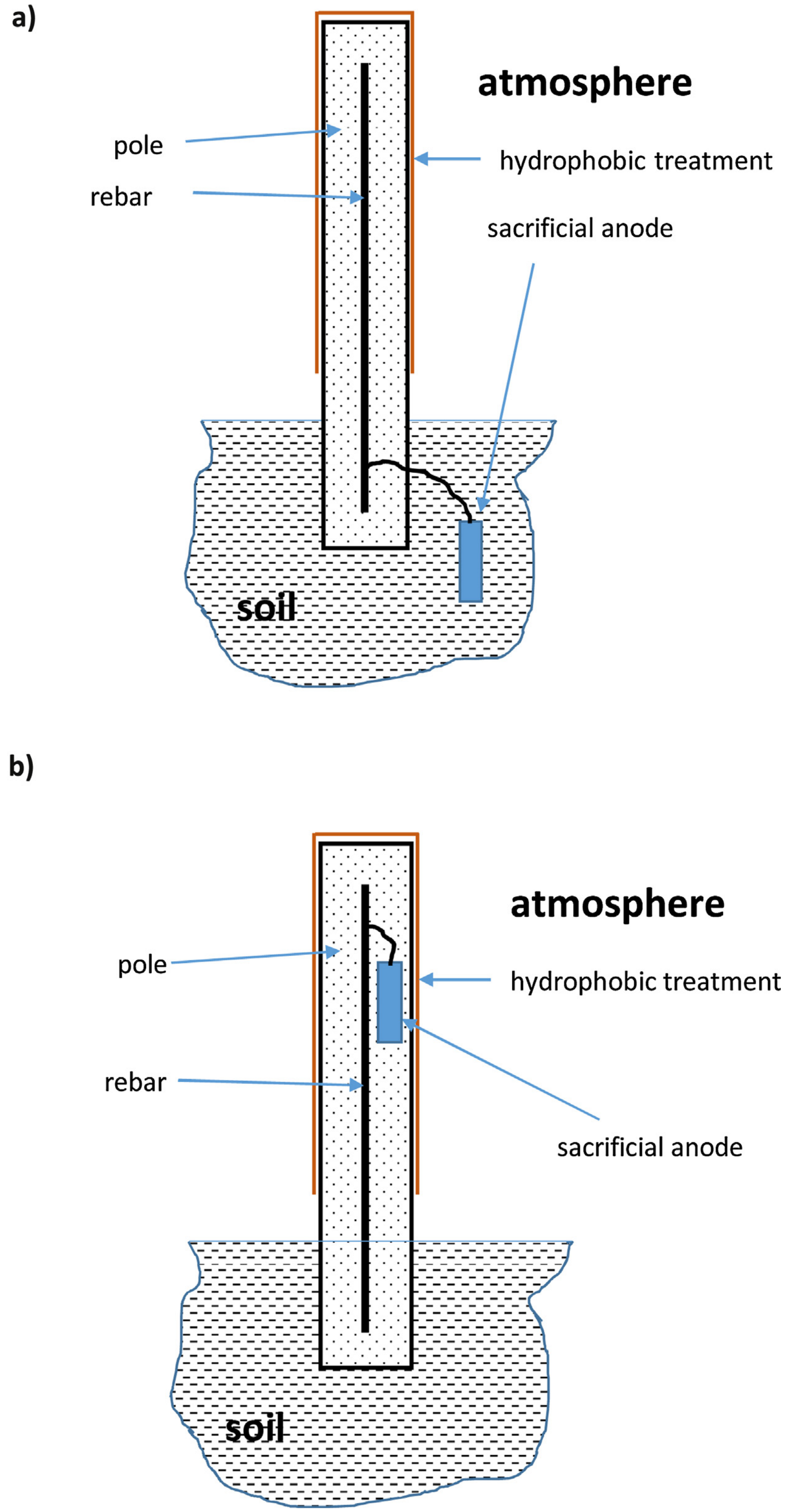

Fig. 6. Suggested methods of pole protection. Two variants: sacrificial anode situated in soil (a) and sacrificial anode situated inside concrete cover of the pole (b).

In order to increase the efficiency of protection and lifetime of the pillars equipped with cathodic protection systems it is also proposed to apply hydrophobic treatment to the pillars (Fig. 6). In this way thin film of water repellent agent is going to be deposited on the concrete surface significantly elongating the time of water ingress into vicinity of the reinforcement.

a)

b)

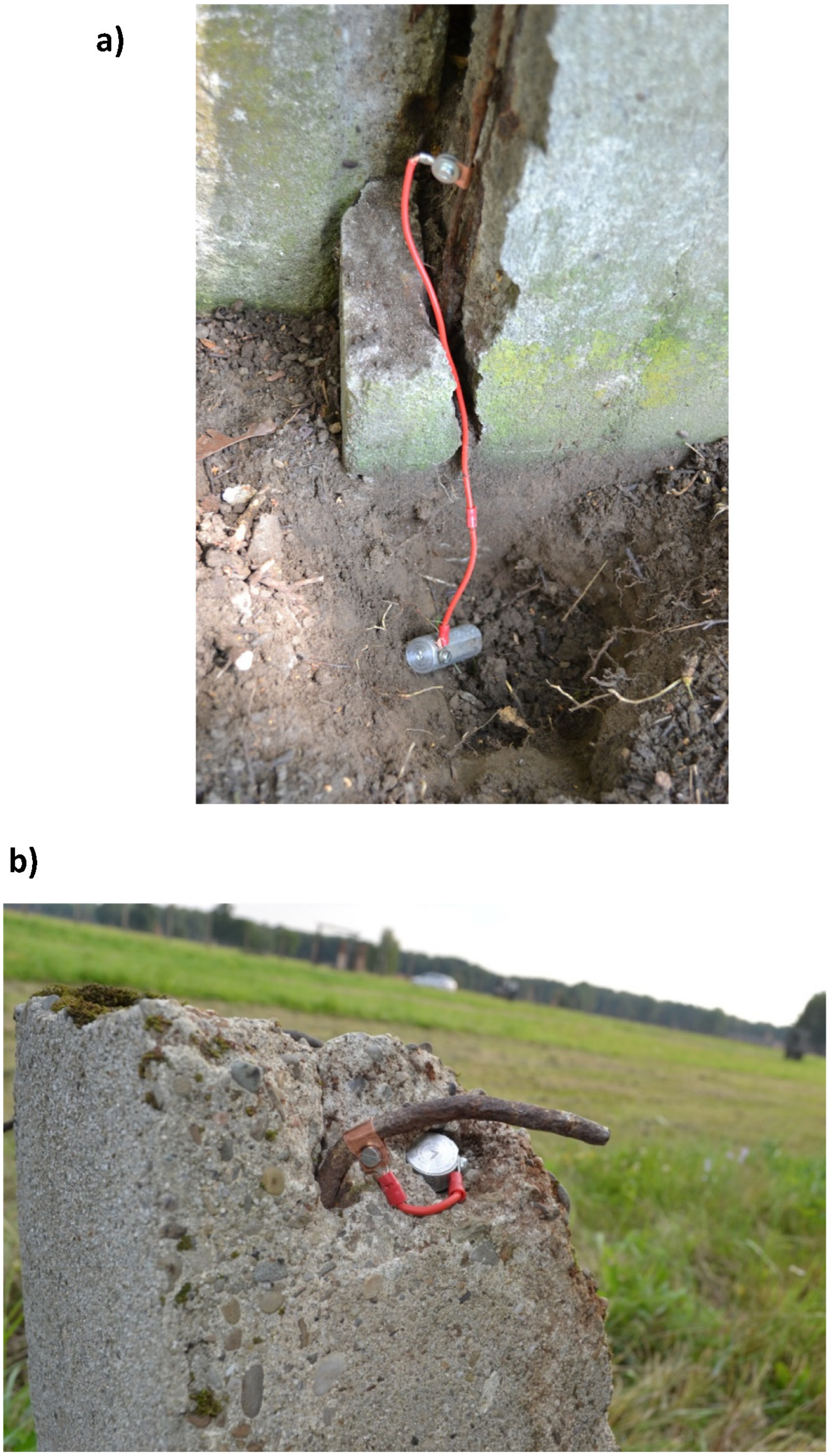

Fig. 7. Pillars located in the former Auschwitz camp protected with sacrificial anodes before applying a new repair mortar: variants with protector buried in soil (a), variant with protector placed directly on reinforcement (b).

5. Summary and conclusions

The case-study presented allows to draw the following conclusions:

- A number of reinforced concrete pillars present on the area of former Auschwitz concentration and extermination camp call for restoration due to their significant degradation following 70 years of atmospheric exposure.
- The pillars, which were subjected to repair 10 years ago reveal deficiencies in applied restoration exemplified as cracking between original concrete part of the pillar and the fresh mortar applied during the restoration.
- The possible reasons of the interfacial cracking between original and new concrete layers are: shrinkage of mortar upon settlement or more probably corrosion process occurring on the reinforcement causing the concrete to crack.
- Two variants of protection of the pillars were proposed: the first one consisted in application of sacrificial anode buried in ground in vicinity of the pillar; the second one predicts placement of protector discs or wires directly on the reinforcement and covering them with missing concrete layer.
- Both variants fulfill the requirements for conservation of historical heritage objects as the applied protection methods do not change the appearance of the pillars perceived by the visitors of the Museum.
- Both variants of protection are proposed to be supplemented with hydrophobic treatment of concrete surface to elongate the time necessary for water to reach the reinforcement.

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