# Repair and Strengthening of the Reinforced Concrete Lighting Pole using PCC and FRP Systems

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**Abstract:** This paper describes an unconventional case of the repair and strengthening of the lighting pole made of reinforced concrete using the Polymer Cement Concrete (PCC) and Fiber Reinforced Polymer (FPR) systems. The damage of the element as well as causes are discussed. The concept and technology of the repair and strengthening of the reinforced concrete lighting pole are presented in detail.

**Keywords:** Composite materials, strengthening of the structures, Polymer Cement Concrete (PCC), Fiber Reinforced Polymer (FPR).

## 1. INTRODUCTION

Building constructions often require to be repaired and strengthened due to the deterioration of their technical condition. It is caused by the passage of time, operation, or environmental impact. Until recently, traditional reinforcement methods have been used. Plastics, especially composites, gave new possibilities. The composite materials have got many advantages, among which the basic ones are excellent mechanical parameters. Therefore, they may be used to reinforce elements subjected to various loads, such as tension, compression, bending, or shear. They are increasingly used to reinforce individual elements as well as entire building structures, bridges, etc. The universality of the developed reinforcement technologies allows the use of composites to strengthen various elements. The article analyses such an example, where the case of the repair as well as strengthening of the lighting pole made of reinforced concrete using PCC and FRP systems are described.

## 2. DESCRIPTION OF DAMAGE

The lighting pole is located in Poland, in Busko-Zdrój in the Spa Park. It was placed in the '90s of the last century. Since that time, no maintenance has been carried out. Inspection revealed deviations from the vertical, cracks, loss of concrete, exposure of reinforcing steel, and corrosion. This damage to the lighting pole is clearly visible in Figure **1**.

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## 3. ASSESSMENT OF POSSIBLE CAUSES OF DAMAGE

The main causes of the damage were atmospheric factors (rain, wind, frost) and mainly no maintenance. The reason may also be cracks and longitudinal scratches in concrete, which were not revealed during production. After many years of operation they could be enlarged as a result of atmospheric factors. Nevertheless, the proper maintenance of the lightning post would certainly not lead to such significant damage, which is required in accordance with the Construction Law [1].

## 4. CONCEPT OF REPAIR AND STRENGTHENING

The concept of post reinforcement included the use of a modern Fiber Reinforced Polymers (FRP) consisting of S&P C 240/300 300 mm sheet and a two-component resin adhesive S & P Resin 55. Properties of these components of S&P strengthening system are presented in Tables **1** and **2**.

## 5. REPAIR AND STRENGTHENING PROCESS OF THE LIGHTING POLE

The whole repair and strengthening process included four stages:

### Stage 1. The Concept of Pole Repair and Strengthening

The first stage involved the development of the concept of pole repair and strengthening, as well as the exact determination of the order of execution of construction works. In order to achieve for the repair and strengthening method high strength, durability and efficiency, it was decided to use modern building materials using PCC and FRP systems.

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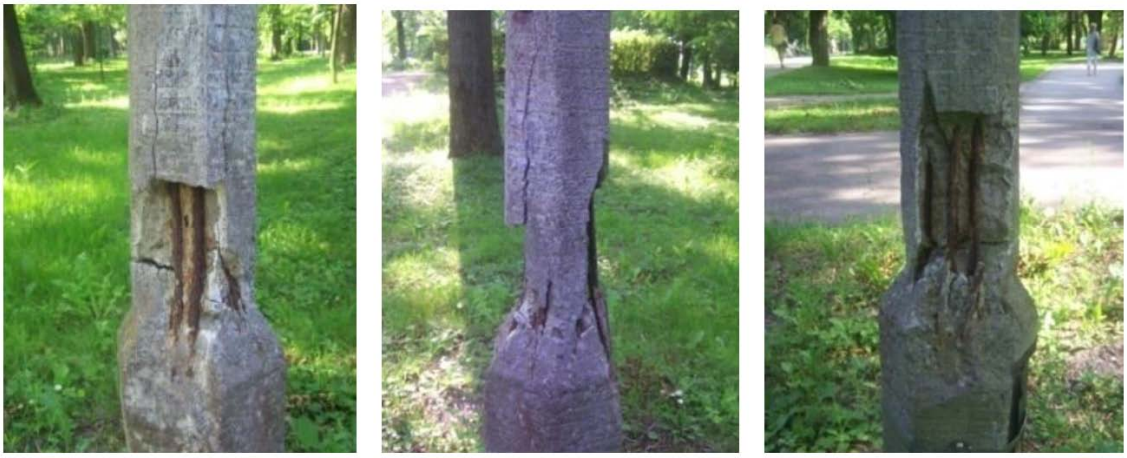

**Figure 1:** Damage of the lighting pole.

**Table 1: Specifications of S&P C Sheet 240/200 300mm [2]**

| Fiber Specifications (Unidirectional) | 200 g/m$^2$ | 300 g/m$^2$ | 400 g/m$^2$ | 600 g/m$^2$ |
|---|---|---|---|---|
| Modulus of elasticity (kN/mm$^2$) | 240 | 240 | 240 | 240 |
| Tensile strength (N/mm$^2$) | 3800 | 3800 | 3800 | 3800 |
| Density (g/cm$^3$) | 1.7 | 1.7 | 1.7 | 1.7 |

**Table 2: Specifications of S&P Resin 55 [2]**

| | |
|---|---|
| Density | 1,11 kg/l |
| Mixing proportions | 2:1 (resin:hardener) |
| Tensile strength after 7 d. | 35 MPa |
| Elongation | 8 – 10% |
| Modulus of elasticity | 5000 MPa |
| Grip on steel and FRP | > 15 N/mm$^2$ |

### Stage 2. Surface Preparation

The second stage was related to the implementation of repair work. The first step was to prepare the surface to be repaired before applying the PCC system. At first, rust was removed from the reinforcing bars using a wire brush disc attached to an angle grinder and a hand-held wire brush. Then, remnants of concrete were removed using a metal putty knife and cutter. The final stage of surface preparation was to remove dust from the surface being repaired using a brush. The surface prepared in this way, free of rust, concrete, and dust, was ready to apply a layer of Ceresit CD30 mortar.

### Stage 3 Applying PCC Mortar Layers

The first step was to prepare Ceresit CD 30 mortar. This is a contact and corrosion protection layer. For this purpose, the contents of the packaging were poured into a measured amount of clean water in the proportions set by the manufacturer in an amount of about 6.75 liters of water per 25 kg and mixed with a slow-speed drill with a mixer until a homogeneous mass without lumps was obtained. Then, the mortar was applied with a brush, first to the reinforcing bars and then to the concrete surface. After 5 minutes, the mineral mortar was applied to the surface of the pole,

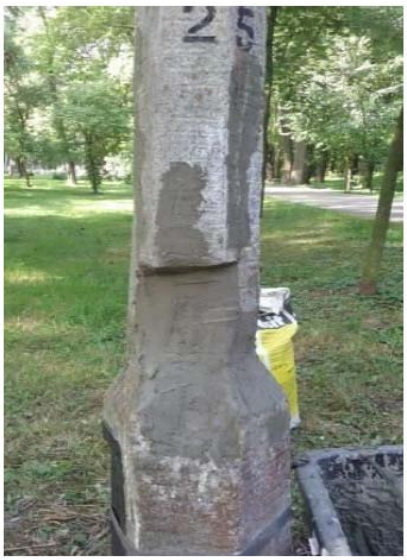

**Figure 2:** Application of the mortar contact layer Ceresit CD 30.

as shown in Figure **2**. Next, at 60 minutes after the initial drying of the mortar, the application of Ceresit CD26 coarse-grained mortar for filling losses from 30 to 100 mm began. The contents of the packaging were mixed with water, using approx. 3-3.2 liters of water per 25 kg of the mortar. The substrate was wetted with water before applying the layers. Then, with a trowel, layers of mortar were applied to the previously laid contact layer, forming the appropriate shape with the help of a trowel (Figure **3**).

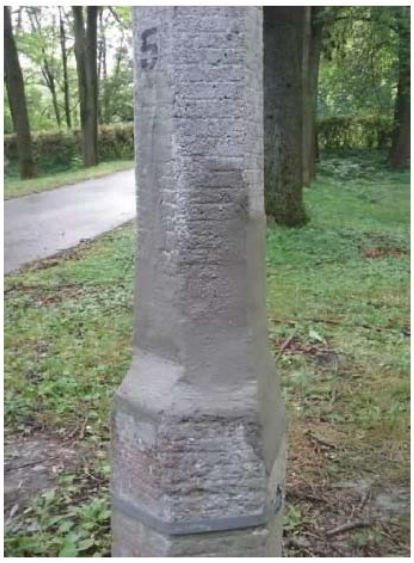

**Figure 3:** Application of finishing layer with mortar Ceresit CD 26.

### Stage 4. Reinforcement of Poles

Work began 48 hours after the last mortar application. First, excess mortar and dust were removed with a putty knife and brush. Then the resin glue was ground S & P Resin 55 consisting of epoxy resin and hardener as directed by mixing both components using a slow-speed drill with a mixer at 200 rpm for 5 minutes until a uniform white color is obtained. Then two thin layers of adhesive were applied to the surface of the pole. The next step was the application of a carbon fiber mat. The sheet was properly tensioned (Figure **4**) to prevent the formation of air bubbles. Finally, the mat was covered with 2 layers of resin glue to obtain the final effect, which is shown in Figure **5**.

## 6. SUMMARY

Reinforced concrete, like any building material, is exposed to the damaging effects of atmospheric, mechanical, and biological factors. However, the resulting damage can be effectively repaired using, for example, the PCC system, instead of replacing it with new ones. There are many methods to strengthen the structure and very diverse. Traditional methods are replaced by new ones, more effective, and less labor-intensive. Currently, the most popular are fiber composites characterized, among others, by very high tensile strength, high corrosion resistance, low own weight, and short time of conducting works that are particularly important in reinforcing works [3-5]. In this article, the exemplary concept of the repair and


**Figure 4:** Carbon sheet application.

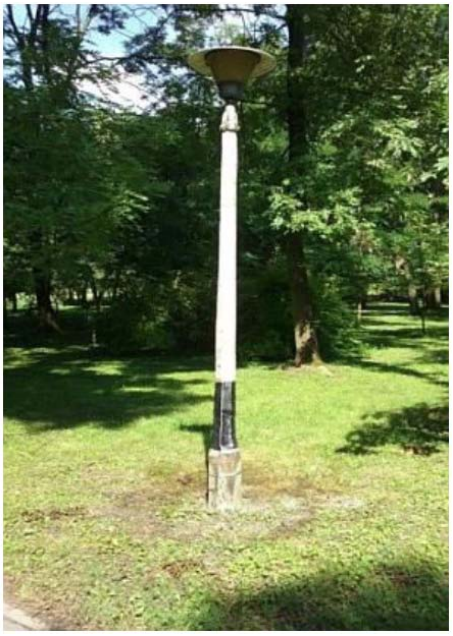

**Figure 5:** The final effect of the lightning pole repair.

reinforcement combines the use of two modern PCC and FRP systems. The numerous advantages of the materials make them a good choice wherever high quality and short repair time count.

## ACKNOWLEDGEMENTS

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