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INVESTIGATION OF DEGRADATION STATE AND PRACTICAL SOLUTIONS OF REHABILITATION FOR REINFORCED CONCRETE STRUCTURAL ELEMENTS

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Abstract: *The paper treats theoretical and practical aspects related to procedures for investigation, diagnosis and rehabilitation of a concrete structure from cellulose and paper platform „CELOHART" Zarnesti.*
Rehabilitation solution proposed leads to the restoration of the bearing capacity of structural elements damage to a 140% assurance.
Key words: *short console, first crack, opening of cracks, chemical corrosion, reinforced concrete degradation*

1. INTRODUCTION

1.1 General aspects

Aggressive operating environment of some buildings from dyestuffs industry, cellulose and paper industry represents a main factor of degradation of their structural elements.

Technological processes carried out in production sections caused significant structural degradation due to the increase in air concentration of Cl^-, SO_4^{2-} ions, the leakage of water loaded with chemicals and prolonged action of CO_2.

Due these causes, several buildings from Codlea and Zarnesti chemical platform of dyes and paper suffered important states of degradation who determined a reduction significant of resistance capacity.

The study on the resistance capacity of reinforced concrete elements, which have acquired a certain state of degradation as a result of destructive actions, is a concern for many experts in the field. This because most of the industrial structures of reinforced concrete (especially in our country) are old and the costs of demolition and replacement with the same or different type of structure are large, often irregular or more exceeding the financial possibilities of the units.

The experimental study includes two practical solutions to rehabilitate the damaged short consoles by placing a cover on them or covering them in rigid metal boxes, (Tuns, 2003).

These solutions were chosen as they are frequently used in the practice of the rehabilitation of structures damaged and there are few studies on the restoration degree of resistance capacity of the reinforced elements by these methods.

In this sense were made experimental study on more buildings from SC Colorom SA Codlea or SC Celohart SA Zarnesti.

Aspects regarding the investigation degradation state for structural elements of „Sulphur storage" section and experimental study on practical solutions of rehabilitation are presented in next chapters.

1.2 Aspects of chemical corrosion behaviour of industrial structures investigated components

Sulphur storage

The building has one floor, with precast reinforced concrete frame structure. Frame's columns are provided with two short brackets, one is to insure rolling beams suspension at an intermediate level and the other (at the end) assure the connection bond column – frame beam at roof level.

Investigations on these elements revealed the following aspects:

- Concrete leaching out on a (1-5) cm thickness range;
- Carbonation products erosion from the surface layer of concrete and highlighting (unveiling) aggregated granules;
- Presence of surface and in-depth cracks on faces of columns and consoles, specific to sulphating corrosion;
- Cracks orientation towards disposition direction of reinforced bars;
- Local detachment of the reinforced bars cover;
- Unveiled reinforced bars corrosion;
- Insufficient thickness of concrete reinforced bars cover;
- Use of metal spacers for maintaining the position of reinforced bars instead of plastic or cement mortar;
- Excessive moisture in the concrete columns due to water seepage from the roof;
- Lack of concrete protection against corrosion.

1.3 Analyze the degradation of structural elements investigated

Process of investigating the damaged items consisted in (Tuns & Mantulescu, 2009):

- Visual inspection of degraded areas;
- Photographing studied areas;
- Laboratory chemical analysis (with determinations result made on samples taken on the spot presented below);
- Determining the thickness of concrete leaching out layer by treatment with phenolphthalein solution;
- Ultrasonic non-destructive testing method on the structural elements investigated, (Tuns et al., 2009).

Investigative methods used revealed the chemical corrosion of concrete from consoles, because:

a. The action of SO_2^{-4} ions;
b. The action of Cl^- ions;
c. Action of CO_2 and electrochemical corrosion of reinforced bars due to:
d. The action of oxygen and/or chlorine.

Non-destructive method indicates advanced degradation process for consoles belonging to Sulphur storage, (Tigges, 2009).

2. EXPERIMENTAL STUDY REGARDING SOLUTIONS OF REHABILITATION OF STRUCTURAL DAMAGED ELEMENTS

2.1 Description of initial experimental elements

The short consoles made for the experimental study are made of reinforced concrete with longitudinal reinforcement under the form of bars and the transversal one under the form of stirrup (Figure 1).

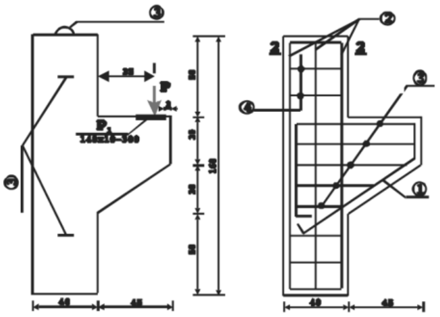

Fig. 1. Experimental element – form, dimensions, fixture

Given the role and importance of short consoles in industrial building structures, to achieve these elements were used the following: concrete class Bc20 (C16/20), having a compression of 7 cm prepared with cement type II AM/32,5 R, and river aggregates (0 / 31) mm.

For determining the geometric dimensions and of the area of transversal and longitudinal fixture an operating burden of 20 tons was taken on the console.

The geometrical dimensions of the consoles were established based on the general structure rules, including the console carried out in the category of short consoles:

$$0{,}4h_c \le a_c \le h_c \tag{1}$$

The sizing of the longitudinal fixture was made at maximum moment in the section of fixing the console in the pole.

And for the transversal fixture the calculations and the specific conditions of constructing structure have been applied.

The same result was reached also after sizing the longitudinal fixture like the Eurocode 2 (Popaescu et al., 1994), through" the process of models of bars".

2.2 Practical way to conduct the experimental program

Experimental program was conducted in three work phases, content of each stage are described below:

First working stage

Testing all the experimental models, of which 3 elements up to breakage and 6 elements up to a burden of 30 tons;

Second working stage

Reinforcement of the 6 tested elements up to 30 tons in the first stage, by replacing to a reinforced concrete cover for 3 elements, respectively into a rigid metal box for the other 3 elements.

Third working stage

Testing up to breakage of the experimental models reinforce in the second stage.

3. COMPARATIVE ANALYSIS OF PROPOSED REINFORCING METHODS

The main objective of the study was to evaluate the restorative capacity of the loading capacity of the restored consoles using the two variants and the mechanism of their yield, under vertical loads.

Following the distribution of capable load (Figure 2) on the experimental non-consolidated and consolidated (both) consoles, tested up to breakage, results the following:

- capable load, determined by series of elements has similar values, between (48 – 50) tons for initial consoles, between (69 – 70) tons for the reinforced ones using the method „reinforced concrete cover", respectively between (70 – 74) tons for the consoles covered by rigid metal boxes";

- reinforcing solutions, using the methods „rigid cover of reinforced concrete" or „metal", approached within the present work, lead to very close values of the capable load.

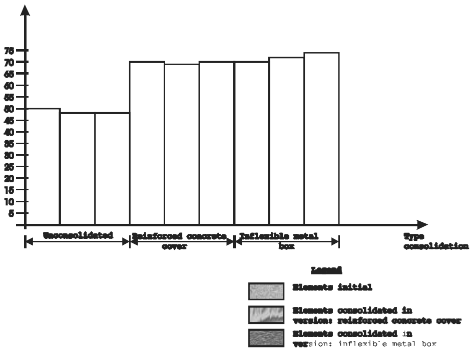

Fig. 2. Capable load on consoles

4. CONCLUSION

Regarding the restoration level of the loading capacity (noted with „n_{RCP}") of the damaged consoles damaged taken into account using the two methods, have resulted the following values:

The reinforcing method „rigid cover of reinforced concrete"

$$n_{RCP} = \frac{\text{Capable load (average) reinforced elements}}{\text{Capable load (average) non - reinforced elements}} = \frac{69{,}7\ \text{tf}}{49{,}3\ \text{tf}} \approx 1{,}41$$

The reinforcing method „rigid metal box"

$$n_{RCP} = \frac{\text{Capable load (average) reinforced elements}}{\text{Capable load (average) non - reinforced elements}} = \frac{72\ \text{tf}}{49{,}3\ \text{tf}} \approx 1{,}46$$

The values obtained indicate that the levels of recovery for the loading capacity for the two types of consolidation are very close and may be considered practically equal.

Following the economic calculation, it results that the type of consolidation through "rigid metal box" leads to a cost price / console higher than approx 40% than the type "rigid reinforced concrete cover"

The comparative analysis of results indicates that the type of consolidation "rigid reinforced concrete cover", is more economical than the "rigid metal box" and provides the same level of recovery as the loading capacity of the latter.

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