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ISSUES CONCERNING THE REHABILITATION OF SOME STRUCTURAL ELEMENTS OF REINFORCED CONCRETE BY COATING THEM IN A RIGID LAYER OF REINFORCED CONCRETE AND HIGH-QUALITY CONCRETE

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REZUMAT

În lucrare sunt prezentate rezultatele experimentale obținute pe modele la scară naturală privind refacerea capacității portante a unor elemente structurale din beton armat degradate şi reabilitate prin îmbrăcarea acestora într-o cămaşă rigidă realizată din beton armat şi beton de înaltă performanță.
Mecanismul de comportare şi cedare sub încărcări verticale, precum şi evaluarea nivelului de refacere a capacității portante pentru elementele investigate, constituie obiectivul central al prezentei lucrări.
Cuvinte cheie: Beton de înaltă performanță, model experimental, consolă scurtă, deschiderea fisurilor, cedarea consolei, cămaşă rigidă din beton armat, cămaşă rigidă din beton de înaltă performanță.

1. INTRODUCTION

1.1. Considerations concerning the necessity of the rehabilitation of the structures of reinforced concrete

A long period of time one has considered that the concrete presents a great durability, being compared in this respect to the "resistance and durability of natural stone" [6].
But as the level of knowledge concerning the mechanical, physical and chemical characteristics on the concrete increased and a certain experience concerning the performances of the concrete structures in aggressive conditions was gained, the concept of durability has gained new meanings.
It was realized that the elements of simple concrete and those of reinforced concrete, situated in an ambiance with chemical aggressiveness, as well as the allied under normal use conditions, suffer degradations after a certain period of time [5].
Because of the deterioration process in time of the concrete, the service duration of a building is limited. After a certain period of time measured in years, the technical status of the buildings must be analyzed in order to determine the remedy measures, consolidation or, in an extreme situation, of partial or total demolition.

Depending on the depreciation degree of the damaged element, on the actual working conditions, on its role and its importance in the structure, one chooses the optimal rehabilitation solution.
The solution one may choose is to ensure the fulfillment of the conditions: rigidity, stability and durability, for the consolidated element as well as for the general construction assembly.

1.2. General aspects concerning the use of bir for the construction of the new structural elements or for the rehabilitation if the damaged one

The beginning of the 70s brings into the specialized literature the new elements concerning the experimental results obtained in the case of concrete structures, initially prepared with devices for grinding from rough rocks, concrete structures with higher resistance to compression, A/C [3] reduced reports and procedures for the implementation providing am energy compacting, referred to as high strength or high-performance concrete structures, abbreviated as BIR or BIP.
The subsequent emergence and expansion on sulphonyl formaldehyde naphthalene plasticizers (NFS) and sulphonyl formaldehyde melamine (MFS) basis have led to the removal of difficulties related to the implementation and compacting due to the reduced values of A/C [3] reports .
By a rigorous dosing and selection of the main elements, accompanied by A/C reports accompanied by the presence of super-plasticizers, mineral surplus and /or metallic and by the use of suitable means of implementation and compacting that achieved to the construction of high performance concrete structures and ultra high performance.
The physical – mechanical and special durability characteristics of the concrete structures previously mentioned compared to the usual ones, during the last decades have led to the expansion of the use of such range of concrete structures within the buildings strength structures.
In the context of the above presentation, the experimental study of this paper aims at operational use of strength items in reinforced concrete, that have acquired a certain condition of degradation that are rehabilitated by their coating into a rigid layer in reinforced BIR and reinforced normal concrete.

2. REHABILITATION OF DAMAGED STRUCTURAL ELEMENTS

2.1. Basic elements in the consolidation by coating

The method consists in coating after a previous preparation of the damaged elements, into a normal concrete coat or reinforced BIP, performed by direct casting in casings or injection of concrete. The procedure is generally applied when the condition of the reinforced concrete items is very obvious, as a result of the reduction of the active section of the concrete and of the reinforcement.

The recovery by coating of the carrying capacity of structural elements must be conceived and directed not to lead to extreme increases of the consolidated areas rigidity. The newly created coating must work with the damaged item in order to achieve the forecasted strength capacity.

Meeting this condition supposes, besides other operations, the provision of a good connection between the two concrete structures of different ages entering into contact, that can be attained by [8],

- Direct adherence between the old and the new concrete ;
- The increase of the old concrete roughness, by removing the damaged concrete;
- breaking the old concrete, in order to join by welding the old and the new fittings;
- joining is created from place to place by the welding of new fittings, in the excess of the existent ones:
- the use welded closed braces:
- insertion of con-expand screws or metallic bolts blasted in the existent concrete;
- Contraction of the new concrete.

2.2. Development of the experimental program

By the experimental program was aimed at the behavior of structural damaged elements belonging to buildings in the chemical industry.

For such purpose, 6 experimental patterns have been created in the form and geometrical size of Fig. 1 and that are frequently met within the investigated industrial structures.

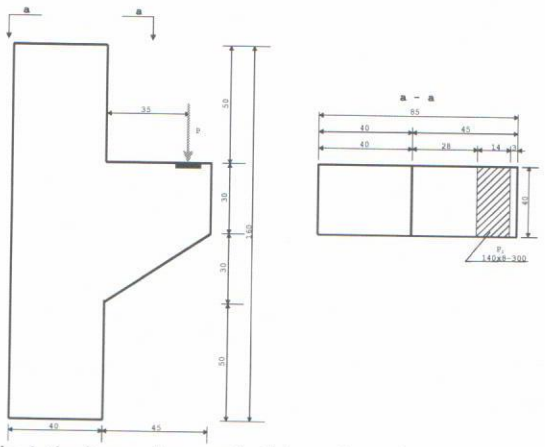

Fig. 1. the form and geometrical sizes of experimental elements

In order to determine the geometrical sizes of the area of longitudinal and transversal fitting, there has been taken into consideration a working load on the bracket of tf.

The characteristic strengths and for calculation for the concrete and reinforcement,

used in the calculation of dimensioning are the following:

* for concrete class Bc 20 (C16/20)
Rc = 12 5 N/mm^2
sectional reinforcement
Rc= 1,75 Re = 21,88 N/mm^2
f_{ck} = 16N/mm^2
$f_{cd} = f_{ck}/1,5$ = 10,67 N/mm^2

reinforcement)

* for reinforcement
OB 37 (cross-

of braces
R_a=210N/mm

PC 52 (longitudinal

Ra= 300 N/mm^2
R_a = 1,35 R_a = 405 N/mm^2
f_{yd}= 300 N/mm^2

The sizes thus obtained care framed in the balance of short brackets. The longitudinal reinforcement dimensioning and transversal on the section of experimental elements has been carried out in compliance with the prescriptions and technical specialty publications [6], [7].
The experimental program has been run at three work staged, as follows:
Work stage 1 testing of all experimental models, of which 3 items until breaking and 3 items up to the value of the vertical load of 30 tf;
Work stage 2 Consolidation of experimental items tested in the first work stage up to 30 tf, by their coating into a rigid layer realized in reinforced BIR or reinforced normal concrete;
Work stage 3 Testing until breaking of experimental consolidated models in the work stage no. 2.

2.3. Testing to breaking of experimental models

For the models CS1-1; CSI-2; CSI-3 (tested at vertical loads up to breaking) the yielding occurred at the value of the force of 48 tf for CSI-2; CS1-3 and de 50 tf for CSl-1.
The panel of cracks formation and development show they appear from two to three and that later are separated into new cracks with smaller length and opening, Fig. 3.a.
The brackets yielding occurred by a stressed opening of cracks 1,,2, 3, the opening and the frequent apparition of branches formed out of the existent cracks and the concrete crushing near the lower corner of connection of the bracket and pillar, Fig. 3-b.

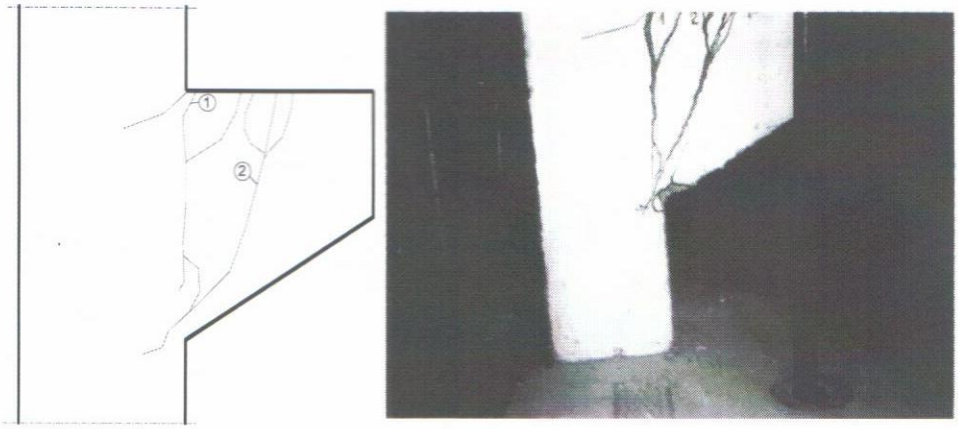

Fig. 2. The rise of cracks and yielding of the bracket
a. cracks formation rise ;
b. broken bracket rise.

2.4. Testing up to the value of 30 tf load of the experimental models

In the case of models achieved in the second series of casting, recorded with CS2-1; CS2-2; CS2-3, the maximum load was limited at the value of 30 tf.
It is found that in this type of testing the apparition on the sides of the brackets of one to three cracks with smaller length and opening.

2.5. Testing of experimental damaged models and rehabilitated by coating into a reinforced coat

The experimental models for which the testing load was limited to 30 tf have been consolidated in order to recreate the strength capacity. Three of these, i.e. CS3-1; CS3-2; CS3-3, have been consolidated by coating.
The reinforced concrete coat covers both the bracket and the pillar area to which it is connected.
From the condition of providing the minimum thickness of the concrete cover layer of reinforcements and the favorable conditions of adherence between it and the concrete, there resulted the 8 cm thickness.
The form and the geometrical sizes of the elements, resulted after the consolidation, are presented in the Fig. 3.

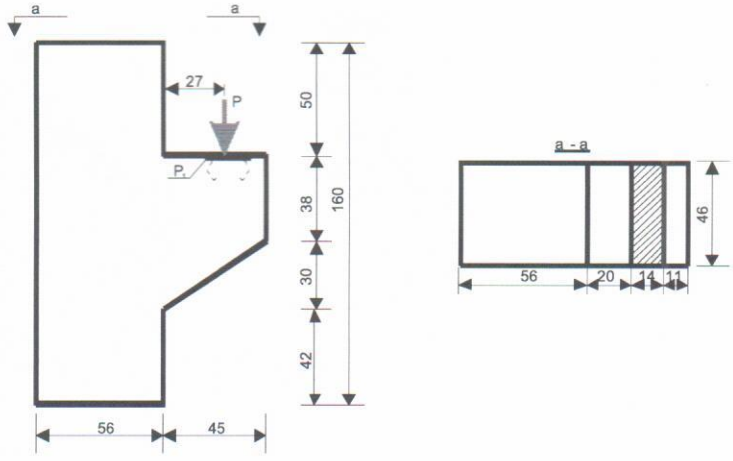

Fig. 3. the form and the geometrical sizes of the experimental items after consolidation

After having exceeding 28 days from the consolidation, the experimental elements have been tested up to breaking. In such purpose, the metallic frame of the stand has been adapted to the new geometrical sizes of the experimental element (Fig- 4).

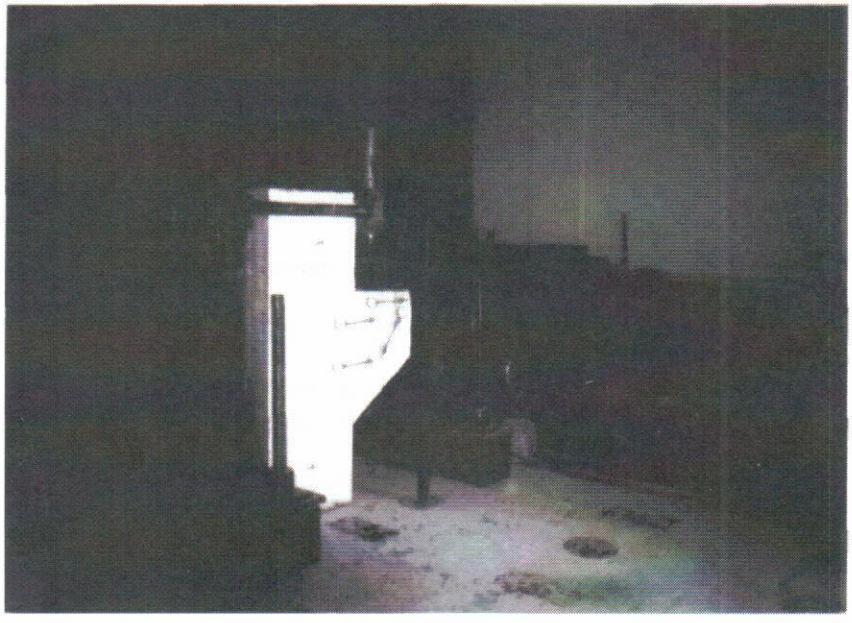

Fig. 4. Experimental element on the testing position

Following the testing plugs, as well as the panel of the formation and development of

cracks (Fig, 5), the following is found:

- The presence on the bracket sides of a number of 4 to 5 main cracks:
- The first crack emerges in the area of connection between the bracket and the pillar for all the brackets, at a vertical load of 30 tf for CS3-1; 20 tf for CS3-2 and 25 tf for CS3-3;
- The other cracks are bent, (approximately 45), start from under /or from near the supporting plate and lay on the brackets height ;
- The second crack is visible at 35 tf for CS3-I, CS3-3 and la 55tf. for CS3-2;
- The third crack is visible at 45 tf for CS3-1, la 50 tf for CS3-3 and la 60 tf for CS3-2;
- The fourth crack is noticed at 50 tf for CS3-I and la 60 tf for CS3-2. CS3-3;
- The fifth crack is visible at the bracket CS3-3. at the vertical load of 60 tf;
- The order of the appearance of cracks for all the elements is from the connection area with the console pole towards its end.

The yielding of the consoles happened at a vertical load of 69 tf for CS3-2 and of 70 li" for CS3-I, CS3-3, by opening and ramificating the main cracks and the crash of the concrete on the basis of the support pole of the console (fig. 5).

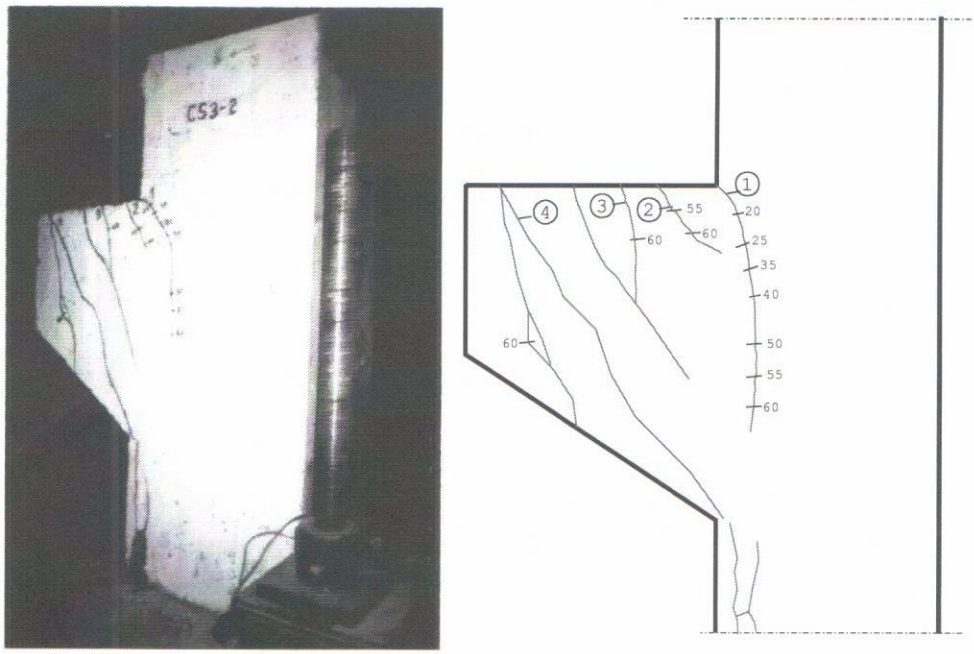

Fig. 5. Rise cracks console (consolidated)

2.6. Trying the experimental degraded and rehabilitated models by coating it in a layer realized from reinforced bl 1*

The rigid layer coating for consolidation of Ibst realized from high-quality concrete, class Uc60/70 with preparation receipt from the table number I.

Table 1

Material composition	**Kg/m^J**
Cement (CEM 152,5 R)	**450**
Extra fine Silica (SUF) 10% C	45
Sand (0-3) mm	525
Gravel (3-7) mm	525
Gravel (7-I6)mm	791
Super-plasticizers	11,7
Water	153

From the analysis of the mde data sheets for the try and by examining the table for the formation and development of cracks, the following aspects must be pointed out:

- The presence on the lateral faces of the console of a number of 4 to 5 main cracks;
- The first crack appears in the connection area console-pole for all consoles, at a vertical load of 45 tf for CS2-1, 38 tf for CS2-2 and 40 tf for CS2-3;
- The other cracks are bent, (approximately 45"), start from under/or near the metallic supporting plate and go up on the bracket's height;
- The second crack is visible at 50 tf for CS2-1, CS2-3 and la 62 tf, for CS2-2;
- The third crack is visible at 67 tf for CS2-1, la 70 If for CS2-3 and la 75 tf for CS2-2;
- The fourth crack is noticed at 74 tf for CS2-I and la 80 tf for CS2-2, CS2-3;
- The fifth crack is visible at the bracket CS2-3, at vertical load of 82 tf;
- The order of apparition of the cracks for all items is coming from the area of the bracket connection with the pillar towards its end.

The bracket yielding occurred at a vertical load of 102 tf for CS2-2 and de 105 tf for CS2-I. CS2-3. by the opening and ramification of the main cracks and crushing of the concrete at the basement of the bracket's support pillar, Fig. 6.

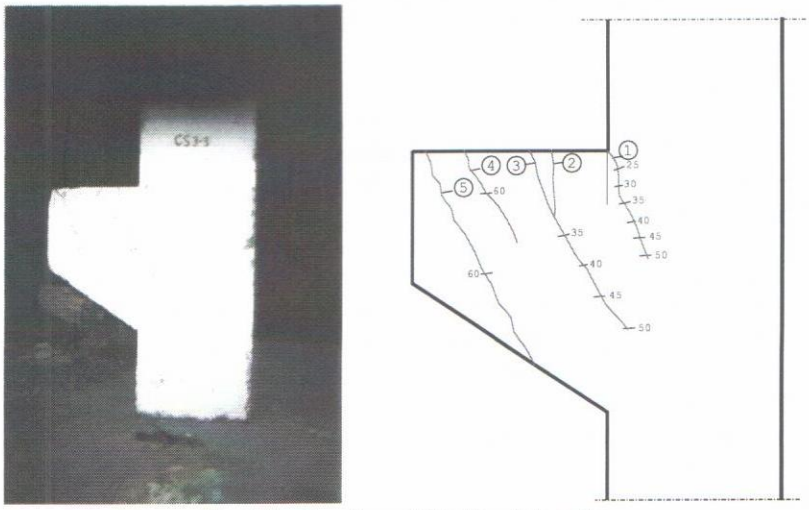

Fig. 6. the rise of consolidated bracket cracks

3. CONCLUSIONS

On the basis of the observations and the interpretation of the results obtained after the execution of the experiments, the following principal aspects are viable:

- The consolidation of the experimental models in the variant „ rigid layer coating from reinforced concrete" indicates an increase in the carrying capacity with appreciatively 41% in comparison to unconsolidated models;
- The consolidation of experimental degraded elements by coating them in a rigid layer realized from BIP, class Re 60/70, leads to the recovery of the carrying capacity with appreciatively 130% over the corresponding value of the not degraded element;
- The yielding of consolidated elements in both variants was produced at a vertical load greater than the estimated theoretical one with appreciatively 35%;
- In both variants of consolidation, one may note the positive role of the realized layer coating on predetermining the carrying capacity and the increase in ductility by the effect on the not degraded concrete;
- The table of formation and development of cracks is analog to the two variant, the differenced consist mainly in the sheer size of the opening of the main cracks and of the ramifications coming from it;
- when the brackets are yielding, the maximum opening of the cracks gets to the value of 0,30 mm for the version of the reinforced concrete coating and de 0,12 mm for BIP coating version BIP;
- The BIP consolidation version leads to decreased thickness of the coat, eliminating

thus sudden variations of rigidity from one section to another.

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