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EHAMPLES FOR BEHAVIOR OF PRESTRESSED CONCRETE STRUCTURES EXPOSED IMPACT LOADING IN THE STAGE OF CONSTRUCTION AND WAY OF REPAIRING DEMAGED STRUCTURAL ELEMENTS

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EXAMPLES FOR BEHAVIOR OF PRESTRESSED CONCRETE STRUCTURES EXPOSED TO IMPACT LOADING IN THE STAGE OF CONSTRUCTION AND WAY OF REPAIRING DAMAGED STRUCTURAL ELEMENTS

SUMMARY

The paper presents two examples for the behavior of the IMS prefabricated prestressed concrete skeleton structure, exposed to impact loading in the stage of construction, as well as the applied way of repairing the damaged structural elements. In the first example, the structure was exposed to a drastic impact due to the collapse of the crane in the stage of construction, while in the second example the impact was caused by the collapsing of a precast shear wall. These accidents resulted in damaging certain elements of the IMS prefabricated skeleton structure made of prestressed concrete. Inspection of the state of the damaged structure ascertained that the prefabricated prestressed skeleton had maintained the IMS structural concept, although the system girders were not grouted, which means that the structure was not totally completed.

Drastic impact loading which was endured by the prestressed concrete structure is another proof that prestressed structures possess a high degree of internal safety which is manifested in practice in dire need.

The selected way of repairing the damaged structural elements enabled considerable savings of financial means and the continuation of the structure's assembly simultaneously with the repairing of the damaged elements and the testing of the repaired ones.

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INTRODUCTION

During the execution of structures, different reasons sometimes lead to the damages of the structure which is under construction. In such cases, it is necessary to carry out repairing which must restore the safety and functionality that the structure possessed prior to the damages. In doing this, it is desirable to select the way of repairing so that the reparatory works influence to the least possible degree the continuation of the structure's construction, that is - if possible, the works on further execution and repairing should be carried out simultaneously.

Further text will present in brief two examples for repairing IMS prefabricated skeleton structure damaged in the stage of construction. The description will not dwell on the basic concept of the IMS prefabricated skeleton structure made of prestressed concrete, whose author was Acad. Prof. B.Zezelj, B.Civ.Eng., since it is presumed that the expert public is already well acquainted with it.

1. REPAIRING IMS PREFABRICATED SKELETON STRUCTURE DAMAGED BY COLLAPSE OF CRANE JIB ON THE BUILDING UNDER CONSTRUCTION

The structure whose characteristic foundation is presented in Figure 1 is designed within the IMS prefabricated skeleton system, its height including the ground floor plus five storeys, with a cellar underneath. The applied span is 3.60 x 3.60 m, except for the stair wells which have the span of 3.60 x 4.20 m. The designed initial prestressing forces for tendons 4 ϕ 7 amount to N_0 =180 kN, and for tendons 6 ϕ 7 they amount to N_0 = 289 kN. As to the acceptance of horizontal influences on the structure, the design provides for reinforced concrete walls with the thickness of d=15 cm, both prefabricated and cast in situ. The structure is founded on piles, while all of the piles - that is, the footings, are connected by a network of reinforced concrete bonding beams in both orthogonal directions. The jib collapsed on the level above the ground floor, that is, on the second row of floor-slabs which had so far been completed. All the tendons on the level above the ground floor had been tensioned and lowered into the designed - polygonal position, but the girders had not been concreted. The level above the cellar had been completed from the structural viewpoint at the moment of the jib's collapse.

1.1. Damages of the structure

The collapse of the jib caused the damages of the structural elements at the level above the ground floor, shaded in Figure 1. The IMS Institute's associates, called by the contractor, carried out all the necessary surveyings of the damages. Individual damages are presented in detail in a separate paper /3/, while this paper gives only a global review of the types of damages.

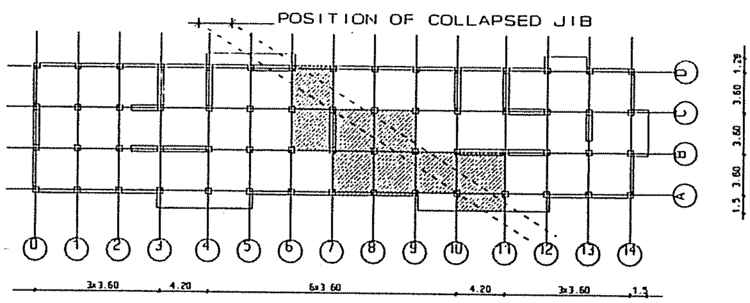

Figure 1. Layout of the damaged structural elements

In the case of ordinary floor-slabs, the damages range from a completely wrecked floor-slab in the B-C/7-8 span to slightly scratched edge ribs, while the cantilever floor-slab in the A/10-11 span was completely destroyed.
The edge girders (D/5-6 and D/6-7) were displaced from the spot of incorporation, since they were directly hit by the jib.
The damages on the columns include "chipped" column heads on the contact with the above-mentioned damaged structural elements and the cracks on the D/11 column head, while the vertical line of the columns in both orthogonal directions was preserved even after the jib's collapse.
Precast shear wall in the 7/B-C axis was displaced from the vertical line, but it was not wrecked, since at the moment of the jib's collapse the bottom anchors were welded, while the upper ones were inserted among the tendons.

The IMS Institute's associates carried out the measuring of stress in all the tendons at the level above the ground floor, upon which the jib had collapsed. The measuring was carried out on the total of 183 points, and the obtained data were used to calculate the average values of the measured stress in tendons. The measurings pointed out that in some tendons (axes 7, 8, 9/B-C) the stress was stress occurred, that is, the prestressing force was completely lost. The remaining measured stresses are within the expected limits. Besides, on certain spots the tendons returned from the executed - polygonal position into the linear one.
The customer submitted - as the basis for repairing - the data on the state of the structure prior to the damages, as well as the report on the subsequent measuring of the vertical position of all the structure's columns. A separate paper /3/ includes all the cited data and the results of surveys and measurings, which represent the basic indicator of the structure's state after the damages occurred, as well as the basis for elaborating the design of repairing.

1.2. Conception of repairing

The conception of repairing stemmed from the insight into the state of the damaged structure, including above all the value of the measured stress in tendons and the kind of damages of individual structural elements. Considering the fact that all the tendons at the level above the ground floor were already tensioned and lowered into polygonal position prior to the jib's collapse, the advantage was given to the repairing by concreting in situ rather than by replacing the damaged elements with new precast ones. In practice, the replacement of all the damaged elements with new prefabricated ones would require cutting and renewed tensioning of most of the tendons. This fact, as well asthe fact that horizontal holes in columns were already injected, and that the complete level above the ground floorwould again have to be supported on the assembly equipmentbefore the cutting of tendons, leads to theconclusion that the replacement of the damaged elements with new precast ones would practically demand more work than the assembly of the entire storey.When the conception of repairing by concreting in situ was being adopted, the essential fact was that the tendons were used only as supports for elements concreted in situ, which means that these elements were "hung" on tendons. In other words, these elements are not loaded by favorable impact of prestressing force and they do not "wear off" by friction like the corresponding precast elements, which practically means that these are not prestressed elements, but reinforced concrete ones. They were thus treated as such in computations, which also neglected the fact that over time a part of the prestressing force would "enter" these elements as well, which will contribute to their safety. In this way, the treated support tendons were controlled by searching for the safety coefficient γ as the ratio between the ultimate shear stress $\tilde{\tau}_L$ which can be accepted by the tensioned wire and the real shear stress $\tilde{\tau}$ in tendons due to loading, i.e.

$$\mu = \frac{\tilde{\tau}_L}{\tilde{\tau}}$$

The contact between old and new concrete, according to the adopted conception of repairing, is improved by coating the old concrete
with Epoxy regin Epocon bond SN immediately prior to concreting, as well as by incorporating "pins" RA ϕ 14. Before concreting floor-slabs and edge girders which are to be repaired, it is necessary to carry out the lowering of linear tendons into polygonal position, which is not possible in the way provided for by the IMS catalogue solution, since the "thimbles" are broken. The lowering is envisaged by prestressing with strands which are anchored at the level above the cellar and which will in this way hold the tendons in the polygonal shape. By cutting the strands 28 days after concreting the elements to be repaired, the vertical component of the prestressing force is released, thus influencing very favorably the newly cast reinforced concrete elements.

The only exception from the adopted repairing concept is the completely destroyed cantilever floor-slab in the A/10-11 span, which is replaced by a new precast floor-slab in the standard way, with preliminary cutting and replacement of one tendon 6 ϕ 7 in each of the axes 10 and 11.

Stresses in the ducts of the skeleton are controlled by computation in the axis 7, in which the lowest values of stress in tendons, i.e., of prestressing force, were ascertained. The data needed for computation were taken from the existing structural design.

1.3. Testing repaired elements

The repaired elements were tested with a view to experimental checking of the degree of safety of the repaired structure. The testing was carried out by the IMS Institute's associates. The conception of the testing included checking, in line with the regulations, the repaired elements and the corresponding elements which were not repaired at the same storey level. The results of the testing are contained in a separate Report /4/ and they show that repairing fully ensured the same degree of the structure's safety which it had before the damages occurred.

1.4. Participants in the survey of damages, designing of the repairing procedure, testing of repaired elements and execution of repairing

The survey of the structure's damages, the measuring of stresses in all prestressing tendons after the impact, the designing of the repairing procedure and the testing of repaired elements were carried out by the associates of the Institute for Testing of Materials of the Republic of Serbia - the IMS Institute, while the reparatory works were executed by RAD Civil Engineering Company of Belgrade.

2. REPAIRING OF IMS PREFABRICATED SKELETON STRUCTURE DAMAGED BY COLLAPSE OF PRECAST SHEAR WALL DURING ASSEMBLY

A reinforced concrete shear wall with the thickness of d=15 cm collapsed during assembly and fell on the structure which was being executed in the IMS prefabricated skeleton system. Due to forcible impact, the wall pierced three levels of floor-slabs and stopped at the fourth level - the level above the cellar. At the moment of damaging, all the levels were fully completed from the structural viewpoint.

In the way similar to the one presented for the first example, the IMS Institute's associates carried out the survey of the structure's damages, while the customer provided the necessary data on the structure's state prior to the damages, as well as the report on the subsequent measuring of the vertical line of all the columns.

In this case, the damages occurred only on ordinary floor-slabs of the IMS structure, except for the edge ribs which were not damaged, while all the other structural elements retained the state which preceded the collapse of the shear wall /5/. Same as in the previous example, it was thanks to the prestressed skeleton that the IMS structural concept was maintained.

The concept of repairing provided for repairing the damaged floor-slabs by concreting in situ, along with previous removing of the "loose" concrete, strengthening of the secondary ribs, expanding the edge ribs on the part of the floor-slab which is being repaired and introducing an additional joint between secondary and edge ribs. The secondary ribs are supported on the existing edge ribs in such a way that holes ϕ 18 mm are bored in the edge ribs, and the reinforcement of the secondary ribs is then inserted into these holes. They are grouted subsequently by epoxy resin with the addition of fillers. The joint between old and new concrete is envisaged in the way already presented for the first example. The same applies for the testing of repaired elements.

3. CONCLUSION

The above-presented examples for the repairing of the IMS prefabricated skeleton structure damaged in the stage of construction visibly point to the following:

a) Although at the moment of the jib's collapse the system girders were not grouted, the prefabricated prestressed skeleton preserved the concept of the IMS structure, in spite of the fact that it was exposed to a drastic impact loading.

This was ascertained by the insight into the state of the damaged structure, and above all by measuring the stress in tendons after the damages occurred.
b) Complete loss of prestressing force was ascertained only in one tendon (example 1), and it was due to the failure of the edge rib of the cantilever floor-slab, which caused the releasing of that tendon. The destroyed cantilever floor-slab is replaced by a new, precast one, along with the replacement of the adequate tendons. It should be stressed that these are the only two tendons which are being replaced in the entire repairing procedure.

c) The repairing of all the other damaged elements was envisaged by concreting in situ. In this way, the existing tendons were used only as supports for the elements concreted in situ, that is, these elements were "hung" on the tendons. Previously, the tendons were lowered into the polygonal position by prestressing with individual strands. To the author's knowledge, the use of existing tendons only as supports, as well as the lowering of tendons into the polygonal position by prestressing strands, have so far not been applied for repairing purposes.

d) The testing of the repaired elements pointed out that the repairing fully ensured the same degree of the structure's safety which it had before the damages occurred.

e) The selected way of repairing enabled the fulfilment of an extremely important technological requirement that the assembly of the structure be continued simultaneously with the execution of reparatory works and the testing of the repaired elements, thus achieving considerable financial savings.

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