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COMPUTER MODELLING OF STRENGTHENED MONOLITHIC PLANE OVERLAPPING WITH STEEL PLATE IN THE TENSILE ZONE

Abstract. There was proposed the procedure of plane overlapping calculation strengthened with steel plate in the tensile zone by means of modern software package.

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Keywords. Reinforced concrete plane plate, modeling, structures strengthening, stress-strain state.

Introduction. As concrete deteriorates, rehabilitation work on construction elements is often needed. One of several techniques that restores, or even increases, the initial resistance of the element, is the bonding of steel plates to the original concrete element. In general, the new element behaves well under normal load conditions. However, the bonding agent may deteriorate when subjected to temperature increase, and failure may ensure.

The primary reasons for the strengthening of concrete structures are typically to increase existing elements' capacity to carry new loads or to resolve an existing deficiency. Several strengthening techniques such as section enlargement, externally bonded fiber reinforced polymer (FRP) reinforcement, supplemental steel elements, and post-tensioning can be employed to increase the load carrying capacity and improve serviceability of existing structures.

However, there are many technical factors that should be considered when selecting a strengthening system. In addition to technical concerns such as serviceability, strength, durability, appearance, and fire rating, one should consider non-technical factors such as constructability, aesthetics and cost.

Analytical methods of estimation of structures reaction under the external loadings of different physical significance without full-scale modeling have appeared long time ago. Appearance and development of computer engineering have caused the improvement of numerical methods of analysis, which are the main instrument of developer today. Means of automation of engineering analysis, which consist in numerical methods, became the integral part of the designing process [1].

For the modeling of stress-strain state of the structure under strengthening there is possible to use modern software for the structures computation.

So, the new strengthened structure demands the investigation of its stress-strain state. For the solution of the given problem it is necessary to use the software packages intended for the calculation of the structures by finite elements method (FEM).

The use of epoxy bonded continuous steel plates is provided from the bottom of the soffit in the web portion rather than the vertical strips as strengthening members and these externally bonded steel plates provided good enhancement in shear capacity as that provided by conventional internal shear links.

Barnes used two methods of plate attachment, namely adhesive bonding and bolting and method of analysis based on the equilibrium of forces along the critical section was proposed. The adhesively bonded plates provided very high degree of surface crack control but inadequate surface area can lead to interface failure and sudden collapse; additional mechanical anchorage may be required in these circumstances [2].

Literature Review. Today much attention is paid to a question which deals with the strengthening of building structures. Causes and ways of strengthening the r/c beams are analyzed in works of many authors as A.IA. Barashikova, S.V. Bondarenko, A.B. Golyshev, E.V. Klymenko, P.I. Kryvosheev, D.N. Lazovskii, A.I. Malganov, N.M. Onufriev, and others [3-5]. Majority of scientists underline that to solve economically the strengthening process and to estimate the stress-strain state of the bending structures after the reinforcing it is necessary to determine the stress state of the elements before the strengthening, and provide the mutual work between the strengthening element and the structure.

The works of A.IA. Barashikov, S.V. Bondarenko, A.B. Golyshev, E.M. Babych, P.F. Vahnenko, E.V. Gorohov, V.S. Dorofeev, I.E. Prokopovych, O.L. Shagin are dedicated to the investigation of bending elements under different loading impacts and reinforcement types.

The strengthening of r/c structures using metal plates was investigated by the next foreign scientists as Raithby, R.D, Jones, R, Swamny, R.N, Roberts, T.M, Haji-Kazemi, Brown K, Lino, T, Otakawa, R. [6-8].

Research significance and objectives. The given article is dedicated to the investigation of the next problems:

– The urgency of the building structures strengthening;

– Analysis of the peculiarities of work, using the example of r/c monolithic overlapping and methods of its calculation;

– Development and calculation of the spatial design scheme of monolithic r/c overlapping, which demonstrated the maximally approximated stress-strain state of the structure;

– Performing of the comparative analysis of the calculation results of the proposed computer model of monolithic r/c overlapping before and after its strengthening.

Numerical simulation. Any reconstruction, as a rule, is accompanied by changing of loadings on building structures, and the amendment of theirs primary design schemes. All these factors lead to the necessity to determine their standard performance residue, decision-making about theirs further destiny, like to strength, reconstruct or replace them.

The necessity of strengthening or renewal of building structures appears not only during the reconstruction or technical upgrading, but also as a result of premature corrosion or mechanical deterioration. Loss of serviceableness can appear in the result of the complications or unforeseen by the project

changes in the production technology, different damages, defects, etc. This question causes the high interest to the problem of strengthening and reconstruction of the existing building structures [9].

One of the main reasons of building structures strengthening becomes changing of the functionality of a building and the increasing of loadings.

Very often in practice there appears the necessity of strengthening of r/c bending elements, like monolithic overlapping, roof slabs, and beams.

The calculation of bending r/c elements of the structure under the strengthening in accordance to the state regulations is necessary to perform, using cross-sectional strength calculation algorithm, as well as the algorithms for normal and oblique sections for the second boundary state, including checking of the received results of calculation via the boundary design deformations.

As the experimental model of a bending element let's take the monolithic r/c plane overlapping.

To calculate the strength of the strains in a section, normal and longitudinal axis of element, there were accepted the next assumptions:

- Concrete resistance in a tensile region is equal to zero;
- Concrete compression strength is determined by strains equal to R_b and uniformly distributed through the compressed zone of concrete;
- The strains within the steel plate are to be uniformly distributed by height and equal to the design steel strength R_n taking into account the design factor $\gamma_n = 0.8$;

- Strains within the bending reinforcement are to be equal to the design strengths R_s and R_{sc} taking into account the n factor;

- The cross-section, plane before the loading application, remains the same after loading application (hypothesis of plane section);

- Shear along the surface between concrete and steel plate is excluded (such an assumption is substantiated for the adhesive materials with the glued layer thickness equal from 1.0 up to 1.5mm, which can be deformed adherently and elastically, and the deformations of shear in creep and shrinkages are insignificant).

The strengthening system of a structure under reinforcing consists of two important elements as the steel plate and the adhesive. Success of operation of such a system depends on reliable work of each component as well as on the reliability of their interaction.

The main purpose of the adhesive, except of gluing, is the perception of shearing forces and breakout forces between the surfaces, which are connected. To glue the steel plate and concrete surface it is possible to use the adhesives on different bases as the acryl, or epoxy double-component gluing substances.

Strengthening of monolithic plane r/c plate which is subjected to bend is performed by steel plates, gluing them in the tensile region of the plate in longitudinal and transversal directions. Steel plates are placed with step equal to 1000mm in both directions in parallel to maximal tensile forces.

The principle of the method is quite simple: steel strips or steel elements with complex shapes are glued to the concrete surface by means of epoxy adhesive, creating a concrete-glued composite element. In this way it is possible to give a higher strength to the concrete elements against bending moments and

transverse forces, as well as to increase the stiffness of the elements, so that the deformability decreases.

The glue itself must show very high chemical and mechanical properties. The preparation of the steel consists in grit blasting of the area in contact with the glue. The concrete surface is prepared by grit-blasting or by manual grinding, to remove the weak external cement layer and to expose a clean and sound surface for gluing.

The glue is applied to the steel plate, which is then gradually pressed against the concrete, until no more adhesive is squeezed out. The thickness of the adhesive layer varies between zero and 2-3 mm.

There are many features of an adhesive product, in addition to its purely adhesive properties, which will form the basis for the selection of a particular bonding system. Choice of a suitable adhesive is only one of a number of requirements for a successfully bonded joint. Other factors also affect the joint strength and performance namely:

- appropriate design of the joint
- adequate preparation of the adherend surfaces
- controlled fabrication of the joint
- protection from unacceptably hostile conditions in service
- postbonding quality assurance.

To model the specimens, the full 3D simulation simulation using LIRA SAPR software was performed.

Variant 1. Plate calculation without strengthening.

To model the plate, let's accept concrete of class B30. Reinforcement of plate is represented by plane welded meshes. The plate thickness is 200mm. All sides of plate are supported along the contour.

Variant 2. Plate calculation with strengthening.

The parameters of monolithic plate are taken from the first variant. Steel plates were bonded with concrete surface by means of Sikadur-30 glue which has the following characteristics [10]:

- Elasticity modulus at bend – 11200N/mm^2;
- Adhesion (according to DIN EN 24624) for steel >21N/mm^2;
- Adhesion (according to DIN EN 24624) for concrete>4N/mm^2;

Steel plates are performed from steel of mark 09G2S with width equal 100mm and thickness equal 5mm.

To design plane r/c plate by means of software package LIRA SAPR there were used the following finite elements:

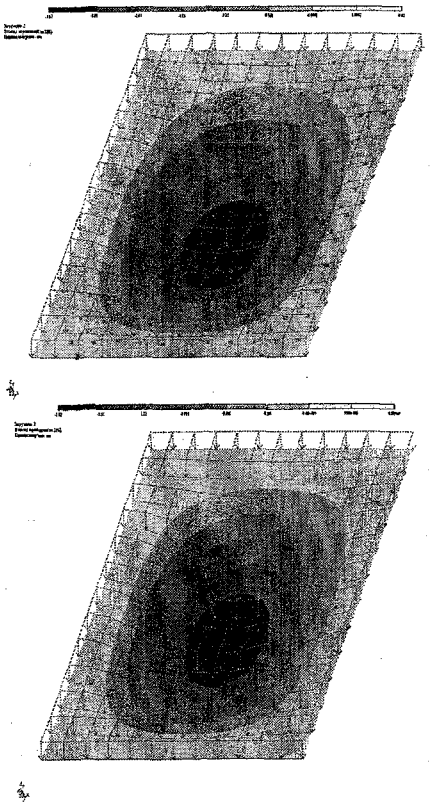
- Plate which was assigned the rigidity type "plate" (41st type of FE);
- Elastic joint between the nodes (10th type of FE);
- Steel plates were assigned the rigidity type "plate" (41st type of FE);

To model the design scheme there was applied the uniformly distributed load through the whole plate surface.

After the results analysis, the maximum bend has appeared in plate without strengthening was 3.62mm, with strengthening – 1.86mm (pic1).

Conclusions. Analysis of stress-strain state of r/c plane overlapping has shown, that for the modeling of the computer model and its adequate computation, it is necessary to use the full 3D simulation LIRA SAPR software. In the given software package it is advisable to model the r/c overlapping by means of spatial FE and plates, as well as the elastic joint between the slab and plate – by typical element (10th type of FE). After the receiving of calculation results it was revealed, that within the monolithic overlapping, which was strengthened by steel plates,

the decreasing of maximal strains and bending has decreased comparing with the initial stress state of the non-strengthened plate.



Pic.1. Computer model of r/c monolithic plane overlapping without and with strengthening. Displacements mosaic along Z axis.

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