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МОДЕЛЮВАННЯ ПІДСИЛЕННЯ ЗАЛІЗОБЕТОННИХ БАЛОК, ШЛЯХОМ ПРИКЛЕЮВАННЯ СТАЛЕВИХ ПЛАСТИН ЕПОКСИДНИМ КЛЕЙОВИМ РОЗЧИНОМ

MODELING OF REINFORCED CONCRETE BEAMS STRENGHTENING USING EPOXY BONDED STEEL PLATES

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В статті приведена методика моделювання підсилення залізобетонних балок, що посилені зовнішнім стальним армуванням за допомогою клейового розчину та приведений розрахунок підсилення з використанням сучасного програмного забезпечення

The article deals with the question of epoxy bonded steel plates for strengthening of building structures in world practice.
The problem of strengthening and renewal of the functional performance of building structures consists in the solution of such a task as the increasing of bearing capacity of structures. The given task is closely related to both change of functionality of a building, and the increasing of loading on its separate structural elements.
One of the principal ways of structure strengthening is the building-up of its cross-section. Such a strengthening, which is performed by gluing steel or composite polymeric fiber, is a quite efficient way of strengthening, which is widely used abroad.
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.

Ключові слова:
Сталезалізобетон, деформативність, підсилення, стальне зовнішнє армування.
Composite and reinforced concrete, deformability, strengthening, external steel reinforcement, modelling

Inroduction. Modern civilization relies upon the continuing performance of a wide variety of structures, ranging from industrial buildings and power stations to bridges. Although these structures may appear very different, their managers are likely to recognise a number of common features:

- structural deterioration perhaps increased by environmental factors;
- changes in use or imposed loading;
- the need to minimise closure or disruption during repairs;
- the need to extend useful life whilst minimising capital outlay;
- more stringent financial disciplines requiring the evaluation of the whole life cost of solutions;

The number of structures in the world continues to increase, as does their average age. The need for increased maintenance is inevitable. Complete replacement is likely to become an increasing financial burden and is certainly a waste of natural resources if upgrading is a viable alternative. The way in which FRP composite plate bonding can help will be illustrated by considering two particular structure types, buildings and bridges.

Experimental study of the failure behavior of concrete beams normal quality has been done by taking the variation of the ratio of reinforcement tensile steel to represent three patterns of collapse with the result is the stress that occurs at the steel reinforcement fascination with pattern collapse of tensile (under reinforced) have reached the yield tension stress (fy = 415 MPa), the pattern collapse balanced 97% of yield stress, and pattern collapse of yield stress reaching 87%, this indicates that the larger the tensile steel reinforcement ratio the stress that occurs at tensile steel reinforcement will be smaller so that the beam will increasingly behave brittle.

The load is applied to the middle span beams with concentrated loads, and the observed value of the load, deflection, and the concrete stress that occurred from the first crack load up to fully collapse.

A reinforced concrete beam material is modeled by 8 node solid elements (SOLID65) with three degrees of freedom at each point and the case of translation in the x, y, and z. This element also has the ability to deform plastically, cracks in the direction of x, y, and z, until the crushed concrete.

Normal strength quality concrete model used is a model of Multininear Kinematic Hardening by compression stress-strain curves of unconfined concrete proposed by Kent-Park and tensile stress is ft = 0.7.√fc'.

Steel bar reinforcement in idealized as axial rod element by taking the discrete engineering models Spar Link Element (LINK8) with similar characteristics as the original, but a line reinforcement. This element has 2 points with 3 degrees of freedom at any point in the x, y, and z, and is able to deform plastically. The reinforcement is assumed to be capable of transmitting axial forces only, and perfect bond is assumed to exist between the concrete and the reinforcing bars. To provide the perfect bond, the link element for the steel reinforcing bar was connected between nodes of each adjacent concrete solid element, so the two materials share the same nodes. Model of stress-strain relationship of steel used is a model Bilinear Isotropic Hardening.

The steel plate used as the basis of concrete pedestal and supports that do not experience excessive local stress concentration which would cause the process to stop running ANSYS. These elements have 8 nodes with 3 degrees of freedom at any point in the x, y, and z.

Cost is probably the most influential factor when assessing the merits of alternative methods. Detailed costing would be out of place in a book of this kind and would date quickly. This is particularly the case for new techniques, as prices can be expected to fall as more material suppliers and contractors enter the growing market. However, the case for bonded fibre reinforced composites can best be illustrated by the fact that these materials are already winning competitive tenders against alternative solutions [1].

Literature Review. A lot of foreign scientists as L.C. Hollaway, M.B. Leeming, R.O. Adams, W.C. Wake, J. G. Al-Sulaimani, A. Sharif, Sano, M., Miura,T., M.H. Baluch, B.N. Chaleb, H.N. Garden, R. Jones, R.N. Swamny, Nisal Abheetha Peiris, Tumialan, J. G., Belarbi, A., Nanni, Yoshida, E., Murakoshi, J. and Tanaka, Y who have paid a great attention to a question of strengthening concrete members by steel-plate-bonding and FRP composite plate bonding [2-9].

Research significance and objectives. In the given article there are considered the next problem:

- analysis of world experience of application of the adhesive bonding for strengthening of building structures;
- computer modeling of strengthening r.c. beam using ANSYS.

Background. Structural adhesives are generally accepted to be monomer composites which polymerise to give fairly stiff and strong adhesive uniting relatively rigid adherends to form a load-bearing joint (Shields). The feasibility of bonding concrete with epoxy resins was first demonstrated in the late 1940s (ACI, 318), and the early development of structural adhesives is recorded by Fleming and King. Since the early 1950s adhesives have become widely used in civil engineering Mays.

However, although the building and construction industries represent some of the largest users of adhesive materials, many applications are non-structural in the sense that the bonded assemblies are not used to transmit or sustain significant stresses (e.g. crack injection and sealing, skid-resistant layers, bonding new concrete to old).

Truly structural application implies that the adhesive is used to provide a shear connection between similar or dissimilar materials, enabling the components being bonded to act as a composite structural unit. civil engineering is given by Hewlett and Shaw, Tabor and Mays and Hutchinson.

Assessment of an adhesive as a suitable product for structural use must take into account the design spectrum of loads, the strength and stiffness of the material under short term, sustained or cyclic loads and the effect on these properties of temperature, moisture and other environmental conditions during service Mays.

Concern regarding the durability properties of adhesive joints has meant that resistance to creep, fatigue and fracture are considered of greater importance than particularly high strength Vardy and Hutchinson. Temperature is important at all stages in the use and performance of adhesives, affecting viscosity and therefore workability, usable life and contact time, rate of cure, degree of cross-linking and final cured performance Tu and Kruger.

Controlled conditions are therefore generally required during bonding. This applies equally during the surface treatment procedures if a durable system is to be achieved. Adhesives, which are workable and cure at ambient temperatures, have been used and are able to tolerate a certain amount of moisture without a marked reduction in performance.

These must have adequate usable time under site conditions and a cure rate which does not hinder the construction programme. Workmanship under conditions prevalent on site is less conducive to quality control than in other industries, and thus ability to tolerate minor variations in proportioning and mixing, as well as imperfect surface treatment, is important.

In addition, the products involved are more toxic, require more careful storage and, bulk for bulk, are considerably more expensive than traditional construction materials. Nondestructive test methods for assessing the integrity of bonded joints are now available for civil engineering applications.

Despite some drawbacks, structural adhesives have enormous potential in future construction applications, particularly where the combination of thick bondlines, ambient temperature curing and the need to unite dissimilar materials with a relatively high strength joint are important Mays and Hutchinson.

The principal structural adhesives specifically formulated for use in the construction industry are epoxy and unsaturated polyester resin systems, both thermosetting polymers. The formulation of adhesives is considered in detail by Wake, whilst Tabor offers guidance on the effective use of epoxy and polyester resins for civil engineering structures.

The use of ANSYS software is very good to know the process of collapse a reinforced concrete beam flexural cracks start to the shear cracks (linear), but the result is having a significant deviation in the phase of destruction of concrete (plastic). However, this shortcoming can be overcome by using multilinear plasticity material models available in ANSYS.

A simple span reinforced concrete beam is modeled with applying ultimate pointload until crushing representing the reinforced concrete collapsed mechanism with conditions of under reinforced ($\rho \leq 0.75.\rho b$), balanced reinforced (ρ =. ρb) and over-reinforced ($\rho > 0{,}75.\rho b$) with dimensions: 200 mm x 400 mm, L = 3000 mm, and Lc/c = 2800 mm (see Figure 1,2,3).

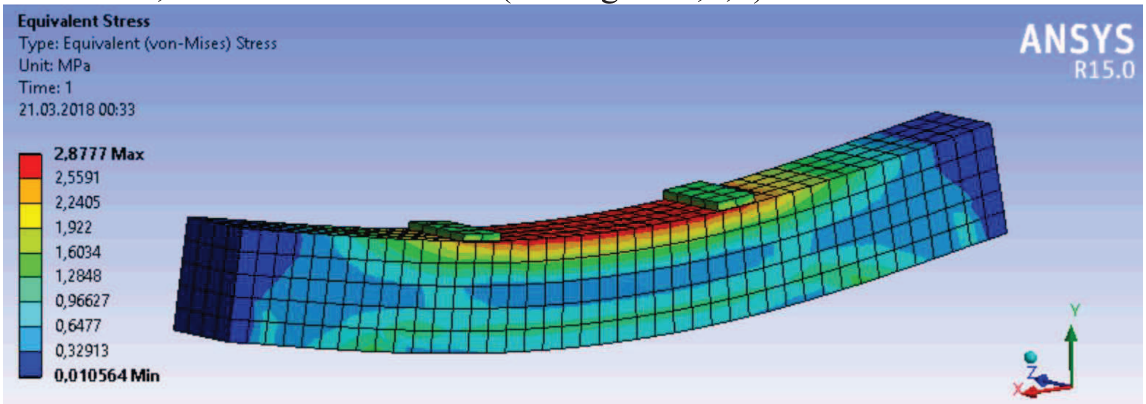

Figure 1. Stress Contour of the Beam under Tensile Collapsed Mechanism (BUR-200.400)

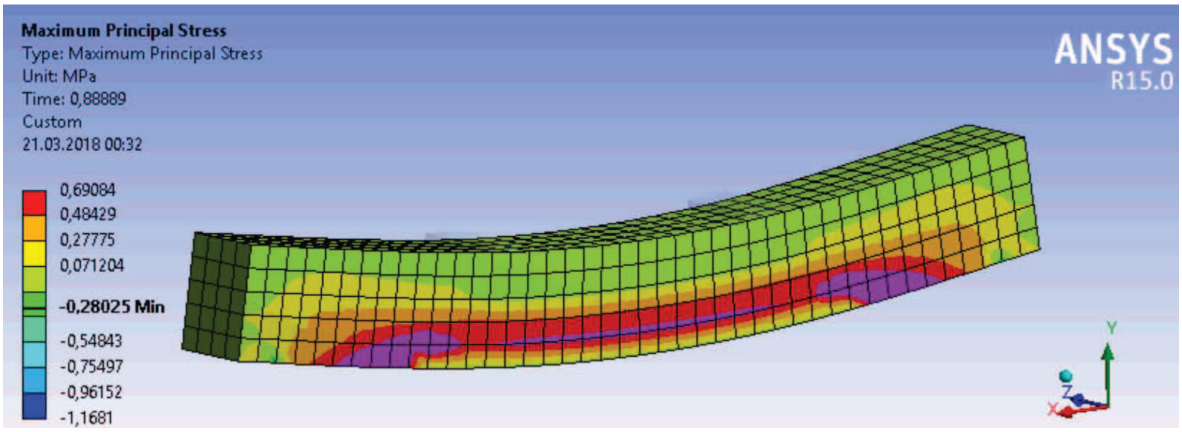

Figure 2. Stress Contour of the Beam under Balance Collapsed Mechanism (BBR-200.400)

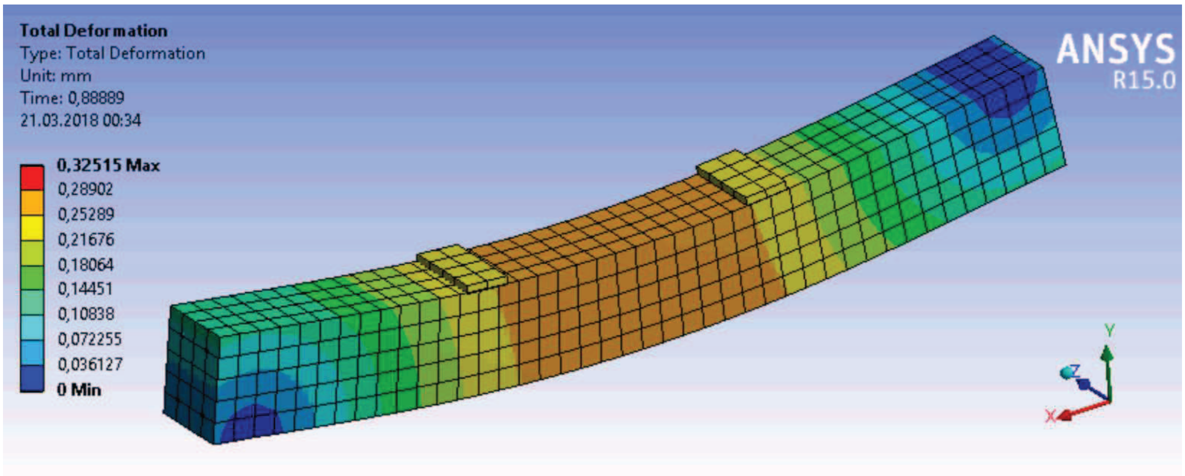

Figure 3. Stress Contour of the Beam under Compressive Collapsed Mechanism (BOR-200.400)

Modeling of reinforced concrete in ANSYS starts by choosing one of three methods that can be used to model steel reinforcement in finite element models.

These methods are: 1) discrete method; 2) embedded method; and 3) smeared method. In the discrete method, reinforcement is modeled using bar or beam elements connected to the concrete mesh nodes. As a result, there are shared nodes between the concrete mesh and the reinforcement mesh, as shown in Figure 1a.

Also, since the reinforcement is superimposed in the concrete mesh, concrete exists in the same regions occupied by the reinforcement. To overcome mesh dependency in the discrete model, the embedded formulation allows independent choice of concrete mesh. In the embedded method, the stiffness of the reinforcing elements is evaluated independently from the concrete elements, but the element is built into the concrete mesh in such a way that its displacements are compatible with those of surrounding concrete elements.

That is, the concrete elements and their intersection points with each reinforcement segment are identified and used to establish the nodal locations of the reinforcement elements. In the smeared method, it is assumed that reinforcement is uniformly spread throughout the concrete element in a defined region of the finite element mesh. This approach is used for large-scale models where the reinforcement does not significantly contribution to the overall response of the structure. For this research work, the discrete method was chosen to model steel reinforcement in the finite element model of reinforced concrete beam. The finite element model itself can be created in ANSYS using command prompt line input, the Graphical User Interface (GUI), or ANSYS Parametric Design Language (APDL). APDL was used for creating the models in this paper.

A number of tests are available for testing adhesive and thin films Adams and Wake. However, appropriate tests for assessing bond strength in construction are complicated by the fact that the loading condition in service is difficult to simulate, and one of the adherents, namely concrete tends to be weaker in tension and shear than the adhesives. As a result, the failure mostly occurs within the concrete. To evaluate strength of bonding steel/concrete a number of shear tests have been carried out. For these tests there were simulated different specimens and the results of testing were in details described by Solomon in 1978.

In the Surrey University there was proposed the testing principles for investigation of three different adhesives, two of which were two-component epoxy resins of cold vulcanization and the third one was two-component acrylic resin. During testing the bonding adhesive/concrete was subjected to bend, and another one – composite/adhesive/concrete was subjected to shear force. Epoxy adhesive, which was used during testing, has demonstrated high strength at both bend and shear, having overcome concrete characteristics. Also several possible test methods have evolved to measure the bond strength between adhesive and concrete substrates, mainly for applications in concrete repair Franke and Naderi. Those tests were carried out to define the characteristics of strength of adhesion in tension, shear and bending, as well as shrinkage and thermal compatibility in concrete/concrete and steel/concrete bonds.

Conclusions. The conclusions of this study based on 3D numerical modelling analysis are:

1) Single reinforced concrete beams with various conditions represented collapse with tensile reinforcement ratio variation can be modeled using 3D modified numerical modeling with spar element.

2) Beams with pull collapse condition has a lower flexural capacity and collapse behavior is more ductile than the beam with the collapse of the compressive and balanced condition

3) The higher the ratio of tensile reinforcement beams, the process of collapse in the area of concrete compressive (crushing) will be more visible

4) The higher the tensile reinforcement ratio the tensile stress that occurs, the lower yield stress.

5) In the beam with the drop collapse condition, results of manual analysis according to SNI 03-2847 when the condition first crack load and ultimate load suitable for beams with tensile collapse condition ($\rho \leq 0.75.\rho b$) is closer to the result of FEA ANSYS.

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