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AN INNOVATIVE METHODOLOGY FOR RESTORATION AND STRENGTHENING OF REINFORCED CONCRETE STRUCTURES VIA CONCRETE OVERLAY AND ITS CAD-IMPLEMENTATION DURING REPAIRS AND RECONSTRUCTION

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The present work introduces an innovative methodology for the restoration and strengthening of reinforced concrete structures through concrete layering, based on the application of advanced Hilti post-installed rebar and shear stud systems. The proposed approach enables the realization of full monolithic connectivity at the "old-to-new" concrete interface, ensuring effective shear force transfer in accordance with international technical reports EOTA TR 066 and TR 069. This methodology offers extensive possibilities for strengthening flexural and compression elements during building reconstruction, allowing for a significant reduction in embedment depth and optimization of material consumption without compromising structural integrity. Particular emphasis is placed on the integration of calculation algorithms into a unified digital environment through specialized software and modern CAD/BIM systems. Such digital implementation ensures a seamless design process: from processing non-destructive testing data of existing reinforcement to the automated generation of detailed 3D models of reinforced nodes within a CAD-environments. The adoption of this methodology minimizes risks and errors, guarantees the precision of reinforcement geometric parameters, and ensures high operational reliability of restored structures under complex loading conditions. The proposed solution serves as a versatile tool for engineers seeking to combine cutting-edge construction technologies with the advantages of automated design to enhance the longevity of the building stock.

Keywords: concrete strengthening, concrete overlay, post-installed rebar, monolithic interface, building reconstruction, CAD/BIM-design.

Introduction

The rapid development in the field of reconstruction and modernization of construction facilities is due to the need to solve the global problem of physical and moral wear and tear of capital structures. Economic and operational analysis confirms that the restoration of structures usually costs less than 40% of the costs of a complete reconstruction, while the service life of the structure is extended by 30–50 years. Restoration and strengthening of reinforced concrete structures by increasing the cross-section is today considered not only as a means of emergency repair, but as a highly effective strategy for extending the life cycle of structures, which allows them to adapt to increasing operational requirements, seismic challenges and changes in functional purpose. In this work, based on the study of the mechanics of the interaction of old and new concrete, the analysis of modern materials and design solutions, and the consideration of the technological features of performing work in difficult conditions, an innovative method of restoration and strengthening of reinforced concrete structures by increasing the concrete layer, with its subsequent CAD implementation, is highlighted.

Formulation of the problem

The problem of restoration and strengthening of reinforced concrete structures by increasing the concrete layer in modern reconstruction conditions is the need to overcome the technological gap between the potential three-fold capacity of the renewed section and the actual reliability of the contact zone of old and new concrete. Today, traditional calculation methods often do not take into account the complex rheology of the contact seam, which leads to uneven stress distribution and premature delamination of reinforcing elements. The relevance of this problem is due to the significant physical wear of capital structures and the need for innovative approaches based on the use of highly adhesive modified mixtures and energy-efficient methods of surface preparation. Improving restoration methods involves the transition from simplified empirical models to a comprehensive consideration of the parameters of roughness, adhesion properties of microlayers and the staged nature of load application during repair work. The key aspect of solving this problem is the integration of the developed analytical dependencies into a modern computer-aided design environment, which allows implementing an end-to-end process from digital scanning of a defective structure to automatic generation of optimal reinforcement parameters in CAD systems. Such CAD implementation ensures the creation of accurate finite element models with integrated interface elements, which allows predicting the operation of a reinforced structure at all stages of the life cycle, minimizing the material consumption of design solutions and significantly increasing the service life of civil and industrial infrastructure facilities.

Theoretical principles and methods of cross-section enlargement

Reinforcement of reinforced concrete elements by section building is based on the fundamental principle of creating a composite system, where a new layer of concrete and additional reinforcement work together with the existing core of the structure. The effectiveness of such reinforcement is determined by the ability of the interface to provide continuous transfer of shear and normal stresses between components. Depending on the geometric configuration and the purpose of the reinforcement, building methods are divided into several main categories: reinforced concrete cages, sleeves and local building of individual faces.

Reinforced concrete cages are closed structures that enclose the element on all sides. This is the most advanced method for strengthening compressed elements, such as columns, because it provides the effect of lateral compression. Under the action of longitudinal loading, the concrete of the core tries to expand in the transverse direction, which is prevented by the rigid cage. This creates a state of triaxial compression, which significantly increases not only the strength of the concrete, but also its ultimate deformability, which is critical for earthquake-resistant construction. Reinforced concrete sleeves cover the element on three sides and are usually used for beams and transoms where the upper face is closed by a floor slab. In such cases, special attention is paid to anchoring the transverse reinforcement of the sleeve in the upper zone of the beam to ensure a closed force circuit. The effectiveness of this design solution is high for bending moments and shear. Local reinforcement involves adding a layer of concrete to one or two faces of the element, with floor slabs often reinforced by installing an upper reinforced lining 50-75 mm thick, which allows increasing the moment of resistance of the section and converting hinged joints into continuous ones.

The key principle of compatibility and joint work is to ensure monolithicity. Usually, joint work is considered to be achieved if the deformations at the contact interface of old and new concrete are equal. However, in practice, they are limited by the difference in elastic moduli, rheological processes taking into account the shrinkage of new concrete and creep of old, and the presence of primary stresses in the structure.

The design of reinforcement should take into account the staged nature of the work. In the first stage, the element carries the existing load, and in the second stage, after gaining strength with a new layer, the reinforced element perceives an additional useful load. If the reinforcement is performed without unloading, the new part of the cross-section is included in the work only in the second stage, which leads to an uneven distribution of stresses. Therefore, for maximum efficiency, temporary full or partial unloading of the structure using jacks or support systems is recommended.

Considering the interaction mechanics, the interface between the existing concrete and the new build-up layer is a critical zone where significant tangential shear stresses occur (Prusov, et al., 2025). Studies show that the failure of reinforced structures often begins with the delamination of the new layer due to insufficient surface preparation.

Interaction at the distribution boundary is ensured by three main factors: through chemical adhesion, in which the cement stone or adhesive bonds with the micropores of old concrete at the molecular level; through mechanical engagement by flowing fresh concrete into the irregularities of the rough surface; and through the friction force under the action of normal stresses that press the layers against each other.

To ensure high bond strength, it is necessary to remove the weak surface layer (cement laitance), carbonized areas and open the porous structure of the concrete together with the coarse aggregate. Modern methods include mechanical chipping, sandblasting, high-pressure water jetting, grooving, which are applied according to the relevant recommendations and necessary conditions regarding the depth of roughness and the effect on bond strength.

Experimental data show that full roughness allows for 77% higher bond strength compared to partial roughness. Of particular interest is the influence of groove direction in column reinforcement: vertical grooves demonstrate better results in axial compression, while horizontal grooves increase shear resistance and compression efficiency.

When reinforcing reinforced concrete elements, the increase in cross-section is necessarily accompanied by the addition of working and structural reinforcement, i.e. the combination of old and new reinforcement. To ensure the joint operation of the reinforcing cages, methods such as welding are used, in which new rods are welded to existing ones using short rods (connecting bars), as well as chemical anchors, when rods or clamps are glued into the body of old concrete using epoxy or polyester resins. This allows for reliable transmission of tensile forces, even if the protective layer of old concrete is destroyed. The anchoring depth is usually 10-15 rod diameters.

The process of strengthening is much more complex than designing new structures, as it requires a deep analysis of the actual condition of the object. The choice between increasing the cross-section and alternative methods depends on the project objectives, as well as the current regulatory framework.

General requirements for the design of reinforced concrete structures (DBN V.2.6-98-2009), which establishes the design values of the strength of concrete and reinforcement, taking into account the reliability of the structure throughout its entire service life. Repair and reinforcement of load-bearing and enclosing building structures (DBN V.3.1-1-2002), which contains specific requirements for the examination and selection of reinforcement methods. Guidelines for performing work using dry mixtures (DSTU-N B V.2.6-212:2016), which is a key technological standard that classifies mixtures for repair (RM1, RM2) and injection (IN1), and also determines the procedure for preparing the bases.

There is a standard for the international professional community (ACI 562-19, 2019) – Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures, that, unlike traditional prescriptive norms, is performance-based (i.e., based on results), allows the use of higher reliability factors if the geometry and properties of the materials are confirmed by full-scale tests. Requires mandatory analysis of the "repair area - original structure" interaction to prevent redistribution of forces, which can lead to the destruction of weak unreinforced nodes. Takes into account the durability of the system: mandatory assessment of the risk of corrosion and electrochemical compatibility of materials.

A comparative analysis of the technical and economic efficiency of the method of building up the reinforced concrete layer shows that the increase in bearing capacity is quite high (up to 300-400%); the change in stiffness is significant, which increases resistance to deflection; fire resistance is high; the cost of materials is low; and the complexity of implementation is also high, due to the need for formwork, concreting, etc.

Therefore, increasing the cross-section is an option in cases where it is necessary to significantly increase the rigidity of the structure (for example, when adding floors) or when the structure is in an extremely unsatisfactory condition with a large deficit of concrete cross-section.

Method of strengthening reinforced concrete structures by increasing the concrete layer for rconstruction, renewal, and repair

The innovative method of restoring and strengthening reinforced concrete structures by building up a concrete layer is due to the fact that the new concrete layer can be connected to the existing one reliably and with high resistance to shear loads.

The construction of new concrete layers to increase the thickness of reinforced concrete elements is becoming increasingly important due to the growing need for repairs, reconstructions and reinforcement of existing buildings and structures. Bridge decking, repair and reinforcement of concrete structures with a new concrete layer are typical examples of the use of anchor supports. These supports are usually used to increase the thickness of beams, slabs, walls and to strengthen or repair bridges, tunnels and roads with concrete pavement.

The behavior of the monolithic structure after the installation of Hilti HCC-B anchor stops. If the shear loads in the composite joint are not sufficiently distributed among the concrete layers that have been concreted at different times, the safety of the structure is at risk. Shear loads at the interface between concrete layers that have been poured at different times must be transmitted properly.

To include the layers of this composite structure in joint work, it is important to transfer internal stress through the connecting element between the new and existing concrete. In order to achieve a monolithic connection, it is usually assumed to install stops for composite structures. As a result, for example, the compressed zone and/or bending zone (structural reinforcement) can be increased or the height of the original area can be restored (reconstruction).

Figure 1(a) shows the stressed state of the beam in which the shear load between the concrete layers is "not activated" (non-stressed binder). In this case, the concrete layers behave independently of each other. Note, however, that this is a simplification: even in the case of an uninstalled connecting element, an adhesive bond acts between the concrete layers. To obtain a monolithic connection, it is customary to use post-installed anchor stops.

In Figure 1(b), these connectors (stops) allow, for example, to increase the compressed zone and/or the bending zone (structural reinforcement) or to restore the height of the original area (reconstruction).

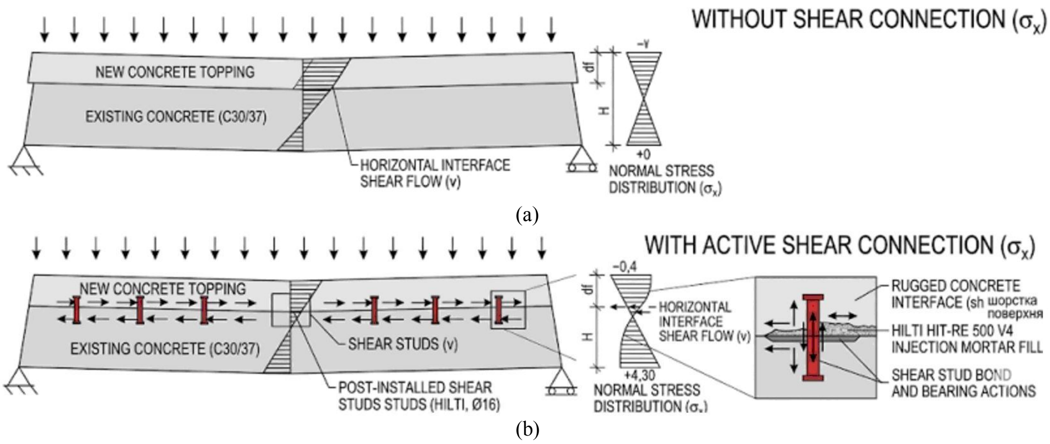


Fig. 1. The stressed state of the beam: without shear connection; and with activation of shear connection

Calibration of concrete connectors according to the TR 066 and the proposed method as well as differences from EN 1992-1-1. The current European standard for the design of reinforced concrete structures EN 1992-1-1 (2004) lists the rules for calculating the shear capacity of concrete, between two layers of concrete and reinforced concrete elements. However, for the calculation of reinforcement with installed connectors, a more suitable method is available: the method proposed by EOTA in TR 066 (Requirements for the design and construction of post-installed shear connections for two concrete layers). While EN 1992-1-1 (EC2) only takes into account adhesion, external load and friction, the new EOTA TR 066 takes into account the "spike" effect of installed connectors. EN 1992-1-1 (EC2) requires sufficiently fixed shear reinforcement, which applies to reinforced concrete elements. For this reason, the yielding of steel is considered to be the most important failure mode. On the other hand, EOTA TR 066 considers individual failure modes of installed connectors. Therefore, the steel stress σs is calculated from the nominal tensile strength according to EN 1992-1-1, and not from the yield point. In joints between reinforced concrete elements cast at different times, shear is transmitted to the concrete interface.

The length of the anchors is calculated taking into account the factor f_{bd}, which exceeds the bond strength of the concrete and can allow for a shallower installation depth. Simple supports can be calculated using EC2 for anchoring.

Calculation of drilling depth (l_v):

$$l_v = l_{bd},$$

where l_{bd} is anchorage depth for post-installed reinforcement.

Formula for total anchoring depth (EN1992-1-1, 8.4.4):

$$l_{bd} = \alpha_1 \alpha_2 \alpha_3 \alpha_4 \alpha_5 \, l_{bd,req} \geq l_{0,\min},$$

$$l_{bd,req} = \frac{\varnothing}{4} \frac{\sigma_{sd}}{f_{bd}}.$$

These formulas determine the depth at which the reinforcing bar must be installed for reliable fixation, where l_v is the drilling depth; according to the document, it is equal to the calculated anchoring length; l_{bd} is the estimated anchorage length for post-installed reinforcement; $l_{bd,req}$ is the basic required anchoring length; $l_{0,\min}$ is the minimum bypass length (lap length); $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ are the Shape-Considering Coefficients taking into account the shape of the bars, concrete cover, transverse reinforcement and pressure (according to EN 1992-1-1, 8.4.4); $\varnothing$ is the reinforcing bar diameter; σ_{sd} is the design stress in the reinforcement at the location from which the anchorage is measured; f_{bd} is the estimated value of the bond strength of reinforcement to concrete.

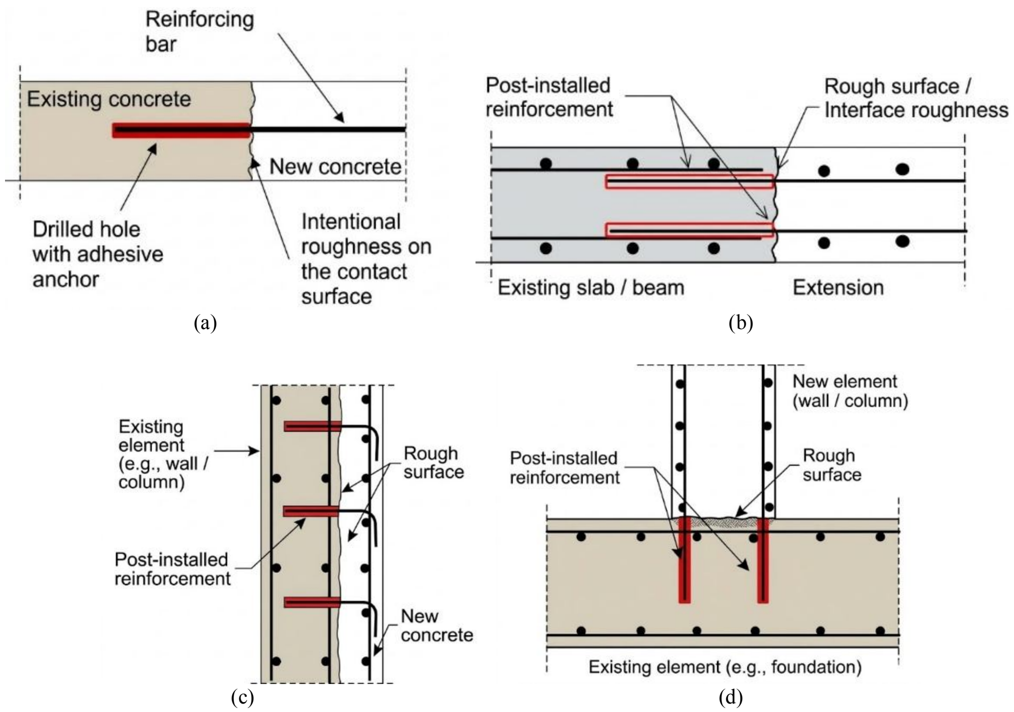


Fig. 2. Methods of overlay the reinforced concrete elements: (a) Overlay via adhesive anchor; (b) Overlay overlap; (c) Overlay in thickness; (d) Anchor fasteners

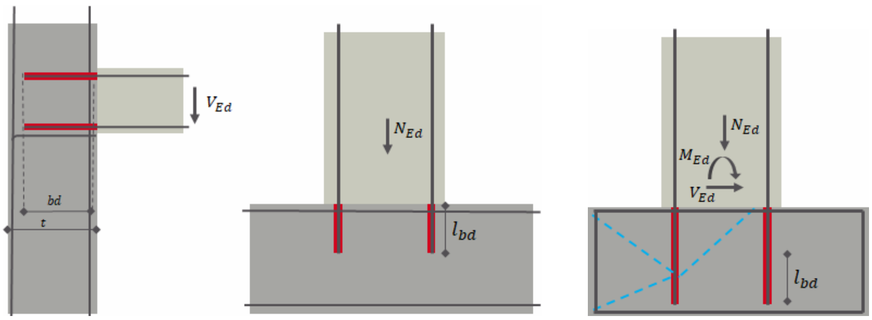


Fig. 3. Schemes for calculating the anchoring of supports

Incorporation into the joint operation using the truss method provides a solution for some cases of uniaxial bending in EC2.

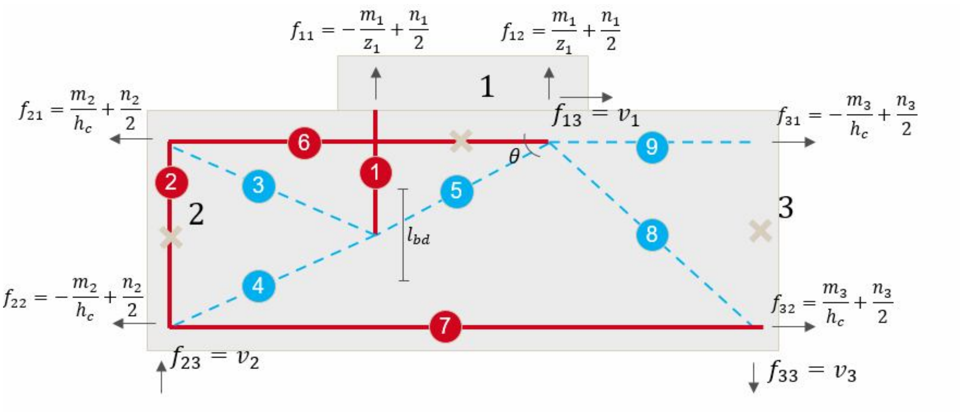


Fig. 4. The bending moment is balanced by the truss method in the base material

The formulas shown in the diagram describe the distribution of forces in the nodes of a reinforced concrete element: f_{11}, f_{12}, f_{21}, f_{22}, f_{31}, f_{32}, are nodal forces (stresses) resulting from bending and axial forces in various cross-sections (1, 2, 3); m_1, m_2, m_3 are bending moments in the corresponding sections; n_1, n_2, n_3 are longitudinal (axial) forces in the corresponding sections; z_1 is the internal force arm (distance between the centers of the compressed and stretched zones) for the first section; h_c is the Element cross-section height (core height); v_1, v_2, v_3 are transverse (shear) forces at corresponding points; θ is the angle of inclination of a concrete compressed strut in a truss model.

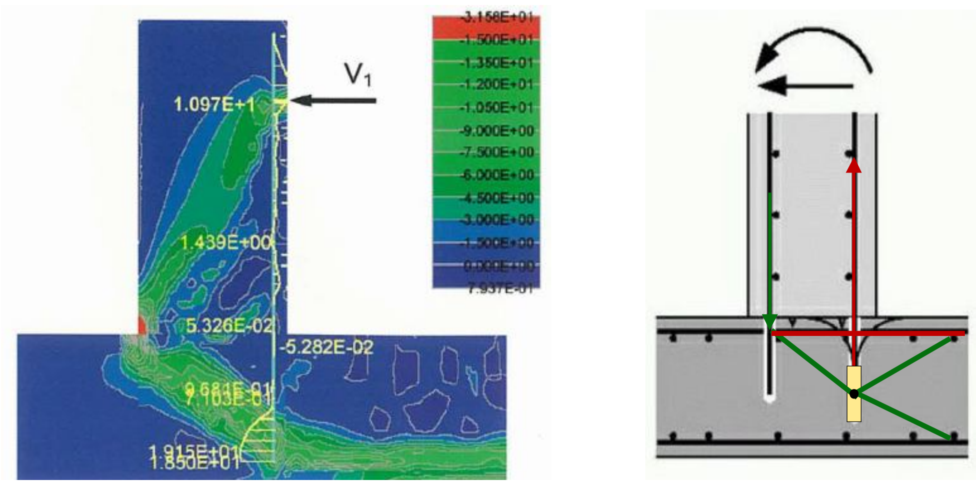
Thus, as follows:

• the forces in each tension and compression element are calculated;

• the anchorage depth for post-installed reinforcement is calculated according to EC2 and the product ETA;

• the compression element is checked, as the forces in it can be decisive, as well as the shear in the existing element;

• the user is responsible for checking that there is sufficient reinforcement in the base material, to enable the truss method to be applied;



(a) (b)

Fig. 5. The model with tension and compression elements is developed for straight rods:
(a) Finite element analysis; (b) Truss method model

Features of the technology of building reinforced concrete elements for monolithic structures

The method under consideration uses chemical anchors (e.g. HIT-RE 500 V4 or HIT-HY 200-R V3) to bond reinforcement bars, which allows creating a monolithic connection between old and new concrete. The system works in extreme conditions: in wet concrete, in water-filled holes and even underwater. This makes it indispensable for both the reconstruction of office centers and for strengthening bridge piers or hydraulic structures. Due to deep anchoring and high adhesion of adhesive compounds, the bonded reinforcement works identically to that which was laid during the initial concreting. This allows the transmission of tensile forces without the risk of cracking the concrete. The use of battery-powered dispensers and special nozzles ensures accurate filling of the hole without air voids. The system also eliminates the stage of manual cleaning of the hole (when using hollow drills), which critically increases reliability, since the human factor is minimized.

The use of chemical compounds (such as HIT-RE 500 V4) allows to achieve characteristics that are not inferior to direct concreting of reinforcement at the stage of frame construction. Due to the high adhesion of the adhesive compound to concrete and steel, the glued rod transmits tensile forces evenly along the entire length of the anchorage. This allows the connection to be designed according to the standards for monolithic reinforced concrete (Eurocode 2), considering the expanded element as an integral part of the existing structure. Unlike mechanical anchors, which create expansion forces in the concrete, Hilti chemical bonding does not create internal pressure in the hole. This allows the installation of reinforcement with minimal edge distances and a small pitch, which is critical for thin-walled structures or when reinforcing columns. The epoxy compound completely fills the space around the reinforcement, creating an impermeable barrier to moisture and chlorides. This ensures that the joint area does not become a “weak link” prone to corrosion, which often occurs with traditional building methods. The method allows for the creation of a rough joint surface with additional shear anchors, which ensures that the old and new concrete work together under transverse loads without slipping.

When it comes to the transmission of shear forces in reinforced concrete structures, the condition of the contact surface is a critical factor. The technology of concrete building-up is specifically designed to eliminate the risks associated with the presence of cracks in the tension zone of the concrete.

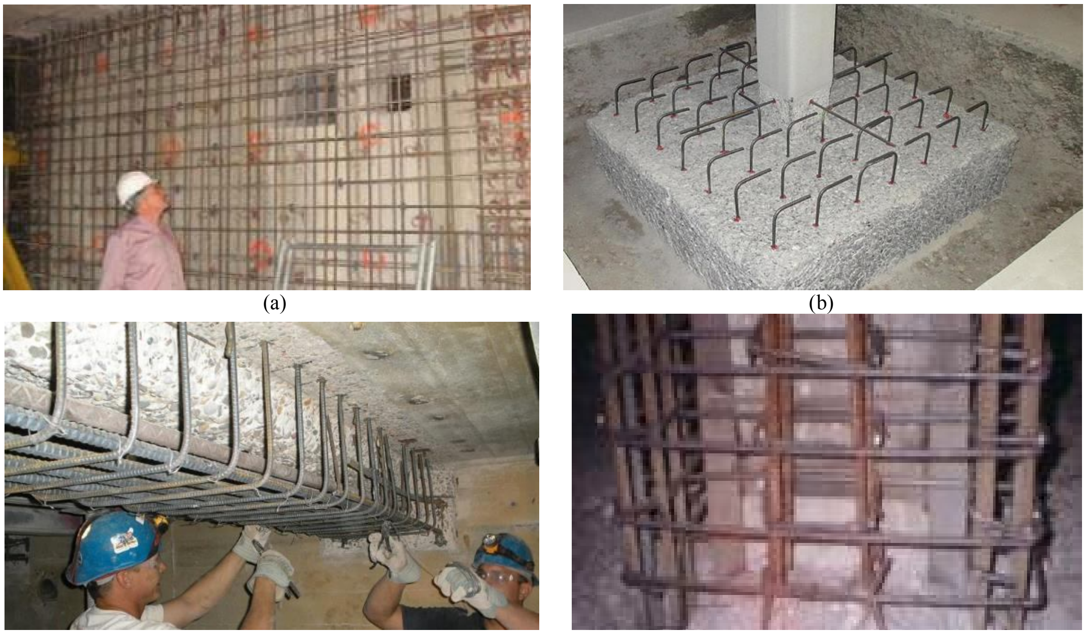
In real structures, concrete almost always has microcracks in the tension zones. Traditional strengthening methods often ignore this fact, which leads to a decrease in the bearing capacity, but in the proposed method, the problem of reliable shear transmission in real conditions can be solved as follows. Adhesive compositions have been tested for operation in cracks up to 0.3 mm wide and more, so even if the crack passes directly through the hole with the glued reinforcement, the composition maintains adhesion, preventing the rod from “slipping through”. The effect of adhesion and friction is also realized: when building up a layer of concrete, shear forces are transmitted through a combination of surface roughness and the work of glued anchors (shear keys). Chemical anchors provide a constant pressing force between the old and new layers, which activates friction forces even under dynamic loads. After polymerization, the resin becomes a rigid element of the system, it fills microcracks in the concrete base around the hole, effectively “healing” the fastening zone and creating a monolithic unit capable of absorbing shear forces without deformation, which creates a high modulus of elasticity of the composition. At the same time, the calculation accuracy is maintained, since it is possible to accurately calculate the required amount of shear reinforcement taking into account the friction coefficient and surface condition, which guarantees the transfer of 100% of the forces from the new layer to the existing base.

One of the main practical advantages of the system is its high adaptability to real construction conditions. The technology of concrete building up (Post-installed rebar) is designed to work perfectly with most standard surface preparation methods already used on sites. Compatibility with different surface preparation methods is also implemented, because for reliable force transfer between the "old" and "new" concrete it is critical to ensure adhesion at the phase interface.

In addition, it is necessary to note the possibility of significantly reducing the embedment depth of reinforcing bars without losing the bearing capacity of the connection. This is achieved due to the exceptional adhesive properties of chemical compositions, which exceed the characteristics of conventional "concrete-rebar" adhesion.

Reducing the embedment depth ensures effective stress transfer: with the creation of a uniform distribution of stresses along the entire length of the gluing, which allows you to achieve the design strength of the connection at a lower depth than when using traditional "cross" joining methods. Reducing the requirements for the embedment length is critically important when used in limited space, when building up thin floor slabs, reinforcing foundation cushions or when working with narrow columns, where it is physically impossible to provide deep drilling. Smaller drilling depth Reduces the risk of damage to existing reinforcement and minimizes the likelihood of the drill bit getting into the "working" reinforcement of the existing structure, which preserves the integrity of the old frame and speeds up the installation process. Reducing the depth of the holes leads to reduced chemical consumption, reduced wear of the drilling tool and reduced labor costs per node. In summary, it can be argued that the concrete build-up method sets new standards of efficiency precisely due to the ability to minimize the geometric parameters of the node.

Below are examples of structures using the concrete layer build-up method.



(a) (b) (c) (d)

Fig. 6. The examples of structures using the concrete layer build-up method:
(a) Strengthening walls; (b) Floor reinforcement; (c) Strengthening beams; (d) Column expansion/strengthening

The integration of survey, calculation, and design processes into a single digital environment is a key trend in modern engineering.

Digitalization of design: implementation of the methodology in modern CAD/BIM systems

Modern software complexes (CAD/BIM) allow not only to automate calculations, but also to create a digital twin of the reinforced structure, taking into account the stages of its work. The main advantage here is the creation of a continuous data chain: from field survey to automated design in the BIM model.

For the digital implementation of the specified technique, an algorithm is proposed, consisting of the following stages, each of which has its own characteristics:

- parametric modeling, which is performed through the creation of special families, where thickness is a controllable parameter, which provides higher detailing of reinforcement and automatic generation of drawings, which is critical for complex joints between the old and new frames;
- automation of construction, in which the use of visual programming allows you to automate the placement of anchors and the calculation of anchor lengths according to the actual surface condition;
- use of specialized plugins that speed up the development of amplification specifications by 60-70%.

Calculation block based on finite element analysis, taking into account the initial stresses in the "old" concrete, which is implemented by stepwise activation of finite elements. This allows you to calculate a structure where the core is already deformed, and the new cage is included in the work only with subsequent load increments. At the interaction modeling stage, delamination is accurately predicted, for which 2D contact elements with friction and adhesion properties that simulate surface roughness are used, with simultaneous verification of the bearing capacity of existing sections and selection of the required area of additional reinforcement in accordance with the relevant standards.

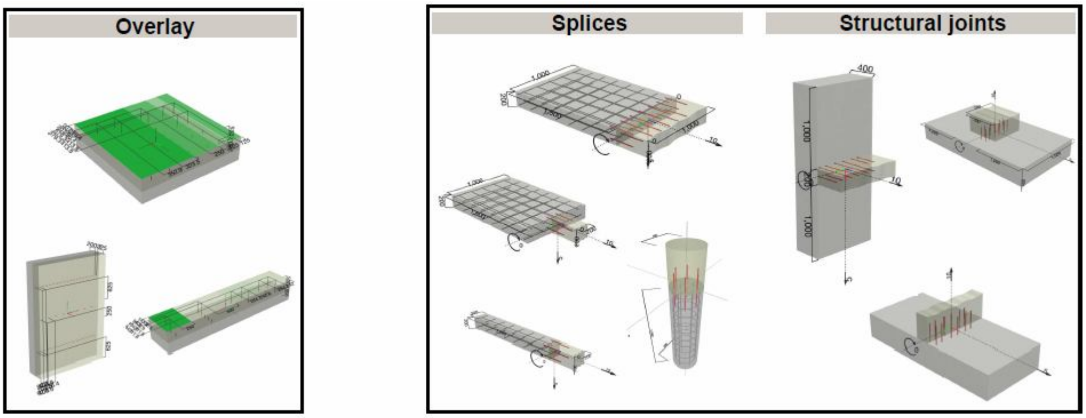


Fig. 7. CAD-elements for overlapping, splicing, structural connections

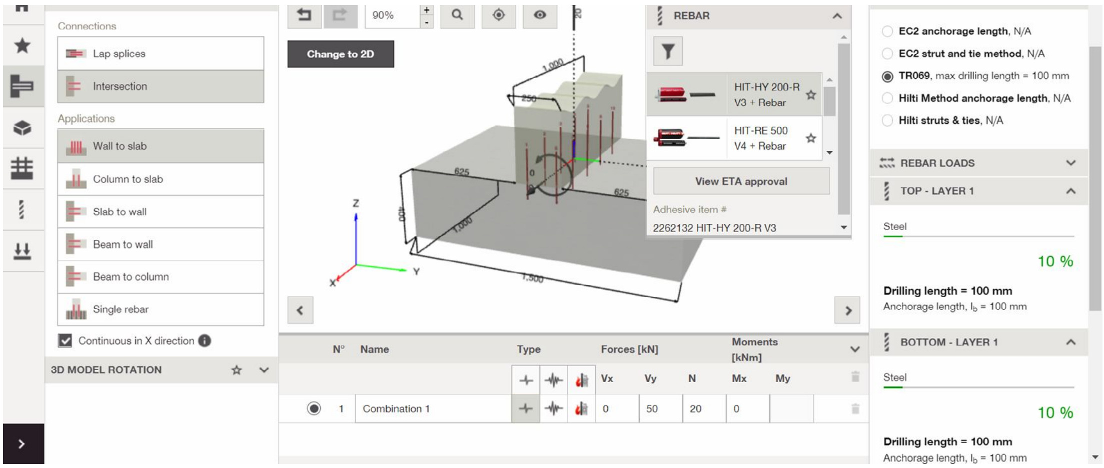


Fig. 8. Implementation in the calculation module "Increasing the thickness of concrete elements"

The methodology is implemented in the specialized module "Increasing the thickness of concrete elements". Concrete connections can be calculated and documented faster and easier, step by step, following both methodologies, including according to TR 069.

Conclusions

The use of the described technology is the implementation of a comprehensive system that includes calculation methods, specialized equipment, and highly reliable materials, which ensures monolithic integrity of the structure even under significant additional loads, and due to the high speed of installation and the absence of the need to destroy large areas of existing concrete, the method is the most economically advantageous and technically justified solution for capital construction and reconstruction.

The application of the proposed solutions eliminates the main risk of reconstruction - delamination of the structure at the point of contact of the "old" and "new" concrete, which makes it possible to obtain not just fastening, but guaranteed monolithic behavior of the node under the design load, which makes the method suitable for objects with a high level of responsibility: from residential high-rises to energy infrastructure objects, where the reliability of the connection is a matter of safety of the entire object.

Unlike standard solutions, where the presence of cracks can lead to sudden brittle failure of the joint, the technique guarantees plastic and stable operation of the structural joint, and the use of specialized adhesive mixtures allows us to consider the built-up structure as a single whole, where shear forces are reliably distributed through the "concrete-concrete" interface regardless of the initial state of the base, which makes the method indispensable for the reconstruction of objects operating under intense load or in seismically active zones.

The method also does not require special surface preparation methods, as practical examples demonstrate stable operation and guaranteed monolithicity when using classical roughness creation methods, which allows the contractor to use existing equipment without losing the quality and safety of the connection, thus transforming standard surface preparation into a highly reliable engineering unit, where chemical anchoring and mechanical bonding work as a single mechanism.

Another advantage of the method is the ability to create a full-fledged monolithic connection even where the deficiency of the thickness of the existing structure does not allow the application of traditional reinforcement methods, because the reduced requirements for the depth of embedment are an adaptive tool for complex reconstruction projects, where every centimeter of drilling depth matters, thereby achieving maximum load-bearing capacity with minimal intervention in the body of the existing structure.

In view of the transition from disparate operations to a single information environment, integration into CAD allows you to transform the complex process of building concrete into a predictable engineering operation with zero uncertainty. Using the presented technique as a digital monolithic, where each glued rod is part of a coordinated model calculated with precision accuracy, which makes the method suitable for modern BIM-oriented reconstruction projects.

Prospects for further research are seen in the use of innovative materials for increasing the cross-section, namely modern technologies and high-recipe compositions. Among them, ultra-high-strength fiber-reinforced concretes (UHPFRC), which is a revolutionary material for increasing the cross-section. In addition, UHPFRC has an extremely low permeability, which protects existing reinforcement from corrosion better than any polymer coatings. The use of self-compacting concretes (SCC) and specialized microconcretes can also be proposed, which have high fluidity and the ability to fill complex volumes under the action of their own weight, providing excellent contact with reinforcement and substrate. In addition, in the context of sustainable development, lightweight alkali-activated slag concretes (LAASC) are actively studied, which allow reducing the weight of the reinforcing layer by 25%, while increasing the bearing capacity by 37% compared to conventional mixtures. The use of steel fiber obtained by recycling used tires (RSF) also demonstrates high efficiency. Also, in modern thin-layer systems, carbon (CFRP) and basalt (BFRP) meshes are actively used instead of steel meshes.

Further development of digitalization of reinforced concrete reinforcement and BIM integration can be developed in such areas as integration of monitoring systems and artificial neural networks into BIM models for structural condition management, updating finite element models (FEM) based on data from full-scale vibration tests, research into the use of non-destructive testing (NDT) methods to create accurate digital twins of damaged buildings, and development of methods for optimizing the management of information about the condition of structures using BIM platforms.

For practical implementation of reinforcement projects, it is recommended to give preference to non-shrink microconcretes and fiber-reinforced mixtures, as they minimize the risks of delamination and provide long-term protection of reinforcement from aggressive environmental influences. It is also recommended to combine modern methods of laser scanning of objects (Scan-to-BIM) with calculation models that take into account physical nonlinearity and gradation of reinforcement.

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Прусов Д.Е., Лакштанов А.О., Рокогон М.С.
ІННОВАЦІЙНА МЕТОДИКА ВІДНОВЛЕННЯ ТА ПІДСИЛЕННЯ ЗАЛІЗОБЕТОННИХ КОНСТРУКЦІЙ ШЛЯХОМ НАРОЩУВАННЯ БЕТОННОГО ШАРУ ТА ЇЇ САПР-РЕАЛІЗАЦІЯ ПРИ ПРОВЕДЕННІ РЕМОНТІВ ТА РЕКОНСТРУКЦІЇ

У межах даної роботи представлено інноваційну методику відновлення та підсилення залізобетонних конструкцій шляхом нарощування бетонного шару, яка базується на використанні сучасних систем вклеєної арматури та зсувних шпонок Hilti. Запропонований підхід дозволяє реалізувати концепцію повної монолітності з’єднання «старий-новий бетон», забезпечуючи ефективну передачу зусиль зсуву на межі розділу фаз згідно з положеннями міжнародних звітів EOTATR 066 та TR 069. Методика відкриває широкі можливості для підсилення вигинистих та стиснутих елементів при реконструкції будівель, дозволяючи значно зменшити глибину анкерування та оптимізувати витрати матеріалів без втрати несучої здатності. Особлива увага приділена інтеграції розрахункових алгоритмів у єдине цифрове середовище через спеціалізовані модулі програмного забезпечення сучасних САПР/БІМ-систем. Така цифрова реалізація забезпечує наскрізний процес проєктування: від обробки даних неруйнівного контролю існуючого армування до автоматизованої генерації детальних 3D-моделей підсилених вузлів у САПР-середовищі. Впровадження цієї методики дозволяє мінімізувати ризики та гарантувати точність геометричних параметрів підсилення та забезпечити високу експлуатаційну надійність відновлених конструкцій у складних умовах навантаження. Пропоноване рішення є універсальним інструментом для інженерів, що прагнуть поєднати передові будівельні технології з перевагами автоматизованого проєктування для підвищення довговічності будівельного фонду.

Ключові слова: підсилення залізобетону, нарощування бетонного шару, вклеєна арматура, монолітне з’єднання, реконструкція будівель, САПР/БІМ-проєктування.

Prusov D.E., Lakshtanov A.O., Rokohon M.S.
AN INNOVATIVE METHODOLOGY FOR RESTORATION AND STRENGTHENING OF REINFORCED CONCRETE STRUCTURES VIA CONCRETE OVERLAY AND ITS CAD-IMPLEMENTATION DURING REPAIRS AND RECONSTRUCTION

The present work introduces an innovative methodology for the restoration and strengthening of reinforced concrete structures through concrete layering, based on the application of advanced Hilti post-installed rebar and shear stud systems. The proposed approach enables the realization of full monolithic connectivity at the "old-to-new" concrete interface, ensuring effective shear force transfer in accordance with international technical reports EOTA TR 066 and TR 069. This methodology offers extensive possibilities for strengthening flexural and compression elements during building reconstruction, allowing for a significant reduction in embedment depth and optimization of material consumption without compromising structural integrity. Particular emphasis is placed on the integration of calculation algorithms into a unified digital environment through specialized software and modern CAD/BIM systems. Such digital implementation ensures a seamless design process: from processing non-destructive testing data of existing reinforcement to the automated generation of detailed 3D models of reinforced nodes within a CAD-environments. The adoption of this methodology minimizes risks and errors, guarantees the precision of reinforcement geometric parameters, and ensures high operational reliability of restored structures under complex loading conditions. The proposed solution serves as a versatile tool for engineers seeking to combine cutting-edge construction technologies with the advantages of automated design to enhance the longevity of the building stock.

Keywords: concrete strengthening, concrete overlay, post-installed rebar, monolithic interface, building reconstruction, CAD/BIM-design.

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Прусов Д.Е., Лакштанов А.О., Рокогон М.С. **Інноваційна методика відновлення та підсилення залізобетонних конструкцій шляхом нарощування бетонного шару та її САПР-реалізація при проведенні ремонтів та реконструкції** // Опір матеріалів і теорія споруд: наук.-тех. збірн. – К.: КНУБА, 2026. – Вип. 116. – С. 263-274.
Представлено інноваційну методику відновлення та підсилення залізобетонних конструкцій шляхом нарощування бетонного шару. Запропонований підхід дозволяє реалізувати концепцію повної монолітності з’єднання «старий-новий бетон», забезпечуючи ефективну передачу зусиль зсуву на межі розділу фаз. Методика відкриває широкі можливості для підсилення вигинистих та стиснутих елементів при реконструкції будівель, дозволяючи значно зменшити глибину анкерування та оптимізувати витрати матеріалів без втрати несучої здатності. Особлива увага приділена інтеграції розрахункових алгоритмів у єдине цифрове середовище через спеціалізовані модулі програмного забезпечення сучасних САПР/БІМ-систем. Впровадження цієї методики дозволяє мінімізувати ризики та гарантувати точність геометричних параметрів підсилення та забезпечити високу експлуатаційну надійність відновлених конструкцій у складних умовах навантаження. Пропоноване рішення є універсальним інструментом для інженерів, що прагнуть поєднати передові будівельні технології з перевагами автоматизованого проєктування для підвищення довговічності будівельного фонду.
Іл. 8. Бібліогр. 12 назв.

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Prusov D.E., Lakshtanov A.O., Rokohon M.S. **An innovative methodology for restoration and strengthening of reinforced concrete structures via concrete overlay and its CAD-implementation during repairs and reconstruction** / Strength of Materials and the Theory of Structures.– K.:KNUCA, 2026. – Issue 116. – P. 263-274.
An innovative method for restoring and strengthening reinforced concrete structures by building up a concrete layer is presented. The proposed approach allows for the implementation of the concept of complete monolithicity of the "old-new concrete" connection, ensuring effective transfer of shear forces at the phase interface. The method opens up wide opportunities for strengthening curved and compressed elements during the reconstruction of buildings, allowing for a significant reduction in the anchoring depth and optimizing material consumption without loss of load-bearing capacity. Particular attention is paid to the integration of calculation algorithms into a single digital environment through specialized software modules of modern CAD/BIM systems. The implementation of this method allows for minimizing risks and guaranteeing the accuracy of the geometric parameters of reinforcement and ensuring high operational reliability of restored structures under difficult loading conditions. The proposed solution is a universal tool for engineers seeking to combine advanced construction technologies with the advantages of automated design to increase the durability of the building stock.
Fig. 8. Ref. 12.

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