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AN EFFECTIVE METHOD OF STRENGTHENING REINFORCED CONCRETE STRUCTURES WITH LOW SHEAR RESISTANCE AND ITS CAD IMPLEMENTATION DURING BUILDING RECONSTRUCTION

D.E. Prusov,
Doct.Tech.Sci., Prof. Dr. Habil.

A.O. Lakshtanov

M.S. Rokohon

Kyiv National University of Construction and Architecture, Institute of Innovative Education
03037, Ukraine, Kyiv, Osvity str., 4

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The choice to strengthen the existing structure or demolish and rebuild is not always easy and depends on the current condition of the structure, the client's brief, and the structure's cultural, historical, and societal importance. If the structural engineer determines that strengthening the entire structure is possible, evidence suggests a 15-70% faster turnaround time (defined as the time between stopping activity in the building or on the bridge and returning it to service) as compared to demolishing and building afresh. Besides saving time, strengthening the structure may achieve a 10-75% reduction in the resource burden through savings in labour and material, directly impacting the structure's environmental and carbon footprint. A faster return and a lower initial investment are also vital considerations for clients.

The proposed technology involves directly increasing the amount of shear reinforcement results in a proportional increase of the shear resistance, and the solutions available presently in the industry are typically minimally invasive and will reduce disruption to other members. Conversely for the concrete shear resistance, the use of other solutions typically results in an under-proportional increase, apart from concrete overlay, which is accompanied by its own trade-offs.

In recent years, the development and sufficient maturity of post-installed anchoring technology have led its use in applications beyond steel-to-concrete fastenings and concrete-to-concrete connections. One use in strengthening is in concrete overlay where both bonded and mechanical fasteners function to reinforce the interface between the existing and new concrete.

Another use of the bonded anchor system in strengthening is in a recently developed Hilti strengthening solution "HIT-Shear" which directly increases the resistance to shear loading of reinforcement concrete members, akin to cast-in stirrups.

Hilti's cloud-based design software Profis Engineeringincludes a new dedicated module for assessing and strengthening concrete members deficient in shear that assists structural engineers when evaluating the resistance of existing members and strengthening them, thereby ensuring a safer and more efficient workflow, with subsequent implementation in the CAD system module.

Keywords: building reconstruction, shear strengthening, concrete overlay, reinforced concrete, civil engineering.

Introduction.

As the world's infrastructure ages, along with evolving building codes and the imperative of sustainability, the rehabilitation and strengthening of existing reinforced concrete structures has become a critical area of modern civil engineering. This report details the fundamental scientific principles underlying various methods used to enhance the load-bearing capacity, durability and safety of reinforced concrete elements in existing buildings and structures.

Many existing reinforced concrete structures, especially those designed according to old codes, demonstrate an inadequate level of protection against modern loads, such as seismic events. Repeated earthquakes that have occurred recently have consistently confirmed the inadequate level of protection of existing buildings against both damage and collapse. Such structures may be insufficiently or lightly reinforced, making them vulnerable to excessive stresses.

The high economic and environmental costs associated with the demolition and reconstruction of poorly designed structures require a shift to the rehabilitation and improvement of existing assets. This is in line with the general principles of sustainable development, which promote the extension of the service life of structures. This approach is not simply a technical choice, but a fundamental paradigm shift driven by economic and environmental sustainability. This means that reinforcement is not simply a repair, but a strategic investment in existing assets, reflecting the broader societal value of resource efficiency and heritage conservation, moving away from a disposable approach to infrastructure.

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Formulation of the problem

The main objectives of strengthening measures are to increase the flexural and shear strength, increase local or global ductility, improve the performance characteristics (e.g., reduce deflection and cracking), and extend the overall service life of the structure. A significant challenge is the accurate assessment of the condition of the existing structure, which is a complex engineering task. In addition, ensuring compatibility and monolithic interaction between the original and new materials is of paramount importance for the success of any strengthening method.

Structural vulnerability is not static, but evolves with new understanding of hazards (e.g., seismic activity) and advances in design philosophy and codes. Structures once considered adequate may now be found to be inadequate, requiring upgrades to meet modern safety standards. This implies a constant need for assessment and adaptation in infrastructure management driven by a dynamic understanding of risks and performance expectations.

A thorough assessment of the condition of the existing structure is an essential first step in any renovation project. This assessment determines the current material properties, identifies deficiencies, and informs the selection of appropriate strengthening methods.

Initial assessment often begins with a visual inspection, which, despite its inherent subjectivity, remains the dominant practice in maintenance management. This involves the identification and categorization of visible signs of degradation, such as crack propagation (bending/shear, longitudinal corrosion cracks), crack location, corrosion damage, and surface degradation.

Basic testing complements visual inspection by providing quantitative data on parameters such as the ratio of concrete cover to rebar diameter, load-induced crack width, longitudinal corrosion crack width, rebar corrosion rate, and deflection coefficient. Common defects found include corrosion of steel reinforcement, cracking, delamination and delamination of concrete, and deflection.

The limitations of purely qualitative assessment are recognized, and efforts are being made to integrate human experience (linguistic judgments) with computational methods to achieve more reliable and objective assessment. This means that advanced computational tools are becoming necessary to transform subjective observations into practical, quantitative data for structural assessment, thereby increasing the reliability and consistency of reconstruction decisions.

A background to concrete strengthening

The high economic and environmental costs associated with the demolition and reconstruction of poorly designed structures require a shift to the rehabilitation and improvement of existing assets. This is in line with the general principles of sustainable development, which promote the extension of the service life of structures. This approach is not simply a technical choice, but a fundamental paradigm shift driven by economic and environmental sustainability. This means that reinforcement is not simply a repair, but a strategic investment in existing assets, reflecting the broader societal value of resource efficiency and heritage conservation, moving away from a disposable approach to infrastructure.

Over the last two decades, the construction industry has come under increasing pressure to reduce its environmental footprint and reuse existing building stock to meet growing socio-economic demands, particularly in urban environments where a sizeable proportion of reinforced concrete buildings and bridges are at the end of their service life and need either refurbishment or demolition. Besides end of service life, a few causes of shear strengthening existing structures may include: a change in use or occupancy; an expansion of the building's footprint; additional floors in dense urban environments that makes expanding horizontally is not viable; the introduction of new building codes; the presence of errors or other deficiencies in the original construction; and the need to address other durability issues caused by known hazards such as fire and earthquake.

The choice to strengthen the existing structure or demolish and rebuild is not always easy and depends on the current condition of the structure, the client's brief, and the structure's cultural, historical, and societal importance. If the structural engineer determines that strengthening the entire structure is possible, evidence suggests a 15-70% faster turnaround time (defined as the time between stopping activity in the building or on the bridge and returning it to service) as compared to demolishing and building afresh. Besides saving time, strengthening the structure may achieve a 10-75% reduction in the resource burden through savings in labour and material, directly impacting the structure's environmental and carbon footprint [1]. A faster return and a lower initial investment are also vital considerations for clients.

General principles of strengthening reinforced concrete structures during the reconstruction of existing buildings and structures

Strengthening of reinforced concrete structures is a set of measures aimed at restoring or increasing their bearing capacity, stiffness and durability. The main reasons for strengthening are the following: increased operational loads; detection of damage or defects; change in the functional purpose of the building; the need to increase seismic resistance.

The basic principles of strengthening are based on the redistribution of stresses in the structure, the involvement of additional elements in joint work and compensation for strength losses. Strengthening of reinforced concrete structures is a set of measures aimed at restoring or increasing their bearing capacity, stiffness and durability. The main reasons for strengthening are an increase in operational loads; detection of damage or defects; change in the functional purpose of the building; the need to increase seismic resistance. The basic principles of strengthening are based on the redistribution of stresses in the structure, the involvement of additional elements in joint work and compensation for strength losses.

Strengthening by adding anchors

Anchors are used to provide a reliable bond between the existing structure and new reinforcement elements. They transfer forces from additional reinforcement or mortar to the main structure, ensuring their joint operation. Anchors create a strong mechanical bond (frictional or adhesive), preventing delamination of existing and new layers. This is especially important when strengthening columns, beams or slabs by increasing their cross-section.

The calculation of anchor connections is based on determining their pullout and shear resistance, as well as on calculating the stresses in the concrete around the anchor. The pullout (tension) resistance of an anchor is determined by the formula:

$$F_{pull}=A_{c,N}\times f_{cd},$$

where $A_{c,N}$ is projected area of concrete around the anchor, f_{cd} is calculated compressive strength of concrete.

Anchor shear capacity:

$$F_{shear}=A_s\times f_{yd},$$

where A_s is anchor cross-sectional area, f_{yd} is designre sistance of tension anchor steel.

Strengthening by adding additional reinforcement

Additional reinforcement takes on part of the tensile and compressive forces, increasing the overall load-bearing capacity of the structure. This can be done by installing new reinforcing cages, meshes or individual rods. The new reinforcement is installed in pre-prepared holes or on the surface of the structure, and then poured with a special repair mortar that ensures its joint work with the existing concrete. This method effectively increases the bending and shear strength. Reinforcement with reinforcement increases the bending and shear strength of the structure. The calculation is carried out taking into account the new moment of resistance and the area of the reinforcement working together.

Increase in bending load capacity (for rectangular cross-section):

$$M_{\text{new}}=M_{\text{old}}+\Delta M,$$

where M_{old} is initial moment of resistance; ΔM isadditionalmomentcreatedbynewreinforcement. ΔM is calculated as:

$$\Delta M=A_{sa}\times f_{ya}\times z_a,$$

where A_{sa} is area of new reinforcement; f_{ya} is designre sistance of new reinforcement; z_a is the armof the internal couple of forces between the new reinforcement and the center of the compressed zone.

Strengthening by increasing the cross-section of the structure.

This method is the most common and consists in increasing the cross-sectional area of an element (column, beam, slab) by adding new concrete (or reinforced concrete). Increasing the cross-section leads to a decrease in stresses in the material and an increase in the moment of inertia, which increases stiffness and strength. Increasing the cross-section is performed after preparing the surface of the existing structure (cleaning, notching, installing anchors) and installing additional reinforcement. New concrete (usually high-strength) is poured into the formwork, forming a monolithic layer that works together with the existing structure. This method is effective for strengthening compression and bending elements.

Increasing the cross-section leads to an increase in the moment of inertia and cross-sectional area, which reduces the stress. The calculation is performed for the composite cross-section, taking into account the joint work of the old and new concrete.

Increasing the compressive load-bearing capacity (for columns):

$$N_{new}=\varphi\times(A_{old}\times f_{cd,old}+A_{new}\times f_{cd,new}+A_{s,new}\times f_{yd,new}),$$

where N_{new}isnewcarryingcapacity; φ is stability coefficient; A_{old}, A_{new}, and $A_{s,new}$ are cross-sectional areas of old and new concrete and new reinforcement; f_{cd} and f_{yd} are calculated concrete and reinforcement supports.

When selecting strengthening methods, a stress-strain analysis is also performed, which is crucial for understanding the current performance of the structure and assessing the effectiveness of strengthening measures. It is based on the principles of deformation and stress distribution. The deformation of the material (concrete and reinforcement) is a key indicator of stresses, using the ratios of the relative deformation of the concrete (compression) and the relative deformation of the reinforcement (tension).

Comparison "before" and "after" reinforcement is carried out by analyzing such key parameters as: bearing capacity (the initial bearing capacity is compared with the new one, increased by the reinforcement coefficient, i.e. the higher K, the more effective the reinforcement); stiffness (the moment of inertia of the section is compared, which is a measure of stiffness and leads to a decrease in deflections and deformations under load); stresses (the maximum stresses in concrete and reinforcement are compared, after reinforcement they should be significantly lower than their limiting values, which indicates a redistribution of forces and an increase in the structural safety margin).

Solutions for strengthening and the selection process

The potential savings are strongly predicated upon the structural engineer's ability to select and the construction industry's ability to provide and install appropriate strengthening solutions that address identified local and/or global deficiencies. While most strengthening projects will usually incorporate multiple solutions, some are ruled out due to architectural, operational, or geometrical limitations, a lack of knowledge in design and / or execution, unavailability of appropriate equipment, which narrows the list of potential solutions. This selection is further influenced by the advantages and disadvantages accompanying these solutions and are not “silver bullets” miraculously resolving structural deficiencies. Adding another layer of complexity is the potential for flawed implementation of these solutions that may lead to strengthening a particular part of the structure but weakening another, illustrated by the following two examples, one at a local and the other at the global level:

1. **Local**: thickening the slab with a concrete overlay but ignoring the additional loads on the supporting beams.
2. **Global**: a high concentration of shear infill walls on one side of the structure increasing the load demand on the other side, achieving the opposite effect.

At a “local” level, deficiencies may include the individual concrete members such as beams, columns, slabs, walls, and foundations lacking sufficient resistance to preclude failure in tension, compression, bending, shear, punching shear, torsion, and other effects caused by new loading demands. Solutions for individual members include, among others:

- Concrete overlays or jackets as seen in Figure 1,
- Post-installed reinforcement,
- Steel jackets,
- Near surface mounted (NSM) or bonded plates,
- Fibre-reinforced polymer (FRP) wraps and strips,
- External post-tensioning.

Strengthening on a “global” level typically includes addressing issues related to the whole structure, such as seismic, fire, fatigue, and wind by introducing solutions such as:

- Shear infill walls as shown in Figure 2,
- Steel braces,
- Micro-piles,
- Base-isolation,
- Energy dissipation / damping devices.

Strengthening concrete members deficient in shear

Assuming a building previously housing offices now changed to commercial use from a change in ownership, higher footfall will increase load on, say, the floor that must be resisted by all structural components – slabs, beams, columns, and the foundations. Typically, after verification, an engineer may find that the beams lack sufficient resistance in both bending and shear or, in some cases, only shear. Recall that in most design standards, such as Section 6.2 of EN 1992-1-1:2004 [2], the resistance of a concrete member in shear depends on the following six parameters:

1. Concrete strength.
2. Section width, and height.
3. Effective depth to the flexural reinforcement from the top of the compression fibre
4. Length of the support
5. The amount of longitudinal reinforcement.
6. The amount of shear (or transverse) reinforcement.

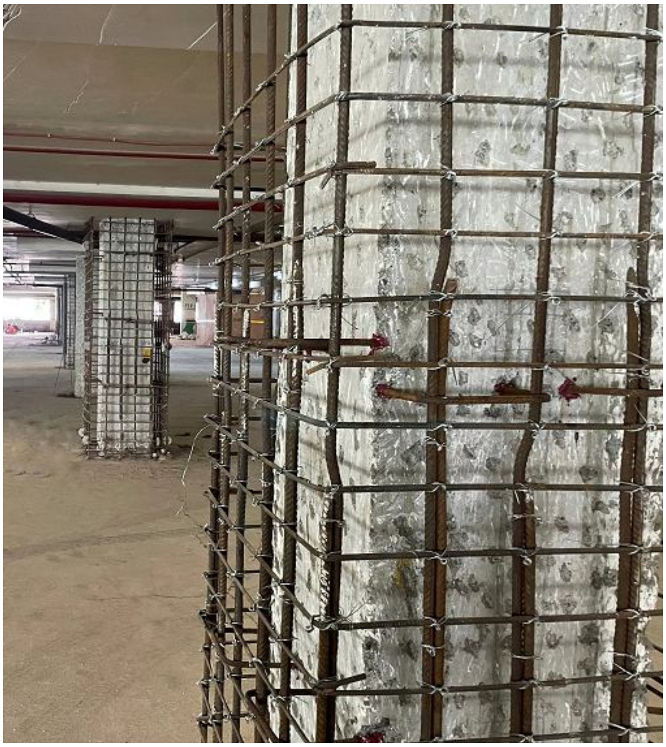

Fig. 1. An example of concrete overlay / jacketing in columns

Fig. 2. Exampleof a shear-in fill wall between columns

Employing a range of potentially available “local”-level solutions to improve one or several of these parameters enhances shear resistance by varying amounts, yet this incurs a trade-off in terms of invasiveness, cost, availability, and other parameters. Some modifications may not be even feasible, such as increasing the concrete strength of an existing beam. Others, such as adding more supports through additional columns to reduce shear demands on one beam may load another beam and will require load transfer to the foundations. Therefore, the potential range of solutions to enhance parameters (1) to (6) may resemble Table 1.

Table 1

Potential solutions to strengthen concrete deficient in shear

	Parameter	Strengthening Solution
1	Increasing the section width and height	Concrete Overlay
2	Increase the effective depth to flexural reinforcement	Steel plates Concrete Overlay with Post-installed rebar Fibre-reinforced polymers
3	Increasing the support length	Post-installed steel capital or struts Corbels
4	Increase longitudinal reinforcement	Fibre-reinforced polymers Concrete Overlay
5	Increase shear reinforcement	Fibre-reinforced polymers Post-installed shear reinforcement

Directly increasing the amount of shear reinforcement results in a proportional increase of the shear resistance, and the solutions available presently in the industry are typically minimally invasive and will reduce disruption to other members. Conversely for the concrete shear resistance, the use of other solutions typically results in an under-proportional increase, apart from concrete overlay, which is accompanied by its own trade-offs.

Post-installed shear reinforcement to increase shear resistance

In recent years, the development and sufficient maturity of post-installed anchoring technology have led its use in applications beyond steel-to-concrete fastenings and concrete-to-concrete connections. One use in strengthening is in concrete overlay where both bonded and mechanical fasteners function to reinforce the interface between the existing and new concrete.

Another use of the bonded anchor system in strengthening is in a recently developed Hilti strengthening solution “HIT-Shear” which directly increases the resistance to shear loading of reinforcement concrete members, as illustrated in Figure 3, akin to cast-in stirrups.

This solution is installed similar to a bonded anchor: i.e., drilling to a fixed embedment depth perpendicular to the concrete surface, thoroughly cleaning the debris from the boreholes, and injecting the mortar and then inserting the rods. Once the mortar cures, the nuts can be torqued up to a maximum specified value.

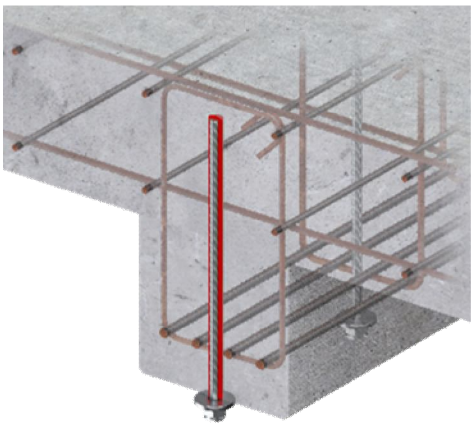

Fig. 3. Hilti HIT-RE 500 V4, HAS(-U) rods, and filling set used as post-installed shear reinforcement

While installation into the concrete member is indeed possible from either side, for instance top-down or bottom-up in a beam or slab, a key feature of the system is the installation of the threaded rods to a specified installation length, lsw, which is function of the thickness, h, and a residual cover, cres, that prevents, from an installation perspective, concrete spalling at the surface opposite to drilling. The residual cover, as illustrated in Figure 4, varies according to the rod diameter.

From a design perspective, the fixed installation length ensures the secure anchorage of the rods to replicate the truss model formed by cast-in stirrups.

In the absence of an existing European Assessment Document (EAD) or a harmonised European standard (hEN), the Hilti HIT-Shear strengthening solution was verified for its fitness for this strengthening application by the Deutsches Insitut für Bautechnik (DIBt) and granted a "general construction technique permit", or aBG, Z-15.5-383 [4]. This fulfils the national requirement for construction works under the MVV TB (Muster-Verwaltungsvorschrift Technische Baubestimmungen), which serve as a model for the Administrative Provisions – Technical Building Rules that are implemented at a federal level in Germany.

Hilti's cloud-based design software Profis Engineeringincludes a new dedicated module for assessing and strengthening concrete members deficient in shear that assists structural engineers when evaluating the resistance of existing members and strengthening them, thereby ensuring a safer and more efficient workflow. The new Profis Engineering Shear Strengthening module enables:

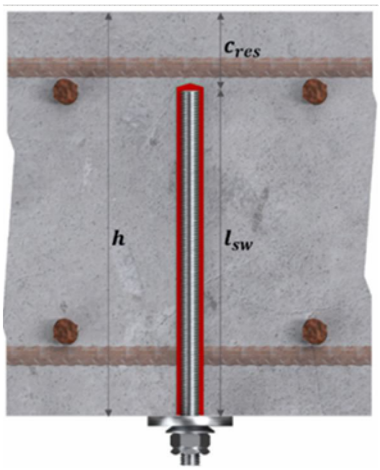

Fig. 4. Cross-section showing the installation depth and residual cover of the HIT-Shear strengthening solution

- Selection between beams, columns, slabs, and walls and definition of its material properties & geometry
- Verification of the existing concrete's resistance to EN 1992-1-1:2004 + National Annex or SIA 262:2017 [5].
- Strengthening with a choice of four reinforcing diameters in carbon- or stainless-steel and a free input the spacing and edge distances.
- Splitting the member into individual zones and leverage the Variable Strut Inclination Method to maximise resistance with the least reinforcement.
- Generation of a comprehensive design report with all verifications, reinforcement detailing, and installation instructions.

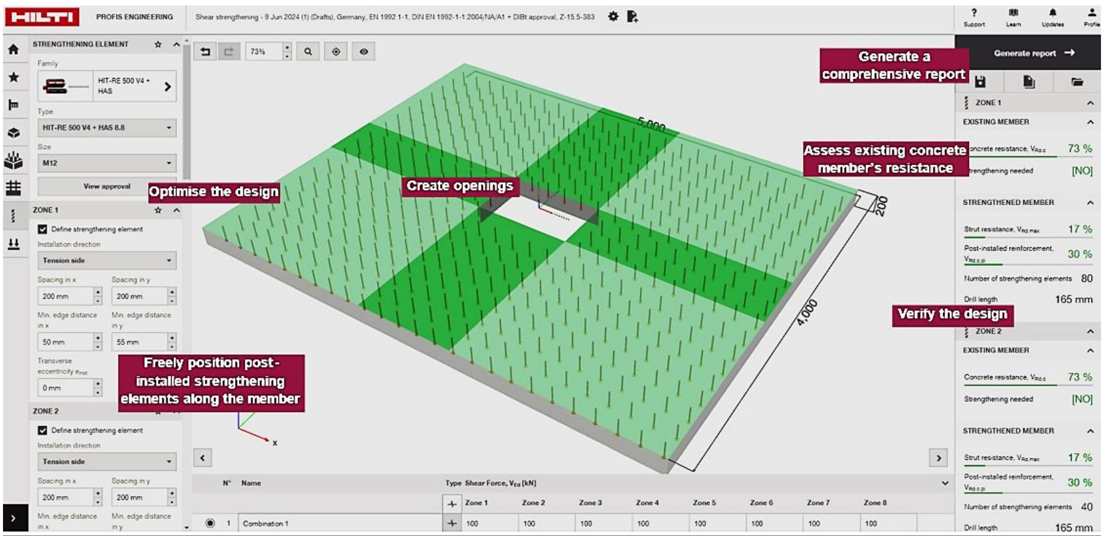

Fig. 5. Example of CAD implementation

Summary

Transforming and reusing older structures can offer many advantages over new build ones, with each structure requiring fulfilment of specific objectives when strengthened. Based on the chosen design philosophy, the structural engineer can address shear deficiencies in linear or planar concrete members through various methods, some less invasive than others. The use of post-installed shear reinforcement, such as Hilti's solution of HAS(-U) threaded rods with the HIT-RE 500 V4 mortar, is a novel example of a minimally invasive method that can significantly enhance the shear resistance of a structural member.

Engineers can use a Eurocode 2-based design approach integrated into Hilti's Profis Engineering Suite to arrive at a feasible solution by selecting between the key design parameters of diameter, spacing and the variable inclined strut. With an intuitive interface, the new Shear Strengthening module assists engineers by saving time during the design phase, bringing value to their clients while also contributing to a safer and more resilient built environment.

Strengthening reinforced concrete structures during the renovation of existing buildings and structures is a multifaceted task that requires a deep understanding of the scientific principles governing material behavior and structural response. The success of such interventions depends on a thorough assessment of the existing condition, the selection of the most appropriate strengthening method, and ensuring impeccable quality of execution.

The basic scientific principles underlying amplification are as follows:

– Composite action of materials: Reinforced concrete works as a single unit due to the effective bond between the concrete and the steel reinforcement, which allows to compensate for the low tensile strength of the concrete. Any reinforcement must maintain or restore this composite action.

– Ensuring ductile failure: The design aims to achieve a ductile failure mode that provides visual warnings and time to react, as opposed to sudden brittle failure. This is achieved by carefully controlling the ratio of reinforcement and cross-sectional geometry.

– Consideration of dynamic behavior: Structures respond differently to static and dynamic loads. Changes in stiffness and natural frequency of damaged elements under dynamic loads require complex analysis and consideration of post-event stability.

– Comprehensive condition assessment: Accurately assessing the existing structure using a combination of visual inspection, destructive and non-destructive testing methods is critical. Non-destructive methods play a key role in proactively detecting defects such as corrosion before they cause significant damage.

– Interface Integrity: Regardless of the reinforcement method chosen (cross-section enhancement, steel plates), success depends on the strength and durability of the bond between the existing and new materials. The interface is often the "weak link," requiring careful surface preparation, the use of appropriate adhesives, and engineering solutions to transmit shear.

– Long-term behavior management: Time-dependent phenomena such as creep and shrinkage, especially differential shrinkage in composite structures, can create internal stresses and reduce load-bearing capacity over time. Design must take these effects into account to ensure long-term safety and serviceability.

Overall, strengthening reinforced concrete structures is not simply about applying new materials, but rather about applying a deep scientific understanding of material interactions, failure mechanisms, dynamic response, and time-dependent effects. This underscores the shift from simple repairs to strategic, science-based asset management that ensures the durability, safety, and sustainability of our existing infrastructure.

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Прусов Д.Е., Лакштанов А.О., Рокогон М.С.

ЕФЕКТИВНИЙ МЕТОД ПОСИЛЕННЯ ЗАЛІЗОБЕТОННИХ КОНСТРУКЦІЙ З НИЗЬКИМ ОПОРОМ ЗСУВУ ТА CAD-РЕАЛІЗАЦІЯ ПРИ ПРОВЕДЕННІ РЕКОНСТРУКЦІЇ СПОРУД

Запропонована технологія передбачає безпосереднє збільшення кількості арматури на зсув, що призводить до пропорційного збільшення опору зсуву, а рішення, доступні наразі в галузі, зазвичай є мінімально інвазивними та зменшують пошкодження інших елементів. І навпаки, для опору бетону на зсув, використання інших рішень зазвичай призводить до непропорційного збільшення, окрім бетонного покриття, що супроводжується власними компромісами.

В останні роки розвиток та достатня зрілість технології пост-встановленого анкерування призвели до її використання в сферах застосування, що виходять за рамки кріплення сталі до бетону та бетонних з'єднань. Одним із застосувань у зміцненні є бетонне покриття, де як скріплені, так і механічні кріплення функціонують для посилення межі між існуючим та новим бетоном.

Ще одне застосування системи скріплених анкерів у зміцненні - це нещодавно розроблене рішення Hilti для зміцнення «HIT-Shear», яке безпосередньо збільшує опір навантаженню на зсув арматурних бетонних елементів, подібно до монолітних стремен.

Розроблене хмарне програмне забезпечення для проектування Hilti Profis Engineering містить новий спеціалізований модуль для оцінки та посилення бетонних елементів з недостатнім зсувом, який допомагає інженерам-конструкторам оцінювати опір існуючих елементів та підсилювати їх, тим самим забезпечуючи безпечніший та ефективніший робочий процес з подальшим впровадженням у модуль системи САПР.

Ключові слова: реконструкція споруд, зміцнення на зсув, бетонне покриття, залізобетонні конструкції, цивільне будівництво.

Prusov D.E., Lakshtanov A.O., Rokohon M.S.

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Прусов Д.Е., Лакштанов А.О., Рокогон М.С. **Ефективний метод посилення залізобетонних конструкцій з низьким опором зсуву та її CAD-реалізація при проведенні реконструкції споруд** / Опір матеріалів і теорія споруд: наук.-тех. збірн. – К.: КНУБА, 2025. – Вип. 115. – С. 315-324.

Запропонована технологія безпосереднього збільшення кількості арматури на зсув, що призводить до пропорційного збільшення опору зсуву, Одним із застосувань у зміцненні є бетонне покриття, де як скріплені, так і механічні кріплення функціонують для посилення межі між існуючим та новим бетоном. Застосування системи скріплених анкерів у зміцненні – це нещодавно розроблене рішення Hilti для зміцнення «HIT-Shear», яке безпосередньо збільшує опір навантаженню на зсув арматурних бетонних елементів, подібно до монолітних стремен. Розроблене хмарне програмне забезпечення для проектування Hilti Profis Engineering містить новий спеціалізований модуль для оцінки та посилення бетонних елементів з недостатнім зсувом, який допомагає інженерам-конструкторам оцінювати опір існуючих елементів та підсилювати їх, тим самим забезпечуючи безпечніший та ефективніший робочий процес з подальшим впровадженням у модульсистеми САПР.

Іл. 5. Бібліогр. 5 назв.

UDC624.12

Prusov D.E., Lakshtanov A.O., Rokohon M.S. **An effective method of strengthening reinforced concrete structures with low shear resistance and its CAD implementation during building reconstruction** / Strength of Materials and the Theory of Structures.– K.:KNUCA, 2025. – Issue 115. – P. 315-324.

The proposed technology directly increases the amount of shear reinforcement, resulting in a proportional increase in shear resistance. One application in reinforcement is concrete pavement, where both bonded and mechanical fasteners function to strengthen the interface between existing and new concrete. The application of bonded anchor systems in reinforcement is the newly developed Hilti strengthening solution “HIT-Shear”, which directly increases the shear load resistance of reinforced concrete elements, similar to monolithic stirrups. The developed cloud-based design software Hilti Profis Engineering includes a new specialized module for the assessment and strengthening of concrete elements with insufficient shear, which helps design engineers to assess the resistance of existing elements and strengthen them, thereby ensuring a safer and more efficient workflow with subsequent implementation in the CAD system module.

Fig. 5. Refs. 5.

Автор (науковий ступінь, вчене звання, посада): доктор технічних наук, професор, завідувач кафедри БІТ Інституту інноваційної освіти КНУБА, ПРУСОВ Дмитро Едуардович.
Адреса: 03037,Україна, м. Київ, вул. Освіти, 4. Інститут інноваційної освіти Київського національного університету будівництва і архітектури, ПРУСОВ Д. Е.
Тел.: +38 (044) 597-19-86
E-mail: prusov.de@knuba.edu.ua
ORCID ID: http://orcid.org/0000-0002-1720-2798

Автор (науковий ступінь, вчене звання, посада): викладач ІІНО КНУБА, директор з маркетингу та інжинірингу компанії Hilti Україна ЛАКШТАНОВ Андрій Олександрович
Адреса: 04080, Україна, м. Київ, вул. В. Хвойки 15/15
Тел.: +38-067-225-55-46
E-mail: andrii.lakshtanov@hilti.com

Автор (науковий ступінь, вчене звання, посада): викладач ІІНО КНУБА, менеджер з інженерного маркетингу компанії Hilti Україна РОКОГОН Марія Сергіївна,
Адреса: 04080, Україна, м. Київ, вул. В. Хвойки 15/15
Тел.: +38-067-225-55-01
E-mail: mariia.rokohon2@hilti.com