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Andriy Tereshko[1], Yaroslav Blikharskyy[2]

STRENGHENING OF RC BEAMS BY FRC AND FRP SYSTEMS – A REVIEW

Lviv Polytechnic National University,
[1] Department of Building constructions and bridges,
[2] Department of Highways and bridges
yaroslav.z.blikharskyy@lpnu.ua

The article examines studies on the reinforcement of reinforced concrete elements of cement -based fibro -based fibro systems (FRC) and polymers reinforcement fibro (FRP). Nowadays, the world economy, and with it, the construction industry is developing at a rapid pace. New materials, mechanization, construction equipment are emerging on the market. Due to this, modern structures impress with their shapes, scale and complexity of structures. The state of construction production in the country can be judged on the state of the economy of this country as a whole. Now the urgent issue in the world is the use of new composite materials in the strengthening of building structures. Such materials include non -metallic fittings, laminates, nets and canvases based on high -strength fibers. In this case, the own weight of fiber materials is slightly small. Only units of the above researchers performed enhancement of experimental samples under load, so the influence of the initial stress-deformed state on the work of the structure after amplification was practically not studied.

Key words: reinforcement, reinforced concrete beams, composite materials, FRC, FRP, flexural structures.

Introduction

Nowadays, the world economy, and with it, the construction industry is developing at a rapid pace. New materials, mechanization, construction equipment are emerging on the market. Due to this, modern structures impress with their shapes, scale and complexity of structures. The state of construction production in the country can be judged on the state of the economy of this country as a whole.

At the same time, reconstruction problems remain relevant. This is due to the following factors:

- the expiration of the life of buildings that have been erected;
- constant increase in design requirements in order to ensure the reliability and durability of structures;
- re -equipment and change of functional purpose of buildings and structures;
- economic advantage of reconstruction over new construction;
- imperfect quality control of construction and installation work.

That is why the problem of reinforcement sometimes appears even in the process of new construction.

Now the urgent issue in the world is the use of new composite materials when enhancing building structures. Such materials include non - metallic fittings, laminates, nets and canvases based on high - strength fibers. For example, the strength of carbon fiber can be 10 times exceeding the strength of reinforcing steel. In this case, the own weight of fiber materials is slightly small.

The main way to use composites when amplified is to glue cloths, nets or laminate to the surfaces of structures. The nutrient in this case will be called a stabilizing matrix. Its function is to transfer effort from the design to high-strength fibers. As a stable matrix, polymer solutions (epoxy adhesives and resins) were first used for the first time. Now composites with a polymer matrix are the most common.

The first studies of these materials began in the second half of the twentieth century, so now a fairly extensive basis for the results of experimental research in this area is available.

In general, the main advantages of using composites for enhancement can be called:

· Low complexity of gain in comparison with traditional methods (cross -sectional extension, introduction of additional elements, etc.);

· insignificant increase in the geometric dimensions of the strengthened structure;

· absence of additional mounting devices or formwork;

· versatility of application.

Strengthening of building structures with non -metallic reinforcement

With the help of FRP rods, you can strengthen the reinforced concrete elements by increasing their bearing capacity in normal and sloping sections. This can be done by installing additional reinforcing rods into the body of concrete. The most common now is the technology of shallow installation of additional reinforcement NSM (Nearly Surface Mounted) Strab on the surfaces of reinforced concrete structures and fixing in them the rods of reinforcement by means of epoxides.

The comparative characteristics of different materials for NSM is presented in (Gómez et al., 2020). The bending tests were performed with a short-term load of 12 beams. According to the NSM technology, in the lower face of the beams, the rods made of carbonlastic, fiberglass, steel, and strips of CFRP laminate (laminate based on carbon fibers) were performed. For comparison, two non -peeled beams and two beams were tested with CFRP laminate strips fixed from the outside. The percentage of additional reinforcement of beams was chosen so that the axial rigidity of the cross-section of the beams (E×A) were approximately the same. The destruction of the samples reinforced by NSM technology was due to the rupture of the strengthened reinforcement (fluidity in the case of steel) or the separation of the rods together with the protective layer of the concrete of the lower face. This indicates an excellent anchorage of concrete reinforcement elements. Deformation of the elements of reinforcement at the time of destruction was 65 – 100 % of the boundary, which indicates the effective use of their bearing capacity. In the case of enhanced by the CFRP laminate, the laminate laminate was made due to the detachment of the laminate near one of the supports. At the same time, the deformities of the laminate at the time of the separation were an average of 43 % of the limit, ie the ns of the laminate was strongly undergraded.

Comparison of the effectiveness of FRP reinforcement by NSM technology and the CFRP laminate strips are given in work (Haddad and Yaghmour, 2020). The reinforcement and test of bending static load to the destruction of reinforced concrete slabs of the existing bridge was carried out. The amplification was performed without termination of the bridge. The FRP replaced by the rods showed an increase in bearing capacity of 29 % compared to the control unspoken and destroyed as a result of the rupture of the rods of the reinforcement at the place of the widest crack. The effect of amplification of CFRP laminate strips was 17 %. The destruction was partially due to the rupture, partly due to the detachment of the laminate. In general, the positive effect of amplification is obtained in both cases, but the author notes that when performing large volumes of use of NSM technology may be less time consuming. This is due to the fact that the preparation of the surface before gluing laminate with the polymer matrix can take more time and effort, as it all depends on the condition of the surfaces of the structure.

In the work (Obaidat et al., 2020) investigated the intensification of inclined cross sections of pre – stressed reinforced concrete beams FRP rods using NSM technology. The destruction of the control sample occurred in an inclined cross section at the magnitude of the transverse force $V = 81.8$ kN. The destruction of the reinforced sample occurred in the normal cross section, with the maximal value of the transverse force was $V = 125.5$ kN. The effect of strengthening was 53 %, but the strains of the strengthening rods at the time of destruction amounted to $\varepsilon = 650\times10^{-5}$, which is 41 % of the limit $\varepsilon_u = 1570\times10^{-5}$. This indicates a non -use of the load -bearing capacity of the entered amplification and the need for methods of calculating a balanced amount of additional reinforcement.

There is another technology for increasing the load -bearing capacity of reinforced concrete beams through sloping sections with the help of FRP rods. Unlike NSM, strengthened reinforcement technology is mounted in drilling holes along the central axis of the lower face of the elements (Nikoloutospoulos et al., 2023). This type of reinforcement was designed for beams with limited or absent access to the side faces. Its advantage is the contact of the entire surface area of the reinforcement with concrete. Experiments with different types of fittings were conducted. Studies have shown that the deformability of reinforced concrete beams with the existing and missing reinforcement is slightly influenced by the loading scheme (in this case, the value of the pure bending zone). However, in the case of pre -strained beams, the effect of loading on deformation of the beam is significant and can affect the nature of the destruction.

Strengthening construction structures by external FRP and FRC by composites

Fastened FRP and FRC composites are increasingly used due to their positive properties (Alberti et al., 2024; Askar et al., 2022; Mohamed et al.; 2020, ROSSI 2023; Siddika et al., 2020). These can be attributed:

- high physical and mechanical characteristics;
- a wide range of materials;
- insignificant weight;
- Easy to apply compared to traditional reinforcement methods.

In the work (Casadei et al., 2005), the test of three TT type TT plates for bending with a short -term load was performed. The plates were enhanced by polymer composite based on steel fibers (SFRP) on the lower edges of the ribs. The percentage of strengthened reinforcement was the same. Studies have shown that the composite material is included in joint work with the design after cracks. This was evidenced by zero relative deformations of the composite before the onset of cracking. After the first cracks of the tension began to show the increase in deformation. The maximum deflection of the control (without reinforcement) plate at a destructive load of 344 kN was 15 mm. Increased samples at the same load levels showed a bend 5 and 7.5 mm. The authors also noted that the presence of reinforcement delay the moment of crack. The same effect is noted in the works (Ascione et al., 2020; Baietti et al., 2021; Sneed et al., 2022). Obviously, this is the result of a decrease in the deformability of reinforced structures.

Laboratory studies of reinforced FRP and FRC composites of beams are highlighted in the works (Marzec et al., 2024; Mukhtar and Jawdhari, 2024; Panahai et al., 2021; Renić and KiŠičekk, 2021) gifts. Researchers have come to the conclusion that the moment of cracking is greater than beams with a higher percentage of reinforcement. Also in the work (Elakhras et al., 2021) the authors point out that in strengthened structures there are more cracks with their lower opening width compared to unspoiled beams.

In the work (Haroon et al., 2021), the effect of the percentage of reinforced concrete beam on its work after reinforcing FRP laminate was investigated. The FRP reinforcement ratio was the same for all experimental samples. The amplification was performed under load, immediately after the first cracks. It was found that the smaller the initial percentage of the beam reinforcement, the better the laminate is engaged. In samples with the ratio of 1/10 of the actual percentage of reinforcement of the beam to the maximum permissible relative deformations of the laminate at the time of destruction of the beam were 52–56 % of the boundary. In samples with the ratio of 1/2 of deformation of the laminate at the time of destruction of the beam were 32 % of the boundary.

Comparison of FRP and FRC composites is presented in the work (Yan et al., 2023). The test of reinforced concrete beams, enhanced by carbon canvases with the use of polymer and cement matrix. The results of the studies have shown that the clutch of the cement matrix with carbon fibers is significantly inferior to polymer. As a result, the effect of enhancement CFRC was only 50 % of the strengthening obtained when using CFRP. It is also noted that CFRC has not affected the rigidity of the beams. On the graphs of the load-proposition the angle of inclination of the unloading section of the unloaded beam is identical to the angle of inclination of the load area of the strengthened beam. It is also concluded that the history of loading does not affect deformability, but affects the load -bearing capacity as a whole. The beam loaded to the flow of working fittings, unloaded, reinforced and loaded to destruction showed an increase in the load-bearing capacity of 7 %. Her “Gemini” without the download history showed an increase in the load-bearing capacity of 14 %. The deflections of both beams were the same.

Most researchers who are engaged in reinforcing the bending elements with composite materials perform tests with short-term loads. Therefore, the durability of such structures is little studied. The tests of beams reinforced by GFRP by the composite for long -term load and atmospheric effects are described in the work (Saha et al., 2005). The beams reinforced in the stretched zone of fiberglass cloths were under the influence of constant load for six months. Some were in the laboratory, others were influenced by atmospheric phenomena. During this period, the deflections of the beams, which were affected, increased by 8–10 % compared to the deflections of those left in the laboratory. At the end of six months, the beams were brought to the destruction of short-term loads. Control samples that did not suffer long-term load and climatic conditions were destroyed due to the fragmentation of the compressed concrete zone. In the rest of the samples, the nature of the destruction varied to the FRP break, which indicated its wear. The composite deformations were not measured during the experiment, although it could give more information about the change in the stressful state over time.

Conclusions

· • the nature of the destruction of the strengthened samples indicate reliable anchoring of FRP composites in the body of concrete;

· • The measures of relative deformations of reinforcement materials built on NSM technology are measured by the marginal technology at the time of destruction of the strengthened sample. This indicates the effective use of the strength characteristics of NSM composite;

· • NSM technology is less time consuming compared to the external fixing of FRP composites;

· • There is no consensus among the researchers on the expense of the influence of composites fixed from the outside of the fracture on the rigidity of reinforced concrete structures;

· • it is necessary to examine the durability of structures attached from the outside by composites, especially if the matrix is an epoxide prone to creep and temperature;

· • the percentage of strengthened reinforced concrete structure affects the efficiency of laminate or canvases;

· • only a unit of the above researchers performed the strengthening of experimental samples under load, so the influence of the initial stress-deformed state on the work of the structure after amplification was practically not studied;

• Without anchorage, the composts are exfoliated from the outside of the structure faster than their strength is exhausted (unless the concrete zone of the concrete zone is exhausted) is exhausted).

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А. Р. Терешко[1], Я. З. Бліхарський[2]
Національний університет Львівська політехніка,
[1] кафедра будівельних конструкцій та мостів,
[2] кафедра автомобільних доріг та мостів

ПІДСИЛЕННЯ ЗАЛІЗОБЕТОННИХ БАЛОК FRC ТА FRP СИСТЕМАМИ – ОГЛЯД ЛІТЕРАТУРИ

У статті наведено огляд досліджень стосовно підсилення залізобетонних згинаних елементів системами фіброармувань на цементній основі (FRC) та фіброармувань полімерами (FRP). У наш час світова економіка, зокрема будівельна галузь, розвивається швидкими темпами. На ринку з’являються нові матеріали, засоби механізації, будівельна техніка. Завдяки цьому сучасні споруди вражають формами, масштабами та складністю конструкцій. Нині актуальним питанням у світі є застосування нових композитних матеріалів для підсилення будівельних конструкцій. До таких матеріалів належать неметалева арматура, ламінати, сітки та полотна на основі високоміцних волокон. Для прикладу міцність на розтяг вуглецевого волокна може в 10 разів перевищити міцність арматурної сталі. Власна вага волоконних матеріалів нехтовно мала. Якщо порівнювати випробування залізобетонних балок, підсилених вуглецевими полотнами із застосуванням полімерної та цементної матриці, то можна зробити висновок, що зчеплення цементної матриці з вуглецевими волокнами істотно поступається полімерній.У результаті ефект від підсилення FRC становив тільки 50 % від зміцнення, досягнутого із використанням CFRP. Виконавши аналіз літератури стосовно методів підсилення композитними матеріалами, можна зробити висновок, що у дослідників немає єдиної думки на рахунок впливу закріплених ззовні FRC композитів на жорсткість залізобетонних конструкцій. Необхідно глибше дослідити довговічність конструкцій, підсилених закріпленими ззовні композитами, особливо якщо матрицею є епоксид, схильний до повзучості та температурних впливів. Лише дехто зі згаданих вище дослідників виконував підсилення дослідних зразків під навантаженням, тому вплив початкового напружено-деформованого стану на роботу конструкції після підсилення практично не вивчений.

Ключові слова: підсилення, залізобетонні балки, композитні матеріали, FRC, FRP, згинані елементи.