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Analysis of the effectiveness of reinforcing bent reinforced concrete elements by extending the compressed zone: review of experience and prospects for application to beams with basalt-plastic reinforcement

Abstract. The global problem of reinforced concrete structure degradation caused by steel reinforcement corrosion has accelerated the transition of the construction industry toward non-metallic composite reinforcement, particularly basalt fiber-reinforced polymer (BFRP) bars. BFRP reinforcement offers significant advantages, including high tensile strength, complete corrosion resistance, and environmental sustainability. However, the absence of a yielding plateau and the relatively low modulus of elasticity of BFRP reinforcement require specific design approaches. To prevent sudden rupture and brittle structural failure, international standards recommend designing such beams as over-reinforced members, which ensures a safer failure mode through concrete crushing in the compression zone but results in increased serviceability deflections and limited utilization of the tensile strength potential of composite reinforcement. This study aims to summarize international experience in strengthening flexural reinforced concrete elements by increasing cross-sectional dimensions and to theoretically substantiate the feasibility of applying concrete overlays to BFRP-reinforced structures. A systematic analysis of previous studies demonstrated that increasing the compressed zone height improves structural stiffness, shifts the neutral axis upward, and increases load-bearing capacity by approximately 60–88%, while showing considerable potential for improving the performance of BFRP-reinforced beams.

Keywords: basalt-fibre-reinforced plastic reinforcement, reinforcement of reinforced concrete structures, section enlargement, concrete overlay, compression zone, stress-strain state

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Introduction.

The issue of the durability and reliability of existing buildings and structures is one of the main challenges facing modern construction. A significant proportion of reinforced concrete structures operating in aggressive environments suffer from premature degradation, the main cause of which is corrosion of the steel reinforcement [1, 2]. In this context, the use of fibre-reinforced polymer (FRP) materials for both reinforcing new structures and strengthening existing ones has become a recognised global trend [3].

Researchers are particularly interested in basalt fibre-reinforced polymer (BFRP) reinforcement, which is regarded as a promising alternative to traditional steel and glass fibre-reinforced polymer (GFRP) [2]. At the same time, the introduction of composite reinforcement into the design of flexural members faces a number of structural challenges. The physical and mechanical properties of FRP materials differ fundamentally from those of steel: they behave in a linear-elastic manner right up to the point of failure (they do not have a yield point) and possess a relatively low modulus of elasticity (for BFRP – approximately 45–55 GPa) [1, 3]. In accordance with the provisions of leading international standards (ACI 440.1R [4], CSA S806 [5]), to avoid sudden brittle failure of the beam due to reinforcement rupture, FRP flexural members must be designed as «over-reinforced». In this case, the loss of load-bearing capacity occurs due to the fragmentation of the concrete in the compressed zone, which provides the structure with a certain degree of pseudo ductility. At the same time, the need to ensure stiffness due to the low modulus of elasticity of BFRP necessitates an increase in the reinforcement area, which exacerbates the over-reinforcement effect. Consequently, the high tensile strength potential of composite reinforcement remains underutilised [1].

Traditional methods for strengthening flexural reinforced concrete elements involve bonding composite strips in the tension zone [2, 3]. Despite its proven effectiveness, this method is often difficult to implement in practice due to the lack of access to the bottom face of the structure [6]. An alternative solution is to reinforce the elements from above – by increasing the cross-section in the compression zone (concrete overlay) [7, 8]. The question of applying this method to structures reinforced with composite (in particular BFRP) reinforcement remains open, which is why this research is relevant.

Literature Review.

Unlike steel reinforcement, fibre-reinforced polymer (FRP) reinforcement exhibits linear-elastic behaviour right up to the point of failure. As noted in the studies by Alhoubi et al. [2], the tensile strength of BFRP reinforcement can exceed 1000 MPa, but its modulus of elasticity is four times lower than that of steel. Such a low modulus of elasticity leads to significantly greater deflections. In accordance with the requirements of ACI 440.1R and CSA S806 [4, 5], FRP flexural members must be designed as «over-reinforced» (1) i.e. the failure of the load-bearing capacity occurs due to the fragmentation of the concrete in the compressed zone. As reviews [1, 3] show, this provides a certain degree of pseudo-ductility to the structure, but leaves a significant safety margin of the FRP reinforcement itself unrealised.

$$\rho_f = p_{fb} \tag{1}$$

To increase the stiffness and load-bearing capacity of flexural members, an effective method is to extend the compressed zone. The mechanism involves increasing the effective depth of the cross-section (d) and the moment of inertia. To summarise global experience, data from experimental studies (Table 1) have been compiled, demonstrating the influence of different materials and reinforcement methods on the increase in load-bearing capacity.

Aim and Objectives.

The aim of this article is to analyse existing international experience with flexural reinforced concrete elements through cross-section enlargement and to provide a theoretical justification for the potential application of top-up reinforcement for structures reinforced with basalt fibre-reinforced polymer (BFRP) reinforcement.

To achieve this aim, the following objectives have been set:

1. To analyse the characteristics of the stress-strain state of beams with FRP reinforcement in the tension zone.
2. To summarise the mechanics of behaviour and evaluate the effectiveness of existing methods for strengthening beams by increasing the cross-section based on statistical data.
3. To justify the feasibility of increasing the compression zone and to identify under-researched aspects regarding the behaviour under load of beams reinforced with BFRP and strengthened by concrete overlay.

Materials and Methods.

The methodological basis of this article is an analysis of data from recent scientific publications on the behaviour of flexural members reinforced with composite reinforcement under load, as well as statistical data on effective methods for strengthening such structures by increasing the cross-sectional area. The analysis of design assumptions is based on the international standards of ACI and CSA.

Results and Discussion.

Analysis of the data presented in the histogram (Fig. 1) and Table 1 reveals a number of important patterns that confirm the specific behaviour of different reinforcement configurations.

Firstly, the highest increases in load-bearing capacity (over 140% in Al-Osta, 2017 [9] and 215% in Chen, 2021 [10]) are characteristic of U-shaped jackets. This is explained by the fact that the reinforcement wraps around the beam on three sides, creating a spatial embrace effect and simultaneously increasing both bending and shear strength. However, under real-world service conditions, access to the side faces of beams is often blocked by other adjacent structures, making this highly effective method practically impossible to implement. It is also worth noting that the record increase of 215% (Chen et al., 2021 [10]) was recorded for a beam in the control series that had pre-existing deep corrosion damage, making an absolute comparison of this percentage with other beams incorrect.

Secondly, the increase in load-bearing capacity when a concrete overlay is applied depends significantly on the strength of the bond. The abnormally low result (only 9.2%) in Genedy's (2014) study [6] is due to premature delamination of the reinforcement layer and a change in the failure mode. In contrast, according to , provided that the 'old' and 'new' concretes act as a monolith (as in the studies by Song et al., 2022 [7] and Yin et al., 2017 [11]), the top-up concrete is capable of increasing the load-bearing capacity by 60–88%, which is a good result for a strengthening method carried out from only one (upper) side.

Table 1 – Summary of experimental data on the reinforcement of reinforced concrete members with high-strength cementitious materials [6…20]

Authors (year)	Base structure	Reinforcement configuration	Overlay material	Overlay thickness, mm	Failure mode	Increase in load-bearing capacity, %
Song et al. (2022)	RC beam with rectangular cross-section (re-reinforced)	Concrete overlay on top	UHPC	30–70	Concrete spalling in the compression zone (without delamination)	88,1
Prem et al. (2016)	RC beam with rectangular cross-section (normally reinforced)	Concrete overlay on top and extension from below	UHPC	25–50		15–35
Al-Osta et al. (2017)		Bottom extension	UHPC	30	Crushing of concrete in the compressed zone with delamination of the reinforcement layer	64,0
Al-Osta et al. (2017)		U-shaped jacket	UHPC	30	Concrete spalling in the compression zone (without delamination)	140,0
Genedy (2014)	RC T-section beam (normally reinforced)	Concrete overlay	UHPC+ +CFRP	51	Failure along the inclined section with delamination of the reinforcement layer	9,2
Chen et al. (2021)	RC beam with rectangular cross-section (with corrosion-damaged reinforcement)	UHPC + +CFRP mesh	UHPC + +FRP mesh	30	Combined failure (along the inclined section and fragmentation of the compressed zone)	215,0*
Garg et al. (2019)	Rectangular section ZB beam (with cracks in the tension zone)	U-shaped jacket	UHPC	30–50	Failure along an oblique section with delamination of the reinforcement layer	24,4–28,4
Yin et al. (2017)	RC slab with solid cross section (normally reinforced)	Concrete overlay	UHPC	25–50	Concrete spalling in the compression zone (without delamination)	30,0-60,0

Notes: * – the increase is given relative to the control series beam, which had previous deep corrosion damage; UHPC – ultra-high-performance concrete; ECC – fine-grained cement composites; UHPFRC – ultra-high-performance fibre-reinforced concrete; CFRP – carbon fibre-reinforced polymer

Continuation of Table 1 – Summary of experimental data on the reinforcement of reinforced concrete members with high-strength cementitious materials [6…20]

Authors (year)	Base structure	Reinforcement configuration	Overlay material	Overlay thickness, mm	Failure mode	Increase in load-bearing capacity, %
Lampropoulos et al. (2016)	RC T-section beam (normally reinforced)	U-shaped jacket	UHPFRC	40	Concrete spalling in the compression zone (without delamination)	50.0
Zheng et al. (2016)		Bottom-up reinforcement	ECC + +BFRP mesh	20–40	Failure of tensile composite reinforcement with delamination of the reinforcement layer	35–85
Nadir et al. (2023)		Lateral reinforcement	UHPC + + FRP	10–40	Failure along the inclined section (without delamination)	40–70
Safaa et al. (2025) [Review]	RC beams with rectangular cross-sections (statistical sample)	Concrete cap on top; reinforcement from below and above; U-shaped formwork	UHPC	10–70	Concrete spalling, failure along the inclined section	5–188

Notes: * – the increase is given relative to the control series beam, which had previous deep corrosion damage; UHPC – ultra-high-performance concrete; ECC – fine-grained cement composites; UHPFRC – ultra-high-performance fibre-reinforced concrete; CFRP – carbon fibre-reinforced polymer

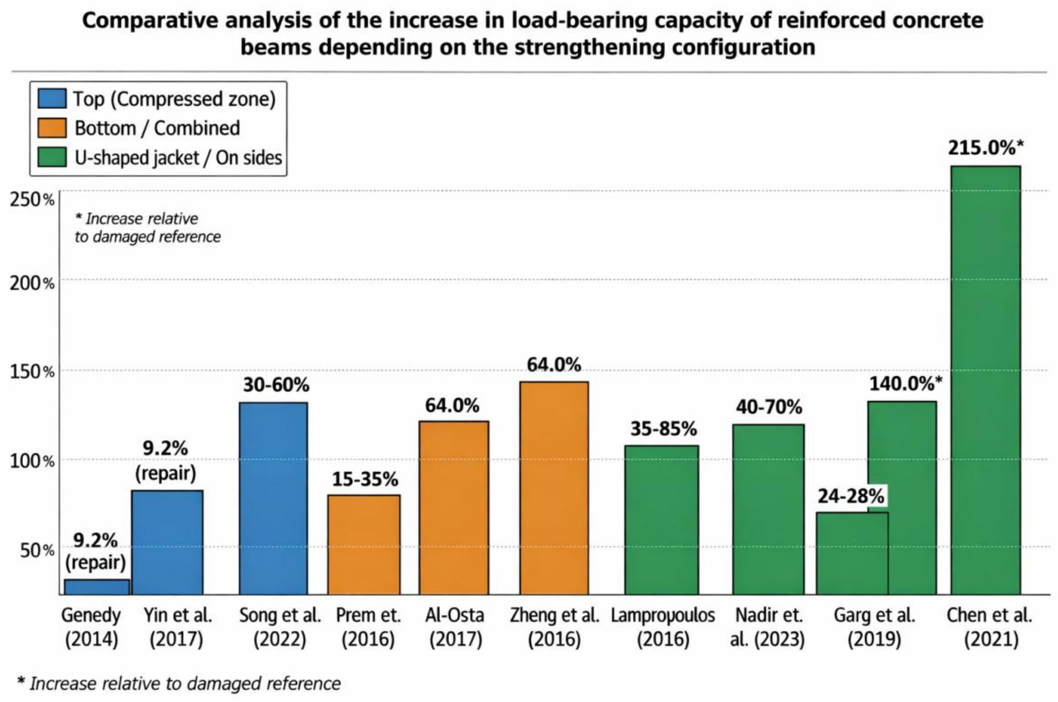

Figure 1 – Increase in the load-bearing capacity of beams depending on the type of overlay

This is precisely why the focus on top-up reinforcement (concrete overlay) remains the most technically sound approach for real-world structures, particularly for beams with composite reinforcement, which primarily require an increase in the area of the compressed zone.

Analysis of statistical data (see Table 1) shows that the method of increasing the compressed zone effectively enhances the load-bearing capacity of traditional reinforced concrete beams. Applying this approach to members reinforced with basalt fibre-reinforced polymer (BFRP) reinforcement is a logical step towards addressing their main structural shortcoming – premature concrete spalling in the compression zone due to the member's low flexural stiffness following crack formation.

By considering the combined action of BFRP reinforcement in the tension zone and an additional layer of concrete (overlay) in the compression zone, a significant optimisation of the stress-strain state of the entire cross-section can be observed. According to computational models (e.g., the non-linear deformation model ACI 440.1R), the installation of the concrete cover fundamentally alters the distribution of deformations along the height of the cross-section (Fig. 2).

As shown in the diagram (Fig. 2), increasing the cross-section from above allows:

1. Increase the effective working height of the cross-section (d) and the area of the compressed zone, which significantly increases the concrete's resistance to compressive stresses and delays the moment of its failure.

2. Shift the neutral axis upwards, which increases the arm of the internal force pair (z) and, as a result, increases the bending moment that the cross-section can withstand.

3. Significantly increase the moment of inertia of the cross-section, which is critical for compensating for the low modulus of elasticity of BFRP reinforcement and limiting service deflections.

4. To ensure conditions under which the basalt-fibre-reinforced plastic reinforcement in the tension zone can achieve significantly higher values of relative strains and stresses prior to the failure of the compressed concrete. This ensures a more rational utilisation of the composite material's strength characteristics.

Despite the obvious theoretical advantages of such a comprehensive approach, the analysis conducted has shown that, to date, there is virtually no experimental data on the behaviour under load of beams, reinforced with BFRP and strengthened by a concrete overlay in the compression zone. Most modern studies focus either on conventional reinforced concrete beams with a concrete cover, or on FRP beams reinforced with composite strips exclusively in the tension zone. The lack of empirical data prevents a reliable assessment of the actual nature of force redistribution, changes in crack width, and the real increase in load-bearing capacity. This indicates that this issue has not been sufficiently studied and presents a pressing scientific challenge for further research.

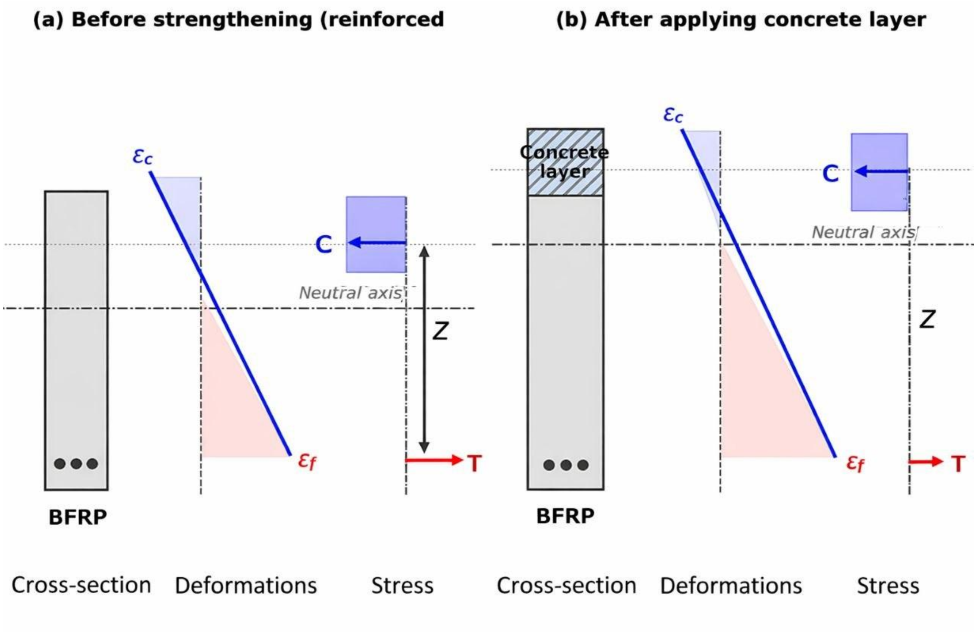

Figure 2 – Change in the stress-strain state in the normal section of a beam with BFRP reinforcement: (a) before reinforcement; (b) after installation of a top-up slab in the compression zone

Conclusions.

1. The use of basalt fibre-reinforced polymer (BFRP) is an effective solution to the problem of corrosion. However, the absence of a yield point and the low modulus of elasticity of BFRP necessitate the design of elements as 'over-reinforced' (to ensure failure occurs in the concrete rather than through reinforcement rupture). This leads to significant service deflections and prevents the full realisation of the tensile strength potential of composite reinforcement.

2. The method of increasing the compressed zone of the cross-section (by adding a concrete overlay) has proven highly effective (providing an increase in load bearing capacity of between 60% and 88%) for traditional reinforced concrete beams. It allows the effective depth of the cross-section to be increased, its stiffness to be improved, and the neutral axis to be shifted.

3. An analysis of the current literature has revealed a virtual absence of experimental data on the strengthening of beams reinforced with BFRP using concrete caps. At the same time, it has been theoretically demonstrated that increasing the height of the compression zone allows the neutral axis to be shifted upwards and prevents premature concrete spalling. This creates conditions under which the composite reinforcement in the tension zone is capable of withstanding greater deformations and stresses, which significantly improves the performance of the entire cross-section.

4. The need for further experimental studies has been demonstrated to address the insufficient understanding of the characteristics of the combined behaviour of BFRP reinforcement in the tension zone of a beam and the concrete-reinforced compression zone under load.

Areas for further research.

Given the insufficient level of research into this issue and the lack of experimental data on the behaviour of beams reinforced with BFRP and concrete cover, a logical step is to conduct comprehensive experimental tests.

The aim of the forthcoming experiments will be to fabricate and test beams reinforced with BFRP, with the compressed zone reinforced by a concrete overlay. Such experimental tests on reinforced specimens will allow an assessment of the increase in load-bearing capacity, changes in bending stiffness, and the effect of the concrete cover on the ultimate failure mechanism, compared with unreinforced beams from the control series.

References

1. Tran, H., & Nguyen-Thoi, T. (2025). Flexural behavior of beams reinforced with FRP bars: Test database, design guideline assessment, and reliability evaluation. *Buildings, 15*(18), 3373. https://doi.org/10.3390/buildings15183373

2. Alhoubi, Y., Mahaini, Z., & Abed, F. (2022). The flexural performance of BFRP reinforced UHPC beams compared to steel and GFRP-reinforced beams. *Sustainability, 14*(22), 15139. https://doi.org/10.3390/su142215139

3. Ebrahimzadeh, S. (2023). Review of affected parameters on flexural behavior of hollow concrete beams reinforced by steel/GFRP rebars. *International Journal of Structural and Construction Engineering, 17*(7), 298–313.

4. ACI Committee 440. (2015). *Guide for the design and construction of structural concrete reinforced with fiber-reinforced polymer (FRP) bars (ACI 440.1R-15)*. American Concrete Institute.

5. Canadian Standards Association. (2012). *Design and construction of building structures with fibre reinforced polymers (CAN/CSA-S806-12)*. Canadian Standards Association.

6. Genedy, M. (2014). *A new CFRP-UHPC system for strengthening reinforced concrete T-beams* (Master's thesis, University of New Mexico).

7. Song, Y., Yao, S., & Liu, L. (2022). Flexural reinforcement of over-reinforced beam by ultrahigh performance concrete layer. *Mathematical Problems in Engineering, 2022,* 9171300. https://doi.org/10.1155/2022/9171300

8. Safaa, A., & Kadhim, M. M. A. (2025). State of research on shear strengthening/repairing of RC beams with ultra-high-performance concrete (UHPC). *Civil and Environmental Engineering, 21*(2), 1326–1347. https://doi.org/10.2478/cee-2025-0097

9. Al-Osta, M. A., Isa, M. N., Baluch, M. H., & Rahman, M. K. (2017). Flexural behavior of reinforced concrete beams strengthened with ultra-high performance fiber reinforced concrete. *Construction and Building Materials, 134,* 279–296. https://doi.org/10.1016/j.conbuildmat.2016.12.094

1. Tran, H., & Nguyen-Thoi, T. (2025). Flexural behavior of beams reinforced with FRP bars: Test database, design guideline assessment, and reliability evaluation. *Buildings, 15*(18), 3373. https://doi.org/10.3390/buildings15183373

2. Alhoubi, Y., Mahaini, Z., & Abed, F. (2022). The flexural performance of BFRP reinforced UHPC beams compared to steel and GFRP-reinforced beams. *Sustainability, 14*(22), 15139. https://doi.org/10.3390/su142215139

3. Ebrahimzadeh, S. (2023). Review of affected parameters on flexural behavior of hollow concrete beams reinforced by steel/GFRP rebars. *International Journal of Structural and Construction Engineering, 17*(7), 298–313.

4. ACI Committee 440. (2015). *Guide for the design and construction of structural concrete reinforced with fiber-reinforced polymer (FRP) bars (ACI 440.1R-15)*. American Concrete Institute.

5. Canadian Standards Association. (2012). *Design and construction of building structures with fibre reinforced polymers (CAN/CSA-S806-12)*. Canadian Standards Association.

6. Genedy, M. (2014). *A new CFRP-UHPC system for strengthening reinforced concrete T-beams* (Master's thesis, University of New Mexico).

7. Song, Y., Yao, S., & Liu, L. (2022). Flexural reinforcement of over-reinforced beam by ultrahigh performance concrete layer. *Mathematical Problems in Engineering, 2022,* 9171300. https://doi.org/10.1155/2022/9171300

8. Safaa, A., & Kadhim, M. M. A. (2025). State of research on shear strengthening/repairing of RC beams with ultra-high-performance concrete (UHPC). *Civil and Environmental Engineering, 21*(2), 1326–1347. https://doi.org/10.2478/cee-2025-0097

9. Al-Osta, M. A., Isa, M. N., Baluch, M. H., & Rahman, M. K. (2017). Flexural behavior of reinforced concrete beams strengthened with ultra-high performance fiber reinforced concrete. *Construction and Building Materials, 134,* 279–296. https://doi.org/10.1016/j.conbuildmat.2016.12.094

10. Chen, C., Cai, H., & Cheng, L. (2021). Shear strengthening of corroded RC beams using UHPC–FRP composites. *Journal of Bridge Engineering, 26*(1), 04020111. https://doi.org/10.1061/(ASCE)BE.1943-5592.0001653

11. Yin, H., Teo, W., & Shirai, K. (2017). Experimental investigation on the behaviour of reinforced concrete slabs strengthened with ultra-high performance concrete. *Construction and Building Materials, 155*, 463–474. https://doi.org/10.1016/j.conbuildmat.2017.08.077

12. Prem, P. R., & Murthy, R. (2016). Acoustic emission and flexural behaviour of RC beams strengthened with UHPC overlay. *Construction and Building Materials, 123*, 481–492. https://doi.org/10.1016/j.conbuildmat.2016.07.033

13. Garg, V., Bansal, P. P., & Sharma, R. (2019). Retrofitting of shear-deficient RC beams using UHPFRC. *Iranian Journal of Science and Technology, Transactions of Civil Engineering, 43*, 419–428. https://doi.org/10.1007/s40996-019-00241-7

14. Lampropoulos, A. P., Paschalis, S. A., Tsioulou, O. T., & Dritsos, S. E. (2016). Strengthening of reinforced concrete beams using ultra-high performance fibre-reinforced concrete (UHPFRC). *Engineering Structures, 106*, 370–384. https://doi.org/10.1016/j.engstruct.2015.10.042

15. Zheng, Y.-Z., Wang, W.-W., & Brigham, J. C. (2016). Flexural behaviour of reinforced concrete beams strengthened with a composite reinforcement layer: BFRP grid and ECC. *Construction and Building Materials, 115*, 424–437. https://doi.org/10.1016/j.conbuildmat.2016.04.038

16. Nadir, W., Kadhim, M. M. A., Jawdhari, A., Fam, A., & Majdi, A. (2023). RC beams strengthened in shear with FRP-reinforced UHPC overlay: An experimental and numerical study. *Structures, 53*, 693–715. https://doi.org/10.1016/j.istruc.2023.04.117

17. Karpiuk, V., Tselikova, A., Khudobych, A., Karpiuk, I., & Kostyuk, A. (2020). Study of strength, deformability property and crack resistance of beams with BFRP. *Eastern-European Journal of Enterprise Technologies, 4*(7(106)), 24–33. https://doi.org/10.15587/1729-4061.2020.209378

18. Mokhtari, S., & Hassan, M. (2024). Performance of bond between old and new concrete layers: The effective factors, durability and measurement tests—A review. *Infrastructures, 9*(10), 171. https://doi.org/10.3390/infrastructures9100171

19. Mahmoud, M., Eladawy, M., Ibrahim, B., & Benmokrane, B. (2024). Interface shear capacity of basalt FRP-reinforced composite precast concrete girders supporting cast-in-place bridge-deck slabs. *Journal of Bridge Engineering, 29*(12). https://doi.org/10.1061/JBENF2.BEENG-6806

20. Duan, S.-J., Feng, R.-M., Yuan, X.-Y., Song, L.-T., Tong, G.-S., & Tong, J.-Z. (2025). A review on research advances and applications of basalt fiber-reinforced polymer in the construction industry. *Buildings, 15*(2), 181. https://doi.org/10.3390/buildings15020181

10. Chen, C., Cai, H., & Cheng, L. (2021). Shear strengthening of corroded RC beams using UHPC–FRP composites. *Journal of Bridge Engineering, 26*(1), 04020111. https://doi.org/10.1061/(ASCE)BE.1943-5592.0001653

11. Yin, H., Teo, W., & Shirai, K. (2017). Experimental investigation on the behaviour of reinforced concrete slabs strengthened with ultra-high performance concrete. *Construction and Building Materials, 155*, 463–474. https://doi.org/10.1016/j.conbuildmat.2017.08.077

12. Prem, P. R., & Murthy, R. (2016). Acoustic emission and flexural behaviour of RC beams strengthened with UHPC overlay. *Construction and Building Materials, 123*, 481–492. https://doi.org/10.1016/j.conbuildmat.2016.07.033

13. Garg, V., Bansal, P. P., & Sharma, R. (2019). Retrofitting of shear-deficient RC beams using UHPFRC. *Iranian Journal of Science and Technology, Transactions of Civil Engineering, 43*, 419–428. https://doi.org/10.1007/s40996-019-00241-7

14. Lampropoulos, A. P., Paschalis, S. A., Tsioulou, O. T., & Dritsos, S. E. (2016). Strengthening of reinforced concrete beams using ultra-high performance fibre-reinforced concrete (UHPFRC). *Engineering Structures, 106*, 370–384. https://doi.org/10.1016/j.engstruct.2015.10.042

15. Zheng, Y.-Z., Wang, W.-W., & Brigham, J. C. (2016). Flexural behaviour of reinforced concrete beams strengthened with a composite reinforcement layer: BFRP grid and ECC. *Construction and Building Materials, 115*, 424–437. https://doi.org/10.1016/j.conbuildmat.2016.04.038

16. Nadir, W., Kadhim, M. M. A., Jawdhari, A., Fam, A., & Majdi, A. (2023). RC beams strengthened in shear with FRP-reinforced UHPC overlay: An experimental and numerical study. *Structures, 53*, 693–715. https://doi.org/10.1016/j.istruc.2023.04.117

17. Karpiuk, V., Tselikova, A., Khudobych, A., Karpiuk, I., & Kostyuk, A. (2020). Study of strength, deformability property and crack resistance of beams with BFRP. *Eastern-European Journal of Enterprise Technologies, 4*(7(106)), 24–33. https://doi.org/10.15587/1729-4061.2020.209378

18. Mokhtari, S., & Hassan, M. (2024). Performance of bond between old and new concrete layers: The effective factors, durability and measurement tests—A review. *Infrastructures, 9*(10), 171. https://doi.org/10.3390/infrastructures9100171

19. Mahmoud, M., Eladawy, M., Ibrahim, B., & Benmokrane, B. (2024). Interface shear capacity of basalt FRP-reinforced composite precast concrete girders supporting cast-in-place bridge-deck slabs. *Journal of Bridge Engineering, 29*(12). https://doi.org/10.1061/JBENF2.BEENG-6806

20. Duan, S.-J., Feng, R.-M., Yuan, X.-Y., Song, L.-T., Tong, G.-S., & Tong, J.-Z. (2025). A review on research advances and applications of basalt fiber-reinforced polymer in the construction industry. *Buildings, 15*(2), 181. https://doi.org/10.3390/buildings15020181

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Аналіз ефективності підсилення згинаних залізобетонних елементів нарощуванням стиснутої зони: огляд досвіду та перспективи застосування для балок з базальтопластиковою арматурою

Аннотація. Глобальна проблема руйнування залізобетонних конструкцій, спричинена корозією сталевої арматури, прискорила перехід будівельної галузі на неметалеву композитну арматуру, зокрема арматурні стрижні з полімеру, армованого базальтовим волокном (BFRP). Арматура BFRP має значні переваги, зокрема високу міцність на розтяг, повну корозійну стійкість та екологічну стійкість. Однак відсутність межі плинності та відносно низький модуль пружності арматури BFRP вимагають застосування специфічних підходів до проектування. Для запобігання раптовому розриву та крихкому руйнуванню конструкції міжнародні стандарти рекомендують проектувати такі балки як надміцні елементи, що забезпечує більш безпечний режим руйнування за рахунок руйнування бетону в зоні стиснення, але призводить до збільшення прогинів при експлуатації та обмеженого використання потенціалу міцності на розтяг композитної арматури. Мета даного дослідження — узагальнити міжнародний досвід зміцнення залізобетонних елементів, що піддаються згину, шляхом збільшення розмірів поперечного перерізу, а також теоретично обґрунтувати доцільність застосування бетонних накладок на конструкції, армовані BFRP. Систематичний аналіз попередніх досліджень показав, що збільшення висоти зони стиснення покращує жорсткість конструкції, зміщує нейтральну вісь вгору та збільшує несучу здатність приблизно на 60–88%, демонструючи при цьому значний потенціал для покращення характеристик балок, армованих BFRP.

Ключові слова: базальтопластикова арматура, BFRP, підсилення залізобетонних конструкцій, нарощування перерізу, набетонка, стиснута зона, напружено-деформований стан

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