

A Review on using GFRP as Shear Connectors in Shear Friction Application in Concrete Structures

Afyaa Saad Niema

Prof. Dr. Hussam Ali Mohammed*

afyaa.saad.tcm.30@student.atu.edu.iq

com.hus@atu.edu.iq

*Al-Furat Al-Awsat Technical University, Al-Mussaib Technical Collage-Building and Construction Department

Abstract:

It is well established that reinforcements can resist shear forces across potentially sliding surfaces in order to resist loads and deformation. In the shear friction hypothesis, it is assumed that the reinforcement will yield before reaching the shear friction capacity. Because GFRP has low elasticity and is a malleable material, it is not a suitable choice for use as shear friction reinforcement. A number of studies from the latest literature are listed and discussed. Some results revealed that the failure of the dowel mechanism in GFRP specimens was largely determined by the width and slippage of cracks, while other results showed that GFRP can act as shear connectors and that its general behavior depends on the concrete strength and reinforcement ratio. . The results are final.

Keywords: GFRP, friction shear, total interlock, reinforced concrete, shear capacity, shear deformation.

استخدام البوليمر المقوى بالألياف الزجاجية موصلات القص في تطبيقات احتكاك القص في المنشآت الخرسانية

د. حسام علي محمد

أفياء سعد نعمة

خلاصة :

من الثابت أن التعزيزات يمكن أن تقاوم قوى القص عبر الأسطح التي يحتمل أن تنزلق من أجل مقاومة الأحمال والتشوه. في فرضية احتكاك القص، من المفترض أن التسليح سوف يستسلم قبل الوصول إلى قدرة احتكاك القص. نظرًا لأن البوليمر المقوى بالألياف الزجاجية يتمتع بمرونة منخفضة وهو مادة قابلة للطرق، فهو ليس خيارًا مناسبًا للاستخدام كتعزيز احتكاك القص. يتم سرد ومناقشة عدد من الدراسات من أحدث الأدبيات. أظهرت بعض النتائج أن فشل آلية الوتد في نماذج البوليمر المقوى بالألياف الزجاجية تم تحديده إلى حد كبير من خلال عرض الشقوق وانزلاقها، بينما أظهرت نتائج أخرى أن البوليمر المقوى بالألياف الزجاجية يمكن أن يعمل كوصلات قص وأن سلوكه العام يعتمد على قوة الخرسانة ونسبة التسليح. تم في هذا العمل تقديم ملخص للأبحاث السابقة حول فعالية تقوية الألياف الزجاجية البوليمر المقوى بالألياف الزجاجية كتعزيز احتكاك القص في الهياكل الخرسانية المركبة. أظهرت نتائج الأدبيات وجود تباين ملحوظ في سلوك القص، وخاصة في انزلاق القص حيث تم العثور على مقاومة القص القصوى. بالإضافة إلى ذلك، تعمل الركابات المغلقة البوليمر المقوى بالألياف الزجاجية بشكل ممتاز وتنافسي عند استخدامها كتعزيز احتكاك القص بالمقارنة مع الفولاذ. ولكن نظرًا للقيود المفروضة على التجارب، لا تزال هناك حاجة إلى مزيد من البحث للنظر في العوامل الإضافية التي قد يكون لها تأثير على أداء البوليمر المقوى بالألياف الزجاجية.



Introduction:

The two main components of reinforced concrete (RC) elements are typically steel reinforcement and concrete. Because the concrete is weak in tension, reinforcing is usually employed to strengthen the weakness by creating the right link between the concrete and the steel. Additionally, the alkalinity of the concrete serves to shield the reinforcement from corrosion by encasing it in the concrete. Nevertheless, under harsh climatic circumstances, particularly during the winter, when de-icing salt is utilized, the steel might corrode. To stop the reinforcement from corroding, epoxy coated reinforcement is frequently used in buildings that are exposed to harsh climatic conditions, like parking garages, bridges, and maritime structures. In the meanwhile, Bianca et al. (2005) state that this protective method is still insufficient to prevent corrosion, and the repair and maintenance are required, and maintenance cost is high to extend the service life of the structures.

In areas susceptible to extreme environments, non-corrosive materials like fiber-reinforced polymer (FRP) have been chosen as an alternative to steel. When using FRP as a reinforcement in constructions, there are important differences between it and steel that must be taken into account. For example, whereas FRP is a brittle material with exclusively elastic behavior, steel is a ductile and elastic-plastic substance. Additionally, The Young's modulus of steel in an elastic region remains mostly constant at 200,000 MPa, while the Young's modulus of steel in fiber-reinforced polymer (FRP) will change dramatically depending on the fiber type and density. The flexural and shear strengths in addition to deformation capacities are greatly affected by this difference in material properties (Oehlers and Seracino 2004; Oehlers et al. 2008; Muhammad Ali et al. 2008).

. Glass fiber-reinforced polymers, or GFRP, have shown beneficial in areas that experience shear and flexural loads during the past few decades (El-Sayed et al., 2005). But because GFRP reinforcements are isotropic, their characteristics are largely dependent on the orientation of the rebar, and their high tensile strength is only evident in the direction of the reinforcing fibers. As such, this isotropic behavior has a major impact on the shear strength and dowel action of GFRP bars when employed for shear applications .Because GFRP exhibits linear-elastic behavior up to failure and does not go through a ductile phase in the form of a yielding plateau prior to the brittle rupture, GFRP bars are comparatively weak in shear. The low shear and compressive strengths of GFRP result in a lower transverse strength, despite the material's widespread use due to its lower cost and higher tensile strain at failure. The GFRP's application as shear friction reinforcement is compromised by its weakness in shear. It is currently unclear how widely GFRP may be used in place of steel when used as a shear friction

reinforcement at cold joints. In this paper, research conducted in this area is listed and discussed and future research is suggested to extent the current literature.

Literature Review:

As previously mentioned, not much research has been done on the suitability of using GFRP across a cold joint to apply shear friction. Numerous factors, including Adhesion/cohesion, cross-linking, friction, and wedge action are involved in resisting shear along an interface between UHPC concrete or cast at different times. Chemical bonding and mechanical interlocking of particles often work together to create intermolecular adhesion of fresh and old concrete. The bond disappears and the load passes through the specimen by means of friction and mechanical interlocking

when the load reaches its maximum. Compression, which increases friction, is usually generated at the interface by An external or in-promoting force (Randall 2013).

Figure 1 shows the theoretical mechanism of friction for shear. Shear displacement (shear slip) Δ comes from the shear force on the length of the sliding plane when the shear force (v) is applied which causes the shear stress (τ_n) on the length of the sliding plane. Which causes total engagement in the expansion sliding plane with slip shear. Where the force is generated by tension in the reinforcement and as a result of sliding, the reinforcement increases in relation to the fracture face as a result of the widening of the sliding plane. Concrete exhibits a distributed normal stress, which is the compressive force equal and opposite to the tensile force. A sliding plane is restricted in the resulting stress and pressure, preventing it from sliding

and widening and permits shear forces or

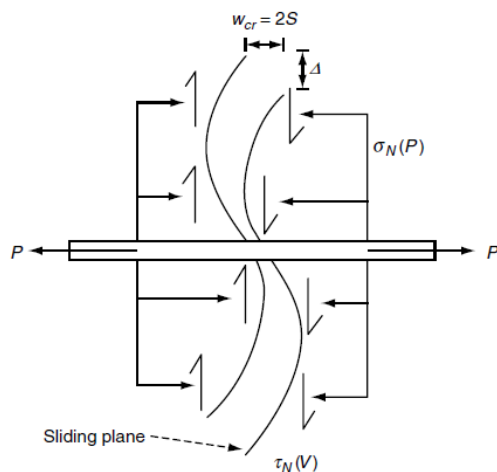


Figure 1. The shear-friction mechanism (Lucas et al. 2012)

The effectiveness of GFRP rebar as shear friction reinforcement was examined in a few research. Lucas et al. (2012) used numerical analysis to examine



the FRP's effectiveness as shear friction reinforcement. The findings showed That the ratio of reinforcement, Young's modulus, and strength of the reinforcement bond all had a major impact on how quickly forces developed to constrain the sliding plane and, thus, how well the specimen could withstand shear pressures. in addition to the shear slip where the maximum shear resistance is found. Significant variations were observed in the shear behavior when comparing the FRP results with the steel behavior, especially in the shear slip where the greatest shear resistance was observed. This indicates that it is invalid to assume that various reinforcing elements will simultaneously achieve peak shear resistance. It's interesting to note that, when compared to steel reinforced concrete, the linear-elastic behavior of fiber-reinforced polymer (FRP) does not negatively impact the ductility of the shear behavior. This is true even though the shear behaviors of the two materials differ.

Connor and Kim (2016) looked at the GFRP's effectiveness as reinforcement against shear friction. This investigation was centered around four key parameters: the orientation angle of the reinforcing bars spanning the crack plane, the width, the slip, and the crack parameters. Nine push-off specimens using GFRP and traditional reinforcements were created with varying steel orientations (45, 90, and 135 degrees). The findings showed that dowel action mechanism failure was noted in GFRP specimens and that fracture width and slip had a significant impact on this mechanism. Additionally, it was discovered that as crack and slip gradually grow, GFRP shear strength increases continuously. Conversely, steel quickly acquired strength.

Aljada (2023) recently looked into how well GFRP performed as shear friction in applications using concrete composite elements. Twenty-six large-scale push-off specimens were built and tested in total. Of these specimens, twenty-one were strengthened using GFRP connectors, while the remaining specimens, which served as control specimens, were reinforced using steel connectors. The purpose of the study was to determine how the overall friction shear behavior was affected by the following factors: Concrete strength (35 and 70 MPa), in case of surface shear (cold joints for rough, cold joint for non-rough, homogeneous),

Reinforcement shape (Z-bars or closed stirrups), ratio (0.17, 0.24, 0.33, 0.36, 0.42, 0.48%), and type (steel or GFRP). The test findings showed that GFRP can be utilized as shear connectors and that the strength of the concrete and the reinforcement ratio affect overall behavior. Furthermore, compared to Z-shaped bars, closed stirrups offered superior clamping stresses, according to the data. Furthermore, compared to their cold-jointed counterpart specimens, the monolithic shear plane condition produced substantially larger capabilities.

Conclusions:



A summary of earlier research on the effectiveness of glass fiber reinforcement (GFRP) as shear friction reinforcement in concrete composite structures was provided in this work. The literature's findings showed a notable variation in the shear behavior, especially in the shear slip where the maximal shear resistance was found. Additionally, GFRP closed stirrups function excellently and competitively when used as shear friction reinforcement in comparison to steel. But given the limitations of the trials, additional research is still required to look into additional factors that may have an impact on the GFRP's performance.

References

- Aljada, B. (2023). Performance of GFRP reinforcement as friction shear connectors in concrete composite elements. Master thesis.
- El-Sayed, A., El-Salakawy, E., and Benmokrane, B. (2005). "Shear Strength of One-Way Concrete Slabs Reinforced with Fiber-Reinforced Polymer Composite Bars". *Journal of Composites for Construction*, 9(2), 147–157. [https://doi.org/10.1061/\(ASCE\)1090-0268\(2005\)9:2\(147\)](https://doi.org/10.1061/(ASCE)1090-0268(2005)9:2(147)).
- Mohamed Ali, M.S., Oehlers, D.J. and Griffith, M.C. (2008). "Simulation of plastic hinges in FRP plated RC beams", *Journal of Composites for Construction*, ASCE, Vol. 12, No. 6, pp. 617–625.
- Oehlers, D.J. and Seracino, R. (2004). *Design of FRP and Steel Plated RC Structures: Retrofitting Beams and Slabs for Strength, Stiffness and Ductility*, Elsevier Science.
- Oehlers, D.J., Haskett, M., Wu, C. and Seracino, R. (2008). "Embedding NSM FRP plates for improved IC debonding resistance", *Journal of Composites for Construction*, ASCE, Vol. 12, No. 6, pp. 635–642.
- Pianca, F., Schell, H., & Cautillo, G. (2005). "The performance of epoxy coated reinforcement": Experience of the Ontario ministry of transportation. *International Journal of Materials and Product Technology*, 23(3–4), 286–308. <https://doi.org/10.1504/IJMPT.2005.007732>.
- Randl, N. (2013). Design recommendations for interface shear transfer in fib Model Code 2010. *Structural Concrete*, 14(3), 230-241.