ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/360499488

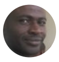
Performance of SFRC with varying surface texture and moisture conditions in overlay concrete

Article *in* Journal of Environmental Science · May 2022

CITATIONS
0

READS
41

6 authors, including:



Ezekiel Babatunde Ogunbode
Federal University of Technology Minna
66 PUBLICATIONS **302** CITATIONS
SEE PROFILE

Adamu malami Bala
Federal Polytechnic Bauchi
3 PUBLICATIONS **4** CITATIONS
SEE PROFILE

Pontip Stephen Nimlyat
University of Jos
29 PUBLICATIONS **211** CITATIONS
SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Project Durability performance of green concrete composite consisting steel fibrous and rice husk ash View project

Project environmental sustainability View project

All content following this page was uploaded by Pontip Stephen Nimlyat on 10 May 2022.

The user has requested enhancement of the downloaded file.

Performance of SFRC with varying surface texture and moisture conditions in overlay concrete

[1]Ezekiel Babatunde OGUNBODE*, [2]Tetengi Alhaji YAHAYA, [3]Adamu BALA, [4]Joseph Aaron ANGO, [5]Pontip Stephen NIMLYAT, [1]Abdullahi Taiwo RAJI

[1]Department of Building, School of Environmental Technology. Federal University of Technology Minna. Niger State. Nigeria.
[2]Department of Building Technology, Federal Polytechnic Bida. Niger State. Nigeria.
[3]Department of Building Technology, Niger state Polytechnic, Zungeru. Niger State. Nigeria.
[4]Department of Architecture, Ahmadu Bello University, Zaria. Kaduna State. Nigeria.
[5]Department of Architecture, University of Jos. Plateau State. Nigeria.
[1]Author correspondance email: ezekiel@futminna.edu.ng

Abstract

This paper presents a study carried out to assess the interfacial bond strength behaviour of Steel Fibre Reinforced Concrete (SFRC) and Plain Concrete (PC) substrate. Steel wire fibre was incorporated as reinforcing agent in the Fibre Reinforced Concrete (FRC) to determine its effect on bonding strength. To better understand the bonding mechanism at the interface, overlaid prism specimens were fabricated with three moisture conditions (air dry, saturated surface dry (SSD), and wet). Five different fibre volume fractions of 0%, 0.5%, 1.0%, 1.5%, and 2.0% were prepared and used as the overlay concrete on three different surface textures (As Cast surface, Grooved surface, and Wire brush surface). It was observed that the bond strength of the FRC samples at all moisture conditions is higher than that of the control specimens. The bond strength of FRC with 1% fibre volume was observed to have consequently improved. This improvement is influenced through grooved surface texture at SSD moisture condition of the old concrete surface. Steel fibre of 1.0% produced sample with the highest interfacial bond strength of 15.19N/mm^2. It was observed that, the bond strength of FRC was more than the control specimen. Based on American Concrete Institute (ACI) Concrete Repair Guideline, the roughened surface textures used in this study were able to meet the minimum bond strength it specified. Considering all inferences and appraisals from this research, 1% steel FRC, grooved surface treatment type and SSD surface condition are recommended in the production of retrofitting/repair concretes with the sole aim of achieving an enhanced interfacial shear bond strength.

Keywords: Steel fibre reinforced concrete, Plain concrete, concrete overlay, bonding strength, slant shear strength

1. Introduction

Most countries' concrete infrastructures are rapidly losing serviceability and safety, as well as suffering damage from the rising and unexpected live loads to which they are exposed and subjected in service (Ogunbode, Yatim, Affendi, Aziz, Yunus, & Hamid, 2019; Shin & Wan, 2010; Banthia, Zanotti, & Sappakittipakorn, 2014). Roads, sewers, and the constructed infrastructure of commercial, household, and public buildings form the foundation of any community's health, safety, and prosperity. As a result, they must be kept in good working order at all times (Banthia *et al.*, 2014). In response to damaged infrastructure, new construction materials such as Steel Fibre Reinforced Concrete (SFRC) are employed to overlay and patch the damaged or failing portions of the structures (Mohammed, Manalo, Ferdous, Zhuge, Vijay, Alkinani, & Fam, 2020; Tayeh, Bakar, Johari, & Lei, 2013; Denarié & Brühwiler, 2006). The idea of using SFRC in engineering is to develop an effective ductile and high tensile concrete. Both new and old constructions contain concrete-to-concrete contacts. There are two distinct situations: (1) placing hardened concrete against hardened concrete parts, as with precast members for viaducts and bridge decks; and (2) placing fresh concrete against hardened concrete parts, as with the rehabilitation and strengthening of existing structures via concrete jacketing or overlay (Aysha, Ramsundar, Arun, & Velrajkumar, 2014).

The use of SFRC to improve the bonding of concrete will eventually contribute to the improvement of the building system's efficiency. The mechanism behaviour of the concrete mixture is critical in the structural system. Numerous applications involving the bonding of concretes, such as repair, casting joints, and precast element connection, require a high concentration of cement to form an acceptable bond with the substrate. The usage of SFRC in place of conventional concrete in repair and rehabilitation applications may have a significant impact on engineering applications' sustainability.

The study's findings revealed that SFRC has the properties that make it suitable for the repair, retrofitting, and replacement of Reinforced Substantial Designs (RCS) as well as for use as a new development material (Banthia *et al.,* 2014). As these components are exposed to usually reasonable openness, any remaining pieces of the designs are kept in standard primary concrete. During strengthening and repair, there is usually a weak relationship between the bond strength of old and new substantial constructions (Feng, Xiao, & Geng, 2020; Momayez, Ehsani, Ramezanianpour, & Rajaie, 2005; Gorst & Clark, 2003).

It is necessary to understand the behaviour at the interface of old and new materials in order to effectively evaluate the repair of deteriorating infrastructures. (Tayeh *et al.*, 2013; Ueda & Dai, 2005). The bond between the composite materials is an element of certain variables, like surface unpleasantness and surface extremity of the composite segments. In estimating the surface energies and bond strength of the composite material, a comprehension of the interfacial attachment between the fibre and the network must be resolved. This exploration will assist with understanding the Interfacial bond conduct of concrete made with steel fibre and plain concrete. The deterioration of concrete structures is a matter of critical concern as it threatens the durability and strength of concrete structures. SFRC can be used with advantage in new structures such as precast and cast in-situ elements, as well as the strengthening, repair and rehabilitation of old structures to improve their resilience properties.

Bonded concrete overlay is a viable option to increase structural capacity and improve reliability of concrete structures. However, property mismatch of new overlaid concrete to old concrete usually create bond problems that lead to early age failure and a shortened service life of concrete composite (Momayez *et al.,* 2005; Gorst & Clark, 2003). Consequently, to better understand the bonding mechanism at the interface between new and old concrete surfaces, it is essential to measure bond strength at the interface and to investigate parameters that affect properties (Tayeh *et al.,* 2013; Ueda & Dai, 2005). In view of the following, the research aims to examine the interfacial bond strength behaviour of SFRC and PC substrate with a view to establishing the parameters affecting the bond strength at the interface. To achieve this aim, the following objectives will be pursued:

i) Determine the effects of three different conditions at substrate surface on the interfacial bond strength.
ii) Investigate the influence of Steel fibre content on the interfacial bond strength of the composite concrete members
iii) Determine the influence of surface roughness of the substrate on the bond strength of the interface of the composite concrete members

2. Materials and Methods

2.1 Materials

CEM 1 (42.5 N) portland cement which conforms with ASTM C150/C150M (2012) with brand name Dangote 3X was used throughout the whole series of tests. Initial and final setting times of the cement were 230min and 330 min, respectively. The specific gravity of the cement used was 3.09 g/cm^3 and Blaine specific surface area was 3220 cm^2 /g. The Steel fibre used is from the conventional straight galvanized steel binding wire. The Fibre diameter measured 1.0 mm and was chopped to a fibre length of 40 mm (Figure 1.) and a specific gravity was 1.27 g/cm^3. The steel fibre volume fraction in the concrete varied from 0.5% to 2.0% at an interval of 0.5%.

(a) Roll of Smooth GSW

(b) 40 mm chopped Smooth GSW

Fig. 1. Galvanized steel wire (GSW)

River sand was utilized as fine aggregate in the concrete mix, with maximum sieve size of 4.75 mm (sieve NO. 4) following ASTM outline. The sand was evaluated; with a fineness modulus of 2.9, specific gravity of 2.6 and a water absorption of 0.70% kept up at saturated surface dry (SSD) condition before use. Locally available, air-dried crushed granite of 10 mm maximum size with specific gravity of 2.7 and water absorption of 0.5% was used as coarse aggregate in all the mixes. Care was taken to ensure that the aggregate is free from organic matters such as dry muds, leaves and other deleterious materials. Municipal tap water supplied to the concrete laboratory of Department of Building, Federal University of Technology Minna, Niger State was used throughout the study for mixing, curing and other purpose. For all mixtures, 0.5% Superplasticizer Conplast SP 430 was used as the water reducing agent at a constant quantity with w/c ratio of 0.5. A typical concrete mix design used in this study is in accordance with the Department of Environment's Design Method (DOE Method) and the mix proportion is presented in Table 1.

Table 1

Mix Proportion for the Plain and Fibrous Concrete

ix No	x ID	Mi	Moisture condition at the old concrete surface	Steel wire fibre volume fractions (%)	Water (Kg)	Concrete (N/mm²)	Coarse Aggregate (N/mm²)	Fine Aggregate (N/mm²)
	D-0	SS	SSD	0	250	521	748.5	748.5
	0	W-	W	0	250	521	748.5	748.5
	-0	AD	AD	0	250	521	748.5	748.5
	D-0.5	SS	SSD	0.5	250	521	748.5	748.5
	0.5	W-	W	0.5	250	521	748.5	748.5
	-0.5	AD	AD	0.5	250	521	748.5	748.5
	D-1.0	SS	SSD	1.0	250	521	748.5	748.5
	1.0	W-	W	1.0	250	521	748.5	748.5
	-1.-0	AD	AD	1.0	250	521	748.5	748.5
0	D-1.5	SS	SSD	1.5	250	521	748.5	748.5
1	1.5	W-	W	1.5	250	521	748.5	748.5
2	-1.-5	AD	AD	1.5	250	521	748.5	748.5
3	D-2.0	SS	SSD	2.0	250	521	748.5	748.5
4	2.0	W-	W	2.0	250	521	748.5	748.5
5	-2.-0	AD	AD	2.0	250	521	748.5	748.5

2.2 Methods

2.2.1 Fresh Concrete Test

The fresh concrete test involves the testing for workability and wet concrete density of the PC and SFRC. The workability of concrete was estimated using Slump (BS EN 12350-2, 2009), Vebe (BS EN 12350-3, 2009), and Compacting factor (BS EN 12350-4, 2009) tests of PC and SFRC. The wet concrete density of the PC and SFRC was carried out in accordance with BS EN 12350-6 (2019).

2.2.2 Hardened Concrete Test

The test conducted on the hardened concrete includes the compressive, tensile and the shear bond strength test.

i) Compressive and Tensile Strength Test

The compressive and tensile strength of specimens of size 100 x 100 x 100 mm cube and Ø100 mm x 200 mm cylinder is evaluated for each mix with and without steel fibre and compared with one another. The cube specimens are water cured for 28 days and left at ambient temperature for compression tests and compressive strength measurement. Five varying volume fraction of steel fibre was introduced into the concrete used as overlay at 0%, 0.5%, 1.0%, 1.5% and 2.0% to form five different mix proportions for the study. The compression test and tensile test are performed in according to BS EN 12390-1 (2012) and BS EN 12390-6 (2009) respectively, prior to the determination of the bond strength of specimens using the slant shear test.

ii) Bond strength Test

In conducting the slant shear bond test, a crystal test made of two indistinguishable parts fortified at 30^o and tried under pivotal pressure and during stacking was utilized to quantify the inclination shear test in deciding the interface surface under pressure. The inclination shear test example size for the crystal is 100 x 100 x 200 mm in agreement with BS EN 12615 (1999) as represented in Figures 2 to 3.

To carry out casting of the samples in the bond strength tests, wooden moulds (100x 100 x 200 mm prism) are used. In order to avoid stickiness and water absorbent of the moulds, the moulds were all lubricated before pouring concrete (see Figure 2).

(a) Plain Concrete (Old Concrete) in form (b) halved (100x 100 x 200 mm) prism (c) Vibrating halved (100x 100 x 200 mm) prism in form

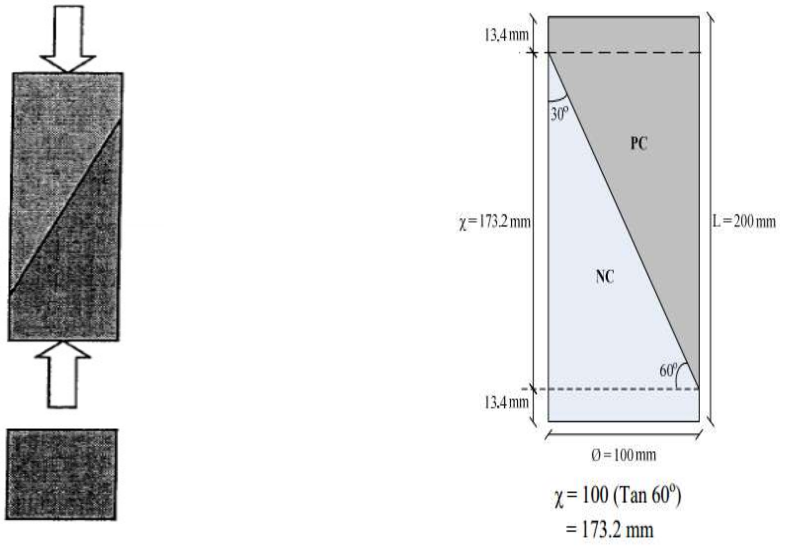
Fig. 2. Plain Concrete specimen casting in progress (Old Concrete)

Slant shear method is adopted to assess bond strength in shear. Here, the specimens are tested under compression (the simulation of shear-compression stress). First, the control prism samples, of 100 ± 2 mm in width and length and 200 ± 4 mm in height, cast in the shape of half-specimens (substrate/old concrete) with the interface at approximately 30^0 to the vertical. A day later, they are all demoulded and stored in water pool for 28 days. No steel fibre is used in the substrate. See mix proportions in Table 1.

Three experiment parameters were used to better understand the interfacial properties of overlaid concrete, including condition of old surface, surface roughness of new concrete and steel fibre content in new concrete as shown in Table 1. Saturated Surface Dry (SSD), Wet (W) and Air Dry (AD) conditions were made on the old concrete surface to study how the bond strength is affected by the moisture condition of the old concrete. While the substrate interface is prepared through etching using three methods which are (a) grooving (b) wire brushing (c) As cast after remoulding to determine the effect of surface texture (roughness) on the bonding strength of concrete interface. Four different steel wire fibre volume fractions (0.5%, 1.0%, 1.5% and 2.0%) were chosen for the experiments and compared with the plain concrete (0%). steel wire fibre was added to the concrete to study its bonding effect on interfacial property.

In preparing the old concrete, one hundred and forty-seven old concrete prism samples halved at 30° (halved 100 mm x 100 mm x 200 mm) were cast at the beginning of the study. After 28 days curing, the surfaces of the halved 100 x 100 x 200 prism were referred to as the old (substrate) concretes and were subsequently used as the interfaces to place new (overlay) concretes. For each test matrix, three replicas were made to find any outlier in making and testing specimens.

Air dry condition of old concrete was achieved by placing the old halved square prism sample in aggregate in the laboratory and keeping the relative humidity of 50% for two weeks before placing new concrete that is the fibrous concrete. The SSD condition was made by immersing the old concrete halved prism samples in water for one day, removing the specimen from the water, and wiping out the moisture at the surface before placing the fibrous concrete. Wet condition was made by putting the old concrete halved prism samples in water for three days, removing the specimen from the water immediately before casting new concrete without wiping surface water.



(a) Bond Test under State of Shear and Compression Stress-rectangular shear (BS EN 12615, 1999)

(b) Dimension of slanted specimen

Fig. 3. Slant Shear Bond Strength Test

Figure 3 displays a schematic view of the slant shear bond strength test while Figure 4(a-c) presents the surface texture of cast old concrete (substrate) rectangular prism halved at 30° (halved 100 x 100 x 200 mm).

(a) The old concrete prism sample halved at 30° (halved 100 x 100 x 200 mm) Grooved surface exposes aggregate

(b) The old concrete prism sample halved at 30° (halved 100 x 100 x 200 mm) As Cast (smooth) surface

(c) The old concrete prism sample halved at 30° (halved 100 x 100 x 200 mm) Wire Brush surface texture

Fig. 4. Prism sample surface texture of cast old concrete (Plain Concrete)

New concrete mixture was poured into old concrete prism forms and the overlaid concrete prism specimen for interfacial bond testing was produced as presented in Figure 5.

(a) Placing Overlay in Form

(b) Overlaid Prism

(c) Weighing Overlaid Concrete Prism Specimen

Fig. 5. Overlaid Concrete Prism Specimen for Interfacial Bond testing

3. Experimental Results and Discussion

3.1 Compressive strength

The 28-day compressive strength values in N/mm^2 and Relative variation in Compressive strength in percent for both the Plain Concrete (Old Concrete) and the SFRC (New concrete/overlay) specimen are presented in Table 2. It can be seen that on average, compressive strength of SFRC is about 5.77-7.97% higher than that of Plain Concrete (Old Concrete) mixture. SFRC with fibre volume fraction of 1.0% showed the highest compressive strength. A comparable observation has been made by Abdul Awal, Yee, & Zakaria, (2013) who reported that an addition of 1.5% steel fibres in concrete resulted in an increase of approximately 6% in compressive strength. The compressive strength of SFRC was considerably affected by the incidence of fibre in the concrete, the failure mode, nevertheless, showed a considerable transformation from brittle to ductile state. Due to bridging influence of the fibre, the cube specimens did not crush catastrophically, but held their integrity up to the completion of the test. Figure 6 illustrates the typical failure mode of plain concrete and steel fibre reinforced concrete.

(a) Plain concrete (b) Steel fibre reinforced concrete.

Fig. 6. Typical failure mode of plain concrete and steel fibre reinforced concrete.

Table 2
Strength Properties of the Concrete Mixes

Mix No	Mix ID	Steel wire fibre volume fractions (v_f) (%)	28 day Compressive strength, f_c (N/mm²)	Relative variation in Compressive strength R_{fc} (%)	28 day Splitting tensile strength, f_{st} (N/mm²)	Relative variation in Splitting tensile strength R_{fc} (%)
1	PC-0	0	45.57	0	3.11	0
2	SFRC-1	0.5	48.30	5.99	5.75	84.89
3	SFRC-2	1.0	49.20	7.97	9.23	196.79
4	SFRC-3	1.5	48.90	6.65	7.97	156.27
5	SFRC-4	2.0	48.60	5.77	6.40	105.79

3.2 *Splitting tensile strength*

The rigidity of the SFRC was found to increase with increasing measures of fibre. The relative splitting tensile strength values of SFRC according to fibre volume fraction are also given in Table 2. The test results indicated that splitting tensile strength of SFRC is about 84.89-196.79% higher than plain concrete mixture. Essentially, steel fibres considerably improved the splitting tensile strength of concrete as related to compressive strength. The results obtained in this study are consistent with preceding study (Abdul Awal *et al.,* 2013).

During the splitting tensile test, the effect of the steel fibres was apparent. The steel fibres appear to control the cracking of SFRC and alter the post cracking behaviour. The steel fibres seem to provide a load redistribution mechanism after initial cracking. Unlike in fibreless concrete, it was difficult to separate the fractured specimens because the steel fibres were bridging the gap that kept the two concrete parts together, as shown in Figure 7.

(a) Plain concrete (b) Steel fibre reinforced concrete.

Fig. 7: Failure mode of plain concrete and steel fibre reinforced concrete cylinder.

3.3 *Shear bond strength test*

The Shear bond test was conducted in concomitant to measuring the tested parameters and responding to the objectives of the study. The age of old concrete cast at the time of testing is 56 days in comparison to the new SFRC overlay which was 28 days. The measured parameters are presented below;

3.3.1 *The effect of three different moisture conditions at plain and fibre reinforced concrete surface on the interfacial bond strength of the composite concrete*

Table 3 shows the interface shear bond strength results for the PC and SFRC mixture with fibre volume fractions of 0%, 0.5%, 1.0%, 1.5%, and 2.0% and moisture condition of SSD, AD and wet, respectively. From this Table 3, it is observed that the bond strength of the FRC samples at all moisture conditions (SSD, W and AD) is higher than that of the control specimens in the presence of the three-surface texture. The bond strength of FRC with 1% fibre volume had thus improved. This improvement is influenced through grooved surface texture at SSD moisture condition of the old concrete surface.

Table 3
Bond Strength of Three Different Types of Surface Texture

Study Parameters					
			Surface texture		
Mix ID	**Moisture condition at the old concrete surface**	**Steel wire fibre volume fractions (%)**	*As cast Surface S (N/mm²)*	*Grooved Surface S (N/mm²)*	*Wire brush Surface S (N/mm²)*
SSD-0	SSD	0	9.69	13.13	11.77
W-0	W		8.26	10.08	9.23
AD-0	AD		7.32	9.74	8.66
SSD-05	SSD	0.5	10.25	13.60	12.09
W-0.5	W		8.68	10.52	9.94
AD-0.5	AD		8.15	10.06	9.43
SSD-1.0	SSD	1.0	11.70	15.19	13.87
W-1.0	W		9.85	13.25	11.57
AD-1.0	AD		7.10	10.96	9.81
SSD-1.5	SSD	1.5	9.77	12.07	10.35
W-1.5	W		9.16	11.25	10.38
AD-1.5	AD		8.82	9.78	9.25
SSD-2.0	SSD	2.0	9.36	10.84	9.55
W-2.0	W		8.59	9.52	8.98
AD-2.0	AD		7.95	8.51	8.41

3.3.2 *Influence of steel fibre Content on the interfacial bond strength of the composite concrete*

To examine the impacts of Steel fibre content on bond strength, full prism samples were set up as represented in Figure 5. Here, the substrate concrete was fibreless and the overlay concrete was cast with volume fraction of 0%, 0.5%, 1.0%, 1.5% and 2.0% steel fibre of constant length of 40 mm. The slant shear strengths of full square prism specimens were measured after curing in ambient conditions and for curing period of 28 days. The results are presented in Figures 8.

Referring to the experimental results of this study, we get closer to the fact that the presence of steel fibre in the repair material with grooved and wire brush surface treatment as a surface texture type between new and old concrete surface, which has made the formation of the transition zone quite different. It was observed that the use of plain concrete mix decreased the bond strength while the use of fibre reinforced concrete mix as an alternative thus enhance the interfacial bond strength. Steel fibre of 1.0% produced sample with the highest interfacial bond strength of 15.19 N/mm^2 as illustrated in Figure 8. A rigid zone is a consequence of bridging effect formed in the overlay through the application of the steel fibre and the high elastic modulus of the fibre. It was observed that, the bond strength of samples repaired by FRC with increasing fibre content repair materials was more than the control specimen.

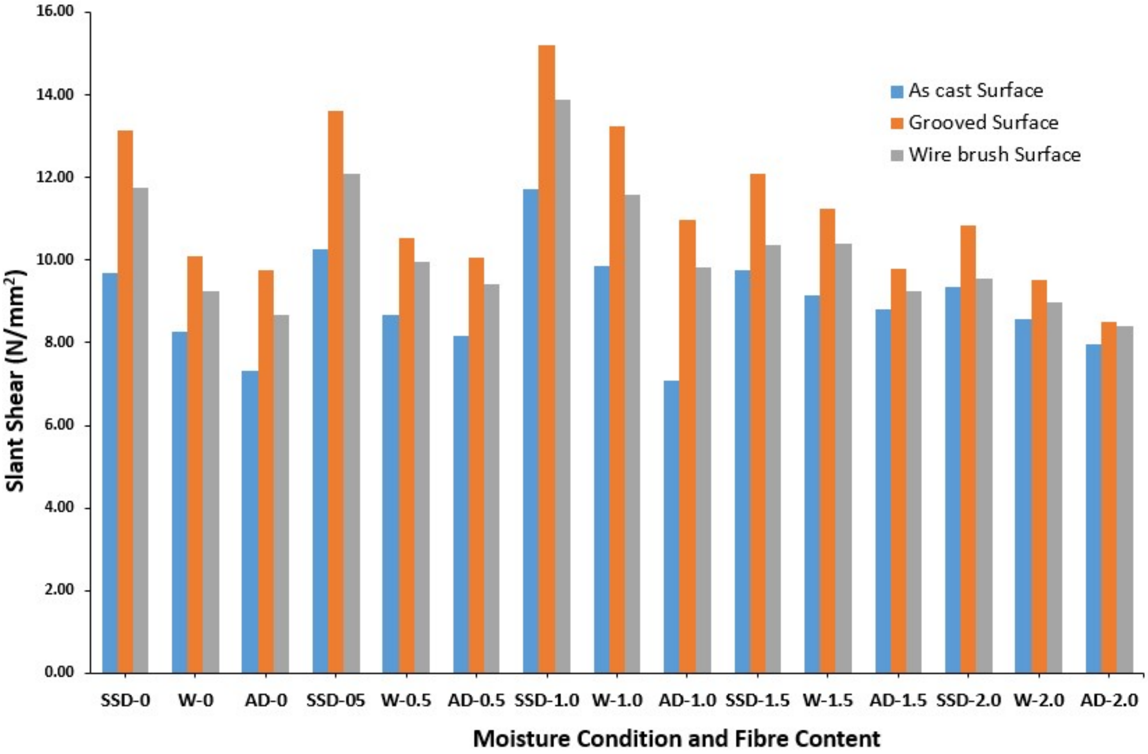


Fig. 8. Slant Shear Strength of Concrete samples at Different Moisture Content and Fibre Volume Fraction of three different surface treatments

3.3.3 *Influence of surface roughness (Texture) of the substrate on the interfacial bond strength of the composite concrete*

In other to examine the effect of the interfacial surface texture on the bond strength of repaired concrete, three different types of surface texture were evaluated for comparison with each other. As Cast surface texture, Grooved surface texture and Wire Brush surface texture are the three different categories of surface texture used on the interfacial surface prior to pouring the repair material (FRC) on the old concrete specimen known as the substrate. The interfacial bond strength results for specimens in presence of three types of surface texture are illustrated in Figure 8. The observations in Figure 8 indicate significant difference of about 35% between the results for Grooved, Wire brush and As Cast surface texture.

The experimental results showed that the interfacial bonding for almost all the grooved surface specimens examined in this research was generally good and strong enough as the interfacial failure mostly occurred after the substrate experienced some degree of damage. In some of the specimens, the bond strength was distinctively stronger than that of the plain concrete substrate because failure occurred mainly in the substrate without interfacial separation or debonding between the PC substrate and the SFRC.

Figure 8 presents the slant shear test results corresponding to different surface textures at different fibre content of the specimens. The results generally exhibit a gradual increase in interfacial bond strength with fibre content which could be linked to the hydration of cement producing calcium silicate hydrate and increasing the strength of the SFRC as well as the interfacial bond strength of the composite. For example, in the case of no surface preparation (As Cast specimens), the average measured shear strengths were 9.69, 8.26 and 7.32 N/mm^2 for SSD, W and AD at 0% steel fibre content, respectively. The grooved surface specimens record the highest 28-day average shear bond strength of 15.19 N/mm^2 followed by specimens with wire brushed (WB) surface, with shear bond strength of 13.87 N/mm^2, respectively. Hence, the results clearly portray that the different surface preparation methods undertaken, significantly improved the shear bond strength of the composite samples when compared with the cast reference samples. The tremendous enhancement in the shear bond strength could generally be attributed to greater adhesion and interlocking between the SFRC and the roughened NC substrate surfaces.

According to ACI Concrete Repair Guide (Chynoweth *et al.*, 1996), materials used in concrete repair work shall have a specified minimum acceptable bond strength based on the slant shear strength presented in Table 4.

Table 4
Minimum Acceptable Bond Strength Range

Days	**Bond Strength (S) N/mm^2**
1	2.76 - 6.9
7	6.9 – 12.41
28	12.41 -20.68

Source: Chynoweth *et al.* (1996).

This guide is useful in the selection of appropriate type of repair materials for rehabilitating deteriorated concrete structures. Based on this guideline, all the roughened surface textures used in this study were able to meet the minimum bond strength as specified in Table 4, with the grooved method giving the highest slant shear bond strength. Furthermore, it is very obvious that the 28-day shear bond strength of 11.70 N/mm^2 for the as cast reference composite does not comply with the specified minimum value (ACI 546, 2014), which further emphasizes the necessities for surface preparation of concrete substrate in concrete repair scenario. The findings of the present study are generally in agreement with the results of previous research (Tayeh *et al.*, 2013; Garbacz, Gorka, & Courard, 2005) on the influence of roughness and surface treatment on bond in concrete repair, i.e. surface preparation has strong influence on bond.

4. Conclusion

This study examined the interfacial bond strength conduct of SFRC and PC Substrate to clarify the conduct at the interface between old construction material and new rehabilitation material since the interface is the weakest connection. It is observed that the bond strength of the FRC samples at all moisture conditions (SSD, W and AD) is higher than that of the control specimens in the presence of the three-surface texture. The bond strength of FRC with 1% fibre volume was observed to have consequently improved. This improvement is influenced through grooved surface texture at SSD moisture condition of the old concrete surface. Steel fibre of 1.0% produced sample with the highest interfacial bond strength of 15.19N/mm^2. A rigid zone is a consequence of bridging effect formed in the overlay through the application of the steel fibre and the high elastic modulus of the fibre. It was observed that the bond strength of samples repaired by FRC with increasing fibre content repair materials was more than the control specimen. Based on ACI Concrete Repair Guideline, all the roughened surface textures used in this study were able to meet the minimum bond strength it specified.

5. References

Abdul Awal, A. S. M. Yee, L. L. & Zakaria, H. M. (2013). Fresh and Hardened Properties of Concrete Containing Steel Fibre From Recycled Tire. *Malaysian Journal of Civil Engineering*, *25*(1), 20-32.

View publication stats

ACI 546.3R (2014). *Guide to Materials Selection for Concrete Repair*. ACI (American Concrete Institute) Committee 546, ACI, Farmington Hills, MI, USA

Aysha H., Ramsundar K. R., Arun M., & Velrajkumar G (2014). An Overview of Interface Behaviour between Concrete to Concrete. *International Journal of Advanced Structures and Geotechnical Engineering*, *3*(2), 110-114

Banthia, N., Zanotti, C. & Sappakittipakorn, M., (2014). Sustainable fiber reinforced concrete for repair applications. *Construction and Building Materials*, *67,* 405–412.

BS EN 12350-2 (2009). *Testing fresh concrete. Slump-test*. British Standard Institution.

BS EN 12350-3 (2009). *Testing fresh concrete. Vebe test*. British Standard Institution.

BS EN 12350-4, (2009). *Testing fresh concrete-Part 4*: *Degree of compatibility*. British Standards Institution.

BS EN 12350-6 (2019). *Testing fresh concrete. Density*. British Standard Institution.

BS EN 12390-1 (2012). *Testing hardened concrete. Shape, dimensions and other requirements for specimens and moulds*. British Standard Institution.

BS EN 12390-6 (2009). *Testing hardened concrete. Tensile splitting strength of test specimens*. British Standard Institution.

BS EN 12615 (1999). *Products and Systems for the Protection and Repair of Concrete Structures - Test Methods-Determination of Slant Shear Strength*. British Standard Institution.

Chynoweth, G., Stankie, R. R., Allen, W. L., Anderson, R. R., Babcock, W. N., Barlow, P. (1996). Concrete Repair Guide. ACI Committee, *Concrete Repair Manual*, *546*, 287– 327.

Denarié, E. & Brühwiler, E. (2006). Structural rehabilitations with ultra-high performance fibre reinforced concretes (UHPFRC). *Restoration of buildings and monuments*, *12*(5), 93–108.

Feng, S., Xiao, H., & Geng, J. (2020). Bond strength between concrete substrate and repair mortar: Effect of fibre stiffness and substrate surface roughness. *Cement and Concrete Composites*, *114*, 103-746.

Garbacz A., Gorka M., & Courard L. (2005). Effect of concrete surface treatment on adhesion in repair systems. *Magazine of Concrete Research*, *57*(1), 24-36.

Gorst, N. J. S. & Clark, L. A. (2003). Effects of thaumasite on bond strength of reinforcement in concrete. *Cement and Concrete Composites, 25*(8), 1089-1094.

Mohammed, A. A., Manalo, A. C., Ferdous, W., Zhuge, Y., Vijay, P. V., Alkinani, A. Q., & Fam, A. (2020). State-of-the-art of prefabricated FRP composite jackets for structural repair. *Engineering Science and Technology, an International Journal,25*(5), 1244-1258.

Momayez, A., Ehsani, M. R., Ramezanianpour, A. A., & Rajaie, H. (2005). Comparison of methods for evaluating bond strength between concrete substrate and repair materials. *Cement and concrete research*, *35*(4), 748-757.

Ogunbode E. B., Yatim, J. M., Affendi, H., Aziz, A. A., Yunus, I. M., & Hamid, H. A. (2019). An evaluation of the interfacial bond strength of kenaf fibrous concrete and plain concrete composite. *International Journal of Built Environment and Sustainability*, *6*(1), 1-6.

Shin, H. C., & Wan, Z. (2010, June). *Interfacial properties between new and old concretes*. Paper presented at the *2nd International Conference on Sustainable Construction Materials and Technologies, Ancona, Italy*.

Tayeh, B. A., Bakar, B. H. A., Johari, M. A. M. & Lei, Y. (2013). Evaluation of Bond Strength between Normal Concrete Substrate and Ultra High-Performance Fiber Concrete as a Repair Material. *Procedia Engineering*, *54*, 554–563.

Ueda, T. & Dai, J. (2005). Interface bond between FRP sheets and concrete substrates: properties, numerical modeling and roles in member behaviour. *Progress in Structural Engineering and Materials*, *7*(1), 27–43.