INTERNATIONAL JOURNAL OF SUSTAINABLE CONSTRUCTION ENGINEERING AND TECHNOLOGY
VOL. 13 NO. 1 (2022) 130-136

IJSCET

http://publisher.uthm.edu.my/ojs/index.php/ijscet

ISSN : 2180-3242 e-ISSN : 2600-7959

International Journal of Sustainable Construction Engineering and Technology

Bond Strength Behavior in Rubberized Concrete

Hussein Al-Quraishi[1], Khudhayer Najim Abdullah Kammash[1], Zinah Asaad Abdul-Husain[1]

[1]Civil Engineering Department,
University of Technology, Baghdad, IRAQ

*Corresponding Author

DOI: https://doi.org/10.30880/ijscet.2022.13.01.012
Received 13 March 2022; Accepted 02 April 2022; Available online May 2022

Abstract: Through an experimental program of eighteen specimens presented in this paper, the bond strength between reinforcing bar and rubberized concrete that produced from adding waste tire rubber instead of natural aggregate. The fine and coarse aggregate were replaced in 0%, 25%, and 50% with the small piece of waste tire. Natural aggregate replacement ratio, rebar size, embedded length of rebar, yield stress of rebar, cover of concrete and concrete compressive strength were the parameters studied in this investigation. Ultimate bond stress, bond stress-slip response and failure modes were presented. The experimental results reported that a reduction of 19% in bond strength was noticed in rubberized concrete compared with conventional concrete. The bond strength of rubberized concrete increased when the concrete cover, compressive strength of concrete and yield stress of rebar were increased. Meanwhile, increase embedded length of rebar and rebar size decreases the bond strength. The push-out and splitting failure were the failure modes observed in rubberized concrete.

Keywords: Bond strength, rubberized concrete

1. Introduction

Replace part of conventional aggregate by a waste tire rubber is named rubberized concrete which represents environment friendly solution. This kind of concrete has benefits especially in building subjected to dynamic loading [1]. The bond between reinforcing bar and rubberized concrete depends on yield stress of rebar, cover of concrete and rebar size [2].

A few studies on the bond strength in rubberized concrete has been investigated meanwhile, many studies were investigated in conventional concrete.

Patidar et al. [1] replaced the fine and coarse aggregate by a waster tire with the percent of 2, 4, 6, 8 and 10% to study the bond strength between reinforcing bar and rubberized concrete. The experimental results showed that the bond strength in conventional concrete is less than that of rubberized concrete. Emiroğlu et al. [2], added waste tire as a fiber to produce rubberized concrete. The bond test result showed that the bond strength decrease when the fiber waste tire increased in rubberized concrete. Gesoglu et al. [3], tested the fracture and mechanical properties of crump and chips waste tire. Different replacement ratio of 19 specimens was tested. The fracture energy, bond strength, modulus of elasticity, splitting tensile strength, and compressive strength were studied. The results indicate that all the mechanical and fracture properties of rubberized concrete were less than that of conventional concrete. Jacintho et al. [4], studied the bond strength of 22 specimens through the pull-out test. The replacement ratio of conventional aggregate by waste tire were 10% and 20%. The results proved that the development length needed for rubberized concrete was less than that in conventional concrete. Bompa and Elghazouli [5], investigated 54 specimens to study the

*Corresponding author: hussain.abbas@yahoo.com

bond strength in rubberized concrete. The test results indicate that the design equations in rubberized concrete can be applied up to 60% replacement ratio.

In summary, it can be noted from literature, a small range of variables effect on the bond strength between rubberized concrete and reinforcing bar were studied. Therefore, the objective of the present investigation is to study a wide range of variables: replacement ratio, cover of concrete, embedded length of reinforcing bar, rebar size and yield stress of steel bar.

2. Experimental Program

2.1 Material and Mix Proportion

Bompa et al. [5] mix design of rubberized concrete was adopted herein according to Table 1. The volumetric replacement ratio of fine and coarse aggregate by waste rubber tire was 25% and 50%. The maximum size of waste tire used in rubberized concrete was 10 mm.

Superplasticiser, silica fume and fly ash were added to increase the workability and strength of concrete.

Reinforcing bar embedded in tested specimens was 12, 16, 22 and 25 mm. The target compressive strength for rubberized concrete according to Table 1 were 24, 30, 35 and 50 MPa. Meanwhile, for conventional concrete was 24 MPa at 28 days.

Table 2 - Mix proportions

f_c (MPa)	24	24	24	30	35	50
Concrete type	Normal	Rubberized	Rubberized	Rubberized	Rubberized	Rubberized
Replacement ratio (%)	0	25	50	50	50	50
Microsilica	-	41	41	41	41	41
flyash	-	41	41	41	41	41
Fine rubber (kg/m3)	0	115	225	225	225	225
Cement (kg/m3)	365	345	345	345	345	345
Sand (kg/m3)	765	548	494	554	613	703
Gravel (kg/m3)	1085	653	605	687	774	905
Admixture	-	7.5	7.5	7.5	7.5	7.5
Water (kg/m3)	188	147	147	147	147	147
W/C	0.51	0.42	0.42	0.42	0.42	0.42

2.2 Specimen Details

A cubic of 150 x 150 x 150 mm was used to study the bond strength through push-out test. A reinforcing bar with 5D to 12D anchorage length was used to describe the bonding area. While, the other parts of reinforcing bar had debonding length using PVC pipe. See Figure 1.

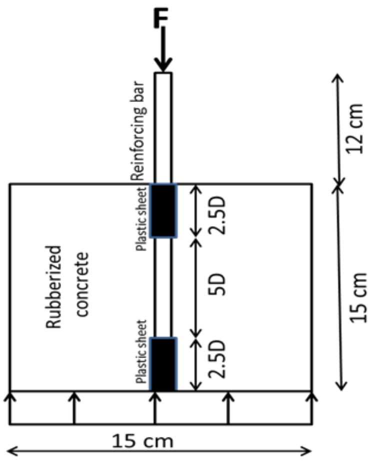

Fig. 1 - Push-out specimen

2.3 Testing Specimens

Six groups of 18 push-out specimens were constructed to investigate the bond between rubberized concrete and reinforcing bar. In first group, the replacement ratio of conventional aggregate by waste tire effect on bond stress was studied on specimens (B3-R0%, B2-R25% and B1-R50%). The second group studied the effect of compressive strength of rubberized concrete on bond stress in specimens (B1-R50%, B4-fc30, B5-fc35 and B6-fc50). The third group studied the effect of rebar size on bond stress (B1-R50%, B7-D16, B8-D22, and B9-D25). The fourth group studied the embedded length of reinforcing rebar in rubberized concrete (B1-R50%, B10-Em7D, B11-Em10D and B12-Em12D). The fifth group studied the effect of yield stress of reinforcing rebar on bond stress (B1-R50, B13-fy325, B14-fy420 and B15-fy625). The sixth group studied the effect of concrete cover on bond stress (B1-R50%, B16-Co100, B17-Co200 and B18-Co250). Table 2 presented the specimens details.

Table 2 - Specimens details

Groups	Specimens	Replacement ratio (%)	f_c (MPa)	Bar size (mm)	Embedded length (mm)	Yield stress of rebar	Concrete cover (mm)
Reference	B1-R50%	50	24	12	5D	525	150
One	B2-R25%	25	24	12	5D	525	150
	B3-R0%	0%	24	12	5D	525	150
Two	B4-fc30	50	30	12	5D	525	150
	B5-fc35	50	35	12	5D	525	150
	B6-fc50	50	50	12	5D	525	150
Three	B7-D16	50	24	16	5D	525	150
	B8-D22	50	24	22	5D	525	150
	B9-D25	50	24	25	5D	525	150
Four	B10-Em7D	50	24	12	7D	525	150
	B11-Em10D	50	24	12	10D	525	150
	B12-Em12D	50	24	12	12D	525	150
Five	B13-fy325	50	24	12	5D	325	150
	B14-fy420	50	24	12	5D	420	150
	B15-fy625	50	24	12	5D	625	150
Six	B16-Co100	50	24	12	5D	525	100
	B17-Co200	50	24	12	5D	525	200
	B18-Co250	50	24	12	5D	525	250

2.3 Testing Procedure

The push-out specimens were tested under 150 kN hydraulic machine. The testing machine pushes the rebar from one side to produce relative slip between reinforcing bar and rubberized concrete. Also, shear stresses along the embedded length were occurred. The specimens were tested in displacement control method of 0.3 mm/min. Underneath the specimens, a steel block was placed as a support. For each displacement increments, the slipping and applied loads were recorded. See Figure 2.

Fig. 2 - Test set-up

3. Experimental Results

The bond stresses along the embedded length cab be determined as follows:

$$\tau ult = Pult / (\square D \square ld) \quad .....(1)$$

where: τult is the ultimate bond stress; Pult is the ultimate applied load; D is the rebar size; ld is the embedded anchorage length.

3.1 Variables Effect on the Bond Strength

The test results are summaries in Table 3 as follows:

•Due to micro-cracks which effect on adhesive force and mechanical interlock, the bond strength of rubberized concrete decrease by 19% when the conventional aggregate replaced to 50%.
•Increase the compressive strength of rubberized concrete from 24 to 50 MPa, increased the bond strength by 27.7%. This confirms the major effect of concrete compressive strength on bond strength.
•Due to Less number of ribs in bigger rebar size, the bond strength decrease by 54.2% when the rebar size increased from 12 to 25 mm.
•Increased the anchorage length from 5D to 12D, decreases the bond strength by 51.1%. This, because small value of bond stresses produced in a long anchorage.
•Due to more stresses transferred between concrete and reinforcing bar, the bond strength increased by 72.1% when the yield stresses of rebar increased from 325 to 625 MPa.
•Due to confinement effect produced from concrete cover on reinforcing bar, the bond strength increased by 3.3% when the concrete cover increased from 100 to 250 mm.

Table 3 - Ultimate bond strength

Groups	Specimens	Ultimate
Reference	B1-R50%	9.09
One	B2-R25%	9.94
	B3-R0%	10.81
Two	B4-fc30	9.12
	B5-fc35	9.89
	B6-fc50	11.65
Three	B7-D16	6.81
	B8-D22	4.94
	B9-D25	4.16
Four	B10-Em7D	7.55
	B11-Em10D	4.98
	B12-Em12D	4.44
Five	B13-fy325	6.1
	B14-fy420	7.5

	B15-fy625	10.5
Six	B16-Co100	8.65
	B17-Co200	8.84
	B18-Co250	8.94

3.2 Bond Stress-Slip Relations

The bond stresses are calculated by dividing the force over concrete surface area. Meanwhile, the relative slip between concrete and the reinforcing bar is recorded from testing machine. In Figure 3, the relation between bond stress and slip response is depicted. In which, chemical adhesion is control which described as linear ascending line. The second part, nonlinear behavior till maximum load which represents the mechanical interlock. The last part describes the bond failure which represent the softening behavior

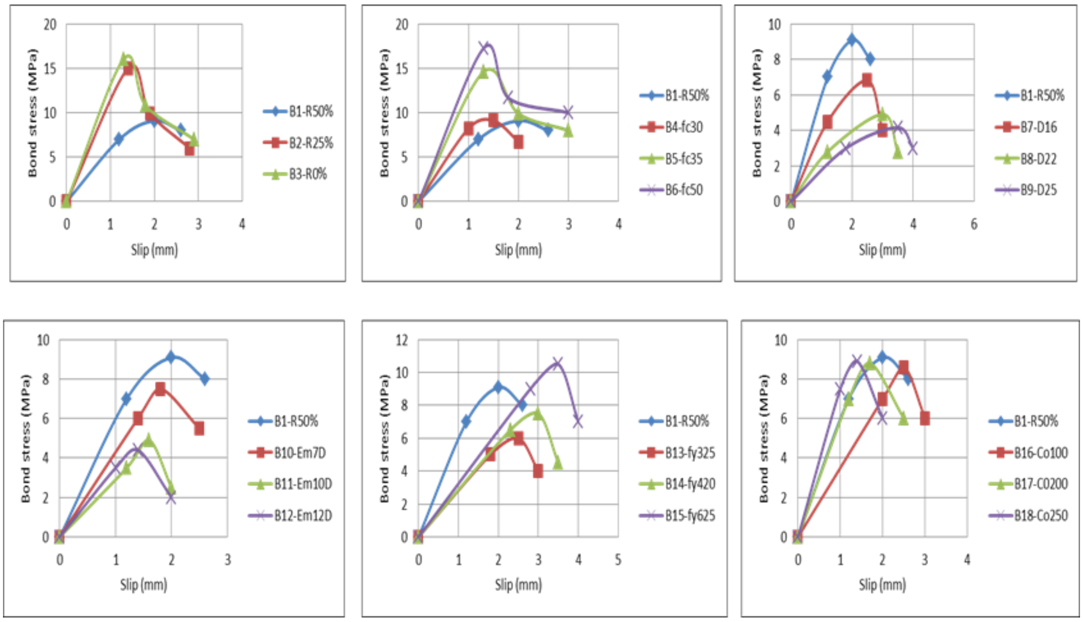

Fig. 3 - Bond stress-slip behavior

3.3 Modes of Failure

The failure starts with the frictional and adhesion failure with small slip between reinforcing bar and rubberized concrete. After that, radial tensile stresses perpendicular to line of compression force are produced. If these stresses reach ultimate tensile strength of rubberized concrete, the circumferences surface cracks happened as splitting failure. While, when no surface cracks occurred and the reinforcing bar penetrate through the other side, this means a push-out failure is occurred.

Increase the concrete cover produce push-out failure, meanwhile, increase the rebar size, replacement ratio and concrete compressive strength produced splitting failure. See Figure 4.

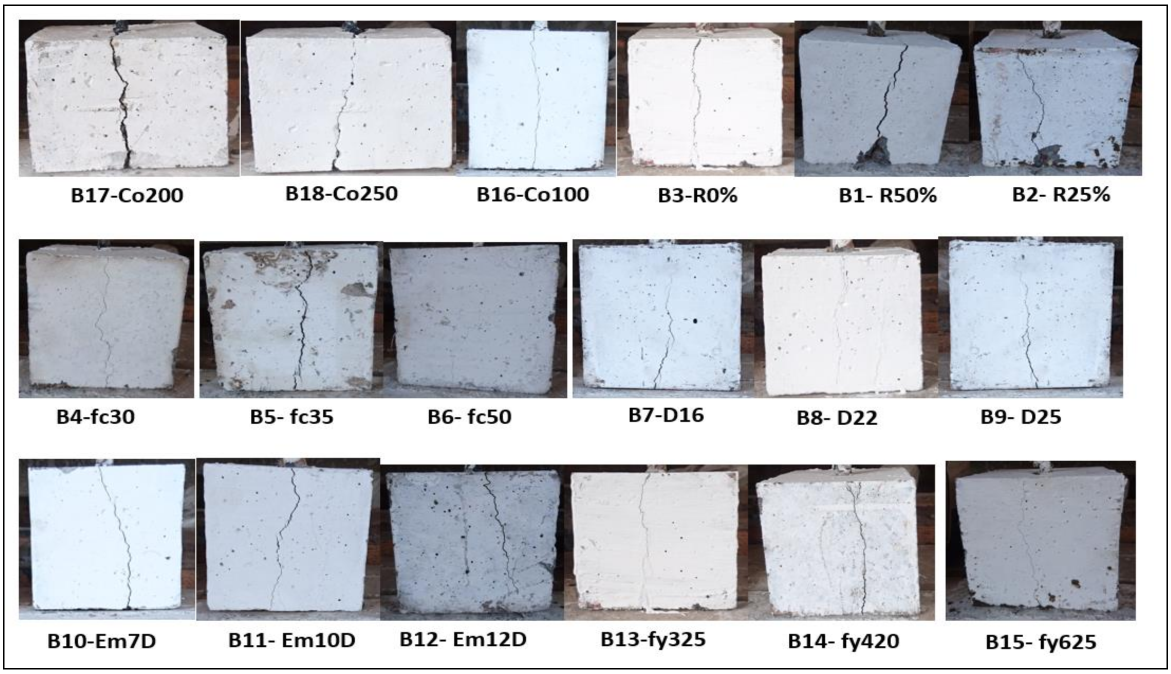

Fig. 4 - Modes of failure

4. Conclusions

The bond strength between rubberized concrete and reinforcing rebar is reduced by 19% when the conventional aggregate is replaced by 50% with the fine waste rubber. The bond strength is increased when increasing the concrete cover, compressive strength of concrete and yield stress of reinforcing bar. Whilst, increase the bar size or anchorage length decreases the bond strength. The modes of failure in rubberized concrete are similar to that of conventional concrete: push-out and splitting failure.

Acknowledgement

The authors would like to thanks the University of Technology, Baghdad, Iraq for giving the opportunity to conduct this research.

References

Patidar G., Sharma G., Shrivastava G., Studies on Bond Strength Characteristics of Tyre Derived Aggregates in Concrete, International Journal of Latest Technology in Engineering, Management & Applied Science, March 2018, 2278-2540.

Emiroğlu M, Kelestemur S., Kelestemur M, Bond performance of rubber particles in the self-compacting concrete,Publisher creations 2012, 78 - 88.

Gesoglu M., Guneyisi E., Hansu O., Ipek S., Asaad D., Influence of waste rubber utilization on the fracture and steel–concrete bond strength properties of concrete, Construction and Building Materials 101 (2015) 1113–1121.

Jacintho A., Pimentel L., Barbosa M., Fonta P., Steel and concrete bond stress: a contribution to the study of APULOT tests using concrete with rubber addition, IBIBRACON Structures and Materials Journal, Vol. 7, No.5, (2014), P. 817-844.

Bompa D., Elghazouli A., Bond-slip response of deformed bars in rubberised concrete, Construction and Building Materials 154 (2017) 884–898.

Simulia, 2016. Abaqus/CAE User's Manual, Version 6.14.

Al-Quraishi H., Mohammed J. Hamood and Nada Sahmi, A new shear strength model for UHPC corbel, International review of civil engineering, Vol.9 N.4 july 2018, 168-173.

Al-Quraishi H., Al-Farttoosi M., and AbdulKhudhur R., Tension lap splice length of reinforcing bars embedded in reactive powder concrete (RPC), Structures 19 (June 2019),362–368.

Alhawat M. and Ashour A., Bond strength between corroded steel reinforcement and recycled aggregate concrete, Structures, Structures 19 (2019) 369–385.

Arezoumandi M., Amanda R., Jeffery S., Ph.D., Evaluation of the bond strengths between concrete and reinforcement as a function of recycled concrete aggregate replacement level, Structures 18 (2018), 1-39.

Al-Quraishi H., J. Mohammed Hamood and S. Nada Sahmi 2018, A new shear strength model for UHPC corbel, International review of civil engineering, Vol.9 No.4 july, 168-173.

Al-Quraishi H., M. Al-Farttoosi, and R. AbdulKhudhur, 2019 Tension lap splice length of reinforcing bars embedded in reactive powder concrete (RPC), Structures 19, 362–368

Abdulazeez A, Abdulkhudhur R and Al-Quraishi H., Bond strength Behavior for deformed steel rebar embedded in recycled aggregate concrete, J. Eng. Technol. Sci., Vol.53, No.1, 2021, 210111.

Al-Quraishi H., Abdulazeez A., and AbdulKhudhur R., Behavior of rubberized concrete beams in shear, 4th international conference on Engineering Sciences (ICES 2020), IOP Conf. Series: Materials Science and Engineering, 1067 (2021) 012004.