Acta Scientific COMPUTER SCIENCES

Volume 2 Issue 11 November 2020

Research Article

Influence of Direction of Application of Oil on Concrete-Steel Bond

Boateng E, Danso AK* and Ayarkwa J

Department of Construction Technology and Management, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

***Corresponding Author:** Danso AK, Department of Construction Technology and Management, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Received: September 14, 2020
Published: October 30, 2020

Abstract

The interaction of steel reinforcement bar with concrete is a complex phenomenon that has significant effects on the performance of reinforced concrete (R C) elements. The presence of oil at the interface of the steel and concrete affect the bond between the two materials. In this paper, the influence of the direction of application of the oil at the steel-concrete interface on bond was investigated. Twenty-five (25) standard 150mm concrete cubes embedded with deformed mild steel rebars were used. Ten sets of the cubes had 50% of the embedded surface area of the rebars coated with oil in the transverse direction while another ten set had the oil applied in a direction parallel to the longitudinal axis of the bar. The remaining cubes were used as control specimen. Tension pull out test technique was used to measure the bond strength of the specimen. Two sample T-test was carried out to find out if significant difference exist in the two results. At 95% confidence level, the findings revealed that there is no significant difference in the bond strength for the two patterns of oil pollution.

Keywords: Bond Strength; Used Engine Oil; Pull Out Test; Reinforced Concrete

Introduction

Force transfer between concrete and steel in reinforced concrete (R C) structures occurs through various mechanisms at the concrete-steel interface which includes chemical adhesion and frictional resistance resulting from the bar surface deformations and the surrounding concrete [1,2]. The use of oil as formwork releasing agent on construction sites has adverse effect on these mechanisms [3,4]. Over the years attempts have been made to increase understanding on how the oil affects the bond mechanism. To begin with, Faiyadh [5] studied the bond strength of concrete cured in oil. Concrete specimens embedded with steel rebar were cured in oil at different durations. Afterward, pullout test was carried out to determine the bond strength of the specimen. The results revealed that irrespective of the type of bar, the average bond strength decreases with an increase in the duration of the soaking period. The specimen absorbs more oil as the curing period increases and this negatively affects the bond between steel and concrete. The plain bars recorded a reduction of about 1.8 - 2.3 times greater in bond strength compared to those with the deformed bars. Moreover, at the maximum applied load, the local bond stress for the specimen cured in oil was six (6) times greater than those cured in water. It was concluded from the study that, the presence of oil at the bond zone reduces the adhesion and frictional resistance between concrete and steel.

Bilal., *et al.* [6,7] also designed a two phase research program to investigate the effect of oil on concrete. The authors employed used engine oil for the preparation of the specimen. In the first study, Bilal., *et al.* [7], it was found that the presence of oil at the bond zone affects the strength properties of the concrete. An average loss of 21% and 17% in flexural strength and splitting tensile strength respectively were recorded. The oil was also found to affect bond and consequently the load-deflection behavior of R C beams [6].

To add up to the above, Adukpo., *et al.* [4] and Musa and Haido [3] looked at how oil as a coating on steel rebar surface affects the adhesion and frictional resistance between concrete and steel. It was found from both studies that oil reduces bond through the formation of a protective barrier between the two materials which impairs the gripping of the steel bars within the bond zone. Musa and Haido looked at various degrees of pollution of the oil on the rebar surface.

In spite of their efforts at investigating the effect of oil on bond strength, the researchers failed to look at how the direction of application of the oil on the rebar surface affects bond. Practically steel rebar may be polluted with oil in the transverse direction or in a direction parallel to the longitudinal axis of the bar but how these influence concrete-steel bond is not known. The current study was thus designed to address this gap by comparing the average bond for the two cases/patterns of oil pollution. The findings are intended to provide further understanding on the influence of oil on concrete-steel bond taking into consideration the pattern of application/pollution of oil on the steel rebar surface.

Materials and Methods

Preparation of specimen

The study investigated two possible cases (patterns) for which oil pollution on steel reinforcement bars on construction sites can occur. In the first case, part of the bonded surface area of the rebar was polluted with oil along the transverse direction of the bar (Figure 1). In the second scenario, the bar was polluted with the oil in the longitudinal direction (Figure 2). The question that arises is “Will there be any significant difference in the bond strength in the two cases? Or will the direction of application of the oil be relevant in determining bond response? To test the hypothesis, ten samples each of specimens with 50% of the embedded surface area of the rebar coated with oil in the transverse and longitudinal directions were used to find out if any significant difference existed in the bond strengths. The specimens were 150 mm concrete cubes with mean compressive strength of 26.563 N/mm^2. The water/cement ratio was 0.5. Each cube was centrally embedded with standard deformed mild steel rebar having a diameter of 16 mm. The fine aggregate was pit sand and the coarse aggregate crushed granite with 20 mm nominal size. Ordinary Portland cement (ASTM C150 Type I; Grade 32.5) was used. The materials were in a ratio of 10:15.6:30.5 kg by weight. The aggregates were obtained from a site in the Accra Metropolis, Ghana. Figure 3 and 4 show the particle size distribution of the aggregates which fall within the limits set by BS 882:1992. In all there were 28 cubes out of which three were used to determine the cube strength of the concrete.

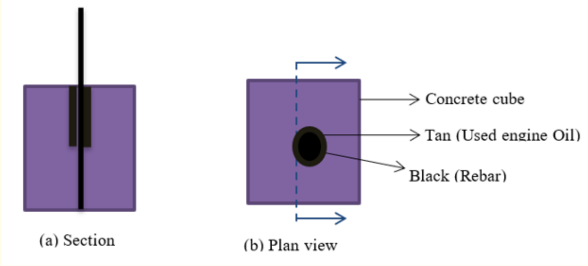

Figure 1: 50% of embedded surface area of rebar pollution with oil in the transverse direction.

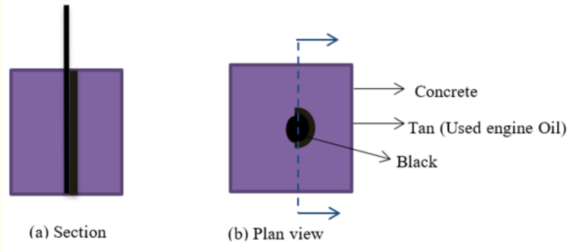

Figure 2: 50% of embedded surface area of rebar pollution with oil in the longitudinal direction.

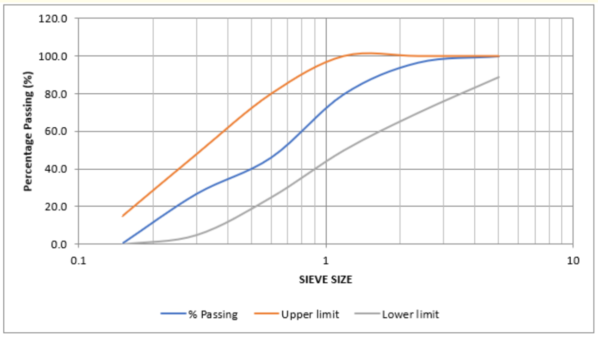

Figure 3: Particle size distribution of fine aggregate.

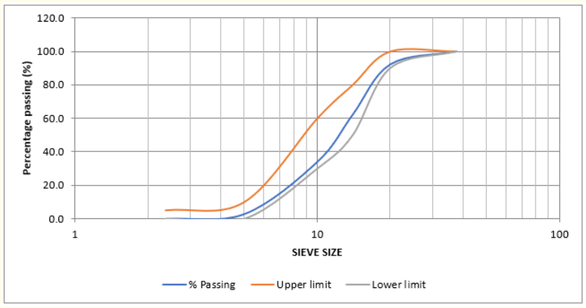

Figure 4: Particle size distribution of coarse aggregate.

Figure 5: Curing of specimen.

Figure 6: Specimen ready for testing.

Figure 7: Pull-out test equipment.

Bond test

Though several methods exist for measuring bond strength however, the current study adopted Tension Pullout test technique due the relative simplicity in the test setup. Each of the cubes were mounted into a 500 kN electronic tensile test machine and loaded until failure through either tensile splitting or pull out of the bar. The load was distributed from the machine to the specimen through a 25 mm thick steel plate at the rate of 2.5 kN/sec. The test was carried out in accordance with ASTM C900 - 15 specifications [8].

Data analysis

For each specimen, the bond strength was calculated using equation. 48 of BS 8110 -1:1997 given as: $f_b = \frac{F_s}{\pi \varphi_e l}$ .... Where, f_b is the bond stress which is assumed to be uniform over the embedment length; F_s = the pull out force l = the embedment length (150 mm); φ_e = the effective bar size (16 mm). For each group, the average force of the three (3) replicate specimens was used to determine the bond stress.

Given a small sample size less than thirty (30) and hypothesis testing involving two independent samples (i.e. differences in the pattern of oil pollution), two-sample t-test was used as recommended by Creswell [9] and Fellows and Lui [10]. For the null hypothesis, H_o equal mean bond strength was assumed for the 2 patterns of oil pollution (i.e. transverse and longitudinal). The data analysis tool pack in Microsoft Excel (version 2013) was used to analyse the data.

Results and Discussion

Table 1 shows the bond strength results for the two patterns of oil pollution. The average bond strength of the specimen with the oil applied in the transverse direction ($\bar{x}$) was 5.661 N/mm^2 compared with the value of 5.959 N/mm^2 recorded for those with the rebars polluted in the longitudinal direction ($\bar{y}$). This was computed mathematical using the formula:

$$\bar{x} = \frac{\sum_i^n x}{n_x} \text{ and } \bar{y} = \frac{\sum_i^n y}{n_y}$$

Where x_i ...... x_n and y_i...... y_n are the bond stresses recorded for the specimen with the rebar polluted with oil in the transverse and longitudinal directions respectively. n_x and n_y is the sample sizes for group *x* and *y* respectively.

At a glance one would observe that pollution of rebar with oil in the transverse direction reduces bond strength slightly more than that along the longitudinal direction. However, the question is "Can this difference be considered to be statistically significant"? A statistically significant t-test result is one in which the difference between the two groups is unlikely to have occurred because the sample happened to be atypical. Statistical significance is determined by the size of the difference between the group averages, the sample size, and the standard deviations of the groups which can be assessed by the value of the *t* statistic given by the formula:

$$t = \frac{(\bar{x}-\bar{y})-(u_x-u_y)}{s\sqrt{\frac{1}{n_x}+\frac{1}{n_y}}} \text{ and } s = \frac{(n_x-1)\,s_x^2 + (n_y-1)\,s_y^2}{(n_x-1)+(n_y-1)}$$

Specimen Type	Sample No.	Failure load (kN) F_s	Bond stress (N/mm²) $f_b = \frac{F_s}{\pi \varphi_e l}$	Average Bond stress (N/mm²)
Control specimen (Without Oil)	1	49.202	6.523	6.663
	2	50.560	6.703	
	3	51.012	6.763	
	4	50.858	6.743	
	5	49.658	6.583	
Specimen polluted with Oil in the Transverse Direction	1	43.164	5.723	5.661
	2	44.487	5.898	
	3	40.449	5.363	
	4	43.500	5.767	
	5	43.600	5.780	
	6	41.700	5.528	
	7	42.000	5.568	
	8	41.850	5.548	
	9	43.250	5.734	
	10	43.000	5.701	
Specimen polluted with oil in the Longitudinal Direction	1	46.183	6.123	5.959
	2	45.278	6.003	
	3	43.392	5.753	
	4	45.751	6.065	
	5	45.851	6.079	
	6	43.951	5.827	
	7	44.251	5.867	
	8	44.101	5.847	
	9	45.501	6.032	
	10	45.251	5.999	

Table 1: Bond strength of specimen ($\varphi = 16$ mm; $l = 9.375\ \varphi$).

Where and are the standard deviations for the two set of specimen. $\mu_x - \mu_y = 0$ *when* a null hypothesis of equal mean bond strength is assumed. From the results shown in table 2, the absolute value of the computed t Stat from the formula above is less than the critical two tail t-value (0.578 < 2.10). The critical t-value explains the minimum t-value required in order to have $P < 0.05$ (i.e. a test results with 5% chance of making an error in the prediction). For t-values less than the critical t-value, there is no significant difference between the population mean of the two groups. This means that in the current study the null hypothesis of equal mean bond strength for the two patterns of application of oil can be accepted with 5% significance level. To add up to the above, the two-tailed P-value of 0.0002 indicates that there is a 0.0002 (or 0.02%) chance that the two sets of values come from the same group.

In summary, the direction of application of oil on steel rebar surface does not play any significant role in determining the bond strength of concrete-steel interface. In other words, the bond strength of the concrete-steel interface is independent of the direction of application of the oil. Once the area covered by the oil is the same, the bond strength does not change irrespective of the direction of application of the oil. In each case, oil reduces the adhesion and frictional resistance at the concrete steel interface as noted earlier on by Musa and Haido [3] and Adukpo., *et al* [4]. When the results were compared with that of the controlled specimen (i.e. those without oil) it was realized that there was a reduction of about 15% and 11% in bond strength when 50% of the embedded surface area of the steel was polluted with oil in the transverse and longitudinal directions respectively [11].

	Transverse direction	**Longitudinal direction**
Mean bond stress	5.661	5.959
Variance	0.02447	0.01584
Observations	10	10
Pooled Variance	0.020155072	
Hypothesized Mean Difference	0	
df	18	
t Stat	-4.700374211	
P(T < = t) one-tail	8.91521E-05	
t Critical one-tail	1.734063607	
P(T < =t) two-tail	0.000178304	
t Critical two-tail	2.10092204	

Table 2: t-Test: Two-sample assuming equal variances (p = 5%).

Conclusion and Recommendations

The study was designed to investigate whether the direction or pattern of application of oil at the concrete-steel interface has any significant influence on bond. Based on the findings of the study it is concluded that even though the presence of oil affected bond strength, the pattern of application of the oil (whether in the transverse or longitudinal direction of the bar) do not have any significant effect on the results. On the other hand, the use of oil as formwork releasing agent on construction sites should be carefully carried out to ensure that the steel reinforcement bars are free from oil since the presence of the oil led to a significant reduction of the bond strength of the concrete-steel interface in both the transverse (15%) and the longitudinal (11%) directions.

Bibliography

1. Darwin D. “Evaluation of Bond Strength of ZBAR Multiple Coated Steel Reinforcing Bars”. University of Kansas Center for Research, Inc., Lawrence, KS (2005).
2. ACI Committee 408 Bond and Development of Straight Reinforcing Bars in Tension, American Concrete Institute, Farmington Hills, Mich (2003).
3. Musa IHA and Haido JH. “Bond Strength of Concrete with the reinforcement bars polluted with Oil”. *European Scientific Journal* 9 (2013): 6.
4. Adukpo Oteng SE and Manu P. “Effect of oil coating on steel bar on the strength of reinforced concrete”. Paper presented at the West Africa Built Environment Research (WABER) conference (2011).
5. Faiyadh FI. “Bond characteristics of oil saturated concrete”. *International Journal of Cement Composites and Lightweight Concrete* 7.2 (1985): 115-131.
6. Bilal SH., *et al.* “Effect of used engine oil on structural behavior of reinforced concrete elements”. *Construction and Building Materials* 17.3 (2003a): 203-211.
7. Bilal SH., *et al.* “Effect of used engine oil on the properties of fresh and hardened concrete”. *Construction and Building Materials* 17.5 (2003b): 311-318.
8. ASTM C900-15 Standard Test Method for Pullout Strength of Hardened Concrete, ASTM International, West Conshohocken, PA (2015).
9. Creswell JW. “Research design: Qualitative, quantitative, and mixed method approaches, 3rd Edition”. California: Sage Publications (2009).
10. Fellow and Lui. “Research methods for construction”. 3rd edition. Wiley-Blackwell Publishing limited (2008).
11. British Standards Institute BS 882. Specification for aggregates from natural sources for concrete (1992).