INFLUENCE OF SHEAR STRENGTH TRANSFER BETWEEN THE ADDED CONCRETE TOPPING AND EXISTING CONCRETE BY PUSH-OFF TEST METHOD

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ABSTRACT

This paper investigates the influence of interface shear strength transfer between the added concrete topping and the existing concrete with different surface textures. The interface shear strength transfer between two layers of concrete is important to maintain the monolithic behavior of composite concrete. The surface textures at concrete base plays an important role to the interface shear strength. The cube compressive strength for the existing concrete as a concrete base is 40 N/mm^2 while for added concrete topping is 25 N/mm^2. There were three types of surface textures at the concrete base.The surface textures were treated with smooth as-cast, longitudinal groove line by using rod steel and wire-brushing roughened. The roughness surface was measured by roughness instrument to correlate it with the interface shear strength. A total of 36 concrete composite specimens of 300 x 300 x 75 mm deep were cast on precast unit of 300 x 300 x 100 mm deep and were tested by push-off test method under 0 N/mm^2, 0.5 N/mm^2, 1.0 N/mm^2 and 1.5 N/mm^2 to determine the shear strength between concrete layers. The friction coefficient was determined from the test and compared with the theoretical based on equation in Eurocode 2. Throughout this experiment, the surface roughness was quantified and correlated with the interface shear strength. Selected roughness parameters were suggested based on high correlation coefficient. According to the findings, roughened by wire brush produced the highest interface shear strength which can develop shear resistance more compare to other different surfaces.

Keywords: Interface shear strength, friction coefficient, surface roughness and roughness parameter.

1. INTRODUCTION

Precast concrete slab and in-situ concrete topping are a type of precast concrete structures. In order to ensure the stiffness of the construction, a composite action is developed between two layers of concrete to be an element of composite concrete. To develop the composite action, the interface shear strength must be transferred adequately across the interface. As the precast construction is increasingly being implemented in nowadays construction, it is important to understand the behavior of horizontal shear strength at the interface. The interface shear is influenced by concrete-to-concrete adhesion, frictional force and clamping force by shear links [1, 2]. These three parameters of interface shear strength depend on the type of surface textures of the concrete base. For the case of this study, the shear reinforcement links was not provided at the interface. Three types of surface textures were provided in the study which includes smooth as-cast, longitudinal groove and wire-brushing roughened. The surface preparation and cleanliness of the surface are the main important parameters to maintain interface shear strength between concrete layers. The surface texture was then measured by using a portable stylus roughness instrument based on requirement in the BS1134[3]. The previous study [4-6]proved that by quantifying the surface roughness profile can be correlated with the interface shear strength instead of determine the surface texture by visual inspection.

Several experiments test had been done previously to determine the interface shear strength with different types of the surface textures. The types of surface textures varied from smooth to very rough surface and the surface with the shear reinforcement across at interface. Gohnert [7] conducted an experimental study on 90 horizontal shear tests by using push-off test method. The surface of the base layer was treated with wire brush and correlated with interface shear strength. The results showed that the roughness profiles can be measured and therefore the researcher concluded that the actual measurement should be specified instead of describing the finishing based on observation.

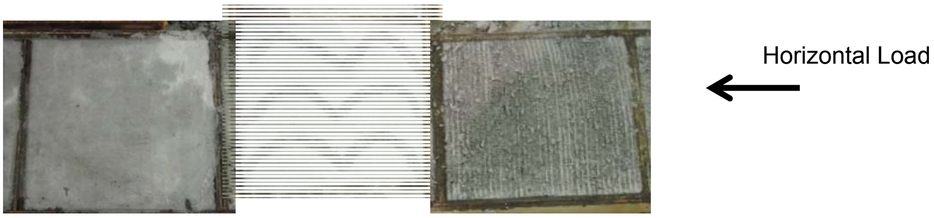
Santos et. al. [8] adopted slant shear and pull-off tests to assess bond strength in shear and in tension. The roughness profiles were then measured by digital image and compared with the bond strength. The surface treatment with sand blasting with exposed aggregate was the highest correlation of coefficient between bond strength and roughness profiles then following the wire-brushing surface and the smooth as-cast surface.

2. EXPERIMENTAL TECHNIQUE

2.1. Surface Treatment

A total number of thirty six (36) specimens were cast at size of 300 mm x 300 mm x 175 mm consists of concrete base with thickness of 100 mm and concrete topping with thickness of 75 mm. The surface of the concrete base was treated at three different surface textures include smooth as-cast, longitudinal groove line and wire-brushing surface. The surface textures were then measured with a portable stylus roughness instrument to measure the peaks height and valleys depth of the roughness profile.

The concrete base were first case and then an hour later after casting, the top of the surface was prepared at three different surface textures as shown in Fig. 1. The smooth surface was left as-cast by trowelled, the groove surface was pierced by a bar size 16 mm into three lines and the rough surface was raked using a stiff brush. Twelve specimens were prepared for each type of surface textures to be tested under variable normal stress at 0 N/mm^2, 0.5 N/mm^2 and 1.0 N/mm^2. The concrete topping was then cast onto the concrete base after achieving the 7 days cube compressive strength. Wet burlap was used for curing and continuously monitored until the test day.



1)Smooth as-cast2)Longitudinal Groove 3)Wire-brushing Roughened

Figure 1. Different types of interface textures

The surface roughness of the concrete bottom was measured by using portable stylus roughness instrument showed in Fig2. The portable stylus is a mechanical device composed of a stylus, digital dial gauge and a ruler set at 150 mm length. The instrument is placed on top of the surface base concrete to measure the peaks height and valleys depth along a sampling length of 150 mm. Readings were taken at an increment of 1 mm.

Figure 2. Portable stylus instrument

2.2. Test setup

In order to develop composite action, a composite concrete is designed to maintain the interface shear strength between concrete base and concrete topping. An experimental was carried on a total number of 36 horizontal shear tests by push-of test method. This method had been used by several researchers to study the composite action between two members and determining the interface shear strength [7, 9, 10]. A schematic diagram of the “push-off” test setup is shown in Fig. 3. The concrete base was fixed to the test frame and the concrete topping was applied with load cell with capacity 1000 kN. A roller support was placed on the top of the specimen to avoid instabilities inherent during the test. Normal load was applied at the top of the roller support using a load cell capacity of 200 kN. Linear variable displacement transducer (LVDT) was used to measure the horizontal displacement of interface slip throughout the test. The LVDT was positioned as close as possible to the interface as indicated in the diagram.

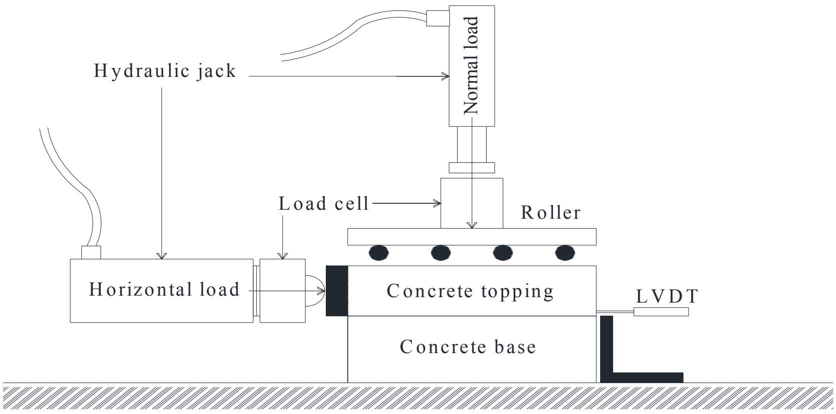


Figure 3. Schematic diagram of the "push-off" test setup

3. RESULTS AND ANALYSIS

3.1. Horizontal Load

Figs. 4 showed the relationship between horizontal load and interface slip for σ_n = 0N/mm^2. The interface slip was measured and this was related to the bond between the concretes. In general, the horizontal load increased steadily with little slip until the bond failure load was reached. The bond failure load was defined as a load at which cohesion concrete bond at the interface was broken [11]. However, when normal stress was increased to 0.5 N/mm^2, 1.0 N/mm^2 and 1.5 N/mm^2, there was a delay of the peak point failure load to occur. After the failure load occurred, the concrete layers were sliding and separate and the load was decreased and leveled off depending on the amount of normal stress applied on the specimens. The state of peak point load before the separation of concrete layers occurred was referred as the pre-crack interface shear strength.

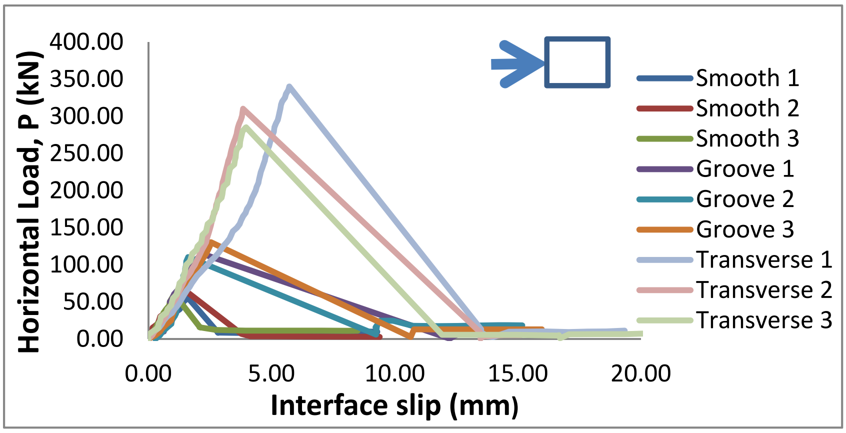


Figure 4. Horizontal load-interface slip relationship for σ_n = 0 N/mm^2

3.2. Roughness parameter

In the Table 1 showed the summary of test results of pre-crack interface shear strength and roughness parameters. The roughness parameters listed in the Table 1 is based on the parameters given in the BS 1134[3]and previous studies [4, 6, 7, 12]. A total number of 14 roughness parameters were determined for each of specimens at different types of surface textures. The roughness parameters were then correlated with the interface shear strength by assuming linear correlation as presented in Table 2. The best roughness parameter was mean peak height, R_{pm}, at correlation of coefficient of 0.950 (0 N/mm^2), 0.956 (0.5 N/mm^2), 0.925 (1.0 N/mm^2) and 0.799 (1.5 N/mm^2). Then, followed by roughness parameter at mean peak-to-valley height, R_z and maximum valley depth, R_v.

Table 1 Summary of Test Results of Pre-Crack Interface Shear Strength and Roughness Parameters at 0 N/mm^2

Test Specimens	Peak Shear Strength (N/mm^2)	R_a	R_z	R_{max}	R_{3z}	R_{3zmax}	R_y	R_{pm}	R_p	R_{vm}	R_v	R_q	R_{sk}	R_{ku}	R_t
S1	0.61	0.35	0.43	0.66	0.30	0.58	0.45	0.83	0.68	0.41	0.64	0.39	1.23	1.59	1.32
S2	0.73	0.07	0.30	0.38	0.15	0.18	0.22	0.36	0.22	0.06	0.19	0.09	1.62	2.80	0.40
S3	0.67	0.48	0.50	0.70	0.37	0.59	0.35	1.04	0.94	0.54	0.79	0.54	1.26	1.67	1.73
G1	1.28	1.11	2.68	3.60	1.37	2.42	3.40	3.27	3.76	0.46	1.98	1.54	1.73	3.61	7.34
G2	1.23	0.86	2.42	3.24	1.01	2.27	3.23	3.00	2.52	0.39	2.05	1.33	2.11	5.37	8.14
G3	1.45	1.37	2.82	4.69	2.44	4.38	3.85	3.40	4.09	0.59	1.63	1.67	1.58	2.89	5.72
T1	3.78	1.52	6.60	7.47	5.36	6.15	5.87	7.66	3.63	1.06	4.66	1.83	0.10	2.16	8.29
T2	3.45	1.29	4.54	6.15	3.60	5.49	5.06	5.91	4.28	1.37	3.69	1.57	1.50	2.60	7.98
T3	3.17	1.29	4.89	5.96	2.36	4.58	4.34	6.69	3.52	1.80	4.62	1.58	1.52	2.75	8.15

S = Smooth, G = Groove & T = Transverse

Table 2 Coefficient of Correlation of Pre-Crack Interface Shear Strength and Roughness Parameters

Coefficient of Correlation , R^2				
Roughness parameters	Peak Shear Strength			
	0 N/mm^2	0.5 N/mm^2	1.0 N/mm^2	1.5 N/mm^2
R_a	0.623	0.523	0.740	0.423
R_z	0.906	0.933	0.831	0.786
R_{max}	0.760	0.891	0.729	0.581
R_{3z}	0.776	0.929	0.750	0.842
R_{3zmax}	0.707	0.779	0.506	0.801
R_y	0.588	0.660	0.484	0.242
R_{pm}	0.950	0.956	0.925	0.799
R_p	0.337	0.714	0.533	0.080
R_{vm}	0.526	0.282	0.662	0.596
R_v	0.907	0.671	0.917	0.788
R_q	0.612	0.574	0.756	0.519
R_{sk}	0.174	0.015	0.126	0.001
R_{ku}	0.003	0.051	0.122	0.000
R_t	0.674	0.801	0.836	0.528

3.3. Determination of friction coefficient

The friction coefficient of concrete-to-concrete bond was determined from equation interface shear strength in the Eurocode 2 [1] :

$$\tau = c.f_t + \mu.\sigma_n + \rho.f_{yd} (\mu.\sin \alpha + \cos \alpha) \quad (1)$$

The clamping stress parameter, $\rho.f_{yd} (\mu.\sin \alpha + \cos \alpha)$ is the presence of shear reinforcement crossing the interface, in which was not presented in this study. Therefore, the Eq. (1) can be simplified as:

$$\tau = c.f_t + \mu.\sigma_n \quad (2)$$

The relationship between interface shear strength and normal stress is shown in Fig. 5. The friction coefficient can be taken as the slope of the line as in coulomb friction equation. The friction coefficient is given in the Table 3. The highest friction coefficient, μ was found for the wire-brushing roughened surface, followed by the groove surface and the lowest was the smooth surface. The friction coefficient from the experimental was higher than the value in Eurocode 2[1]. In the Eurocode 2[1], the surface texture was determined qualitatively by classifying the surfaces as very smooth, smooth, rough and indented. Several researchers [7, 12] mentioned that the codes of practice such as ACI 318[2] and Eurocode 2[1] specify the interface shear strength by observing surface quality and this can lead to incorrect values of friction and cohesion. Therefore, previous study [4, 13, 14] proved that it is possible to use quantitative criterion to classify roughness surface. As shown in Table 4, the friction coefficient can be predicted by quantifying the surface roughness from mean peak height, R_{pm}.While, the other roughness parameters such as mean peak-to-valley height, R_z and maximum valley depth, R_v suggested to be included.

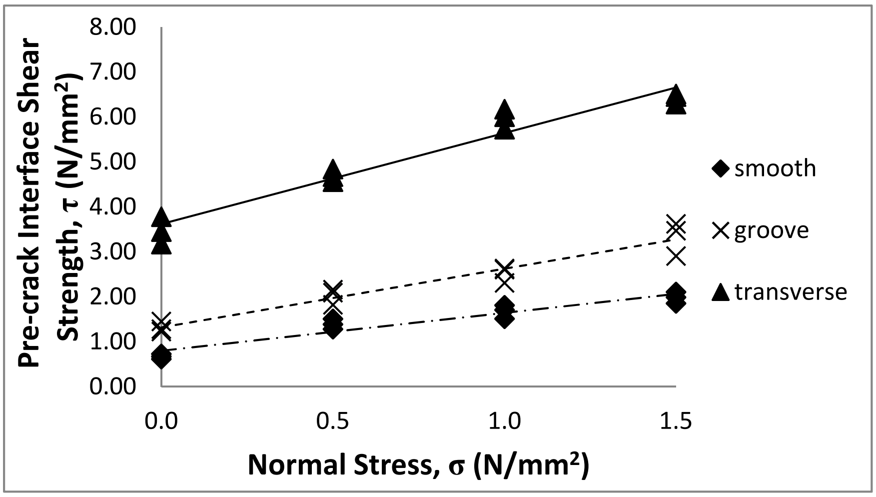


Figure 5. Relationship between interface shear strength and normal stress

Table 3. Friction Coefficient for Varying Surface Textures

Surface Type	Fricton Coefficient, μ	
	Experimental (from Fig. 5)	Eurocode 2
Smooth	0.84	0.60
Groove	1.31	0.70
Wire-brushing roughened	2.02	0.70

Table 4. Friction Coefficient and Roughness Parameter, R_{pm}

Surface Type	Fricton Coefficient, μ	Roughness Parameter, (mm)
	Experimental (from Fig. 5)	R_{pm}
Smooth	0.84	0.36 – 1.64
Groove	1.31	2.22 – 4.53
Wire-brushing roughened	2.02	4.95 – 8.86

4. SUMMARY

Experimental work was carried out to study the interface shear strength of concrete-to-concrete bond using the “push-off” test method. The study can be concluded as follows:

a) The friction coefficient, μ for the smooth as-cast, groove and wire-brushing surface was higher than the value in Eurocode 2.
b) The roughness of the concrete base influences highly the interface shear strength of concrete-to-concrete interfaces.
c) Actual roughness measurement should be specified as by stating the method and specify the roughness is not sufficient.

d) Roughness parameters at mean peak height, R_{pm}, mean peak-to-valley height, R_z and maximum valley depth, R_v are suggested to predict the friction coefficient, since these correspond to the highest correlation coefficient with the interface shear strength obtained.

5. ACKNOLEGDEMENT

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