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# Laboratory Investigation on the Interface Bond Strength between Old and New Concrete

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**Abstract**— Retrofitting of structural member by reinforced concrete (RC) jacketing is a common practice in Bangladesh. Therefore, a new layer of concrete is to cast on the old concrete. The old concrete may found made of brick or stone aggregate and the overlay varies in the similar manner. So new bond is formed between the new and old concrete. Therefore it is essential to know the interface bond behavior between the new and old concrete. In this regard some literatures are reviewed and set parameters those affect the interface bond. From the literatures, it has been found as follows: the bond strength, such as surface pre-wetting, surface roughness, bonding agents, existence of micro cracks, steel connectors, compaction, curing, compressive strength of concrete, etc and these are studied in the current research. In the present study the effect of pre-wetting and surface roughness on the interface bond strength between brick aggregate concrete to brick aggregate concrete found better because of their similarity in texture and monolithic bond at interface. In the Direct shear test bond strength is increased by 105% when roughened by chipping with 24hrs pre wetting and 32.5 % in Slant shear test (SST) than the normal condition.

**Index Terms**— Bond strength, concrete repair, direct shear test, Slant shear test

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## 1 Introduction

The connections between concrete layers with different ages may occur in a wide range of situations, from structures rehabilitation, repairing and strengthening to the construction of buildings both with precast or cast-in-situ elements. The use of these solutions originates the so called composite elements and, as a main requirement, these elements must assure enough bond strength in their interfaces. However, Branco et al. [5] presented that shear stresses transfer mechanism between two concrete layers is a complex phenomenon that involves the combination of different interactions and depends on several parameters that influence the transmission process, such as the pre-wetting, surface roughness, reinforcement crossing the interface, the compressive strength of the weaker concrete, the presence of cracking or the stress caused by normal forces across the interface and differential shrinkage of the layers. As a consequence, Santos [4] is reported that there are large numbers of design expressions nowadays, which are included in several documents, model codes and normative. These equations, which assess the behavior and/or resistance characteristics through the use of variable parameters, were calibrated in order to obtain design values similar to those from empiric tests. One of the key requirements for any kind of repair and strengthening system is to have adequate bond strength between interface of substrate and overlay throughout the service life. When a repair or strengthening is performed, the differences in the properties of two materials will affect bond strength and stress distribution. Of particular relevance are differences in shrinkage, elastic modulus and thermal movement. The repair or strengthening system can be considered as a three phase composite system substrate, overlay and bond zone. Bond zone here refers to the interface and vicinity of bond plane. The bond zone must be capable of withstanding the stresses imposed on the system. Julio et al. [1] and Casal [2] reported that different factors have effects on the bond strength and its integrity such as bonding agents, surface roughness, pre-wetting condition, steel connectors, and micro-cracks on substrate surface etc. Casal [2] find that most the researcher and codes recommended that steel connector is suitable option to obtain adequate bond strength in the interface but main problem is that steel connector act after occurring slip between interfaces. So the bond strength between the interface is important than the steel connector and keys.

In the current research, authors performed Slant shear test (ASTM C882-99) and Direct shear test (ASTM D5321M-14) on specimens with the interface surface left as cast, chipping, wire brushing , pre wetting 24hrs, 16hrs, 8hrs, 0hrs conditions and stone and brick aggregate concrete.

## 2 Experimental Investigation

### 2.1 Materials

The average compressive strength of slant specimens (substrate) was adopted 30.285Mpa (Brick chips) with proportioning ratio cement: sand: aggregates are 1.0: 1.50: 3.0 and water/cement ratio is 0.45. The overlay concrete was compressive strength of brick chips concrete was 40.00Mpa with proportioning ratio cement: sand: aggregates (Bricks) was 1.0: 1.25: 2.50 and W/C ratio is 0.40 and when overlay is adopt with stone aggregates then compressive strength was 32.054Mpa

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with the same proportioning ratio and w/c. For the direct shear test the specimens were cast half portion in 4″ x 8″ clinders with the same properties of mixing condition of slant shear test. In the first phase twelve samples for each test substrate (20cm × 20cm × 40cm) with 30 degrees surface inclination as in [8]. Prisms and cylinders (10cm x 10cm) were cast together at the beginning of the study. After 28 days curing, the specimens were kept in open weather for getting real substrate condition; both specimens were kept open for 110 days from the casting date. Later on, rest portion of concrete prisms and cylinders were cast over the old or substrate concrete with required surface treatment.

## 2.2 Test Set up

Kriegh [11] proposed in a cylinder-shaped specimen for the SST was used to evaluate the bond strength in shear of epoxy based resins. However, a prismatic version was adopted to study the bond strength of concrete-to-concrete interfaces. Two different failure mechanisms can occur on a SST: i) cohesive or monolithic failure and ii) adhesive or interfacial failure. The following objectives were defined for this experimental research: (a) to quantify the influence of Pre-wetting on the bond strength of the interface, considering different methods for increasing the surface roughness; and (b) to observed the failure mode at the interfaces. The slant shear test procedure is adopted to measure the bond strength as shown in Fig. 1 by Aysha et al.[6] and Bonaldo et al.[7]. We have replaced an epoxy resin by an effective surface roughness and condition of pre-wetting.

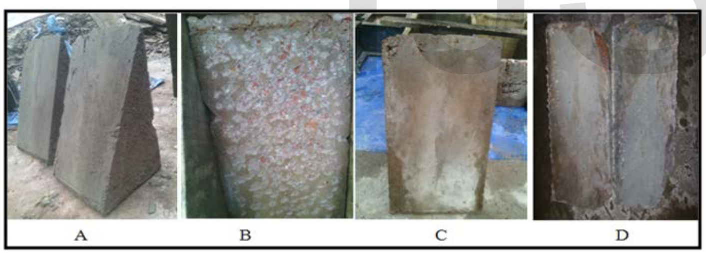


Fig. 1. A) Slant Prism. B) Chipped surface. C) Wire brush surface. D) As cast surface.

The specimens were tested under compression using the standard procedure for the testing of cubes or cylinders for compressive strength. The cut surfaces of old prisms and half cylinders were swiped and chipped using wire brush and chiseled hammer respectively to achieve the surface treatment. Air dry condition of old concrete was achieved by placing the substrate specimens in an aggregate laboratory and keeping the relative humidity of 50% for 110 days. The pre-wetting conditions was ensured by immersing the old concrete prisms and cylinders in water for a period of 24 hrs, 16 hrs, 8 hrs, 0 hrs, respectively and then escaping the specimens from the water, and wiping out the moisture at the surface before placing new concrete as in Fig. 3. After curing the specimens tested using the Universal Testing Machine under compressive force intended to know the Slant shear and Direct shear and subsequently observed the failure modes and shear capacity of planes.

Fig. 2. Substrate concrete cylinders in the forms

Fig. 3. Overlaid new concrete

Shear bond test can be performed with cube specimens, which is phase I and direct shear bond test with cylinder specimens, which phase II as Fig. 4. In the current case all tests were performed for phase II. Direct shear test device is shown in Fig. 5.

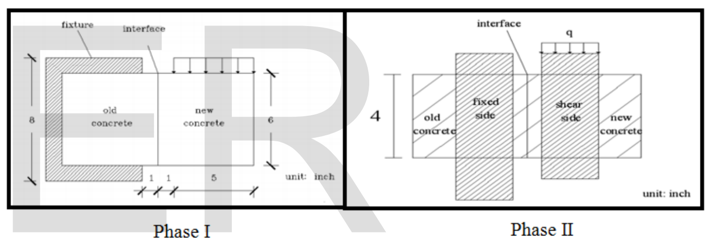


Fig. 4. Shear phases

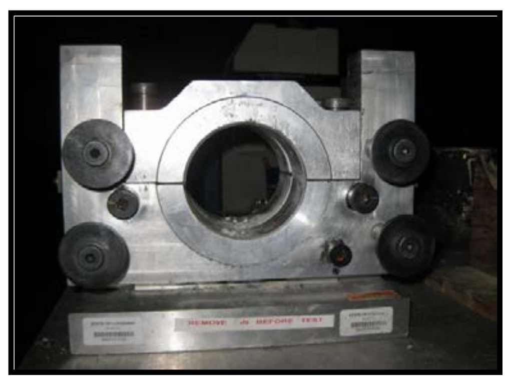

Fig. 5. Direct shear test device (LISST)

## 3 Results and Discussion

Table 1 presents the magnitudes of bond strength of the interface between substrate and overlay for brick aggregate to brick aggregate and brick aggregate to stone aggregate investigated in present study. In the Table 1 and Table 2, Chipped sample, surface roughened sample by wire brush and as cast sample indicates by C, W and As respectively and, the number beside the hyphen denotes its pre-wetting hour. It is seen in the result that chipped sample with 24 hours of pre-wetting period exhibits maximum bond strength followed by pre-wetting period 24, 16, 8 and 0 days. In the same pre-wetting period surface roughened by wire brush samples have a lower value of bond strength than the earlier one. However, as cast sample exhibts poor results than previous two cases. It is to mention that, the failure mode of the samples are found ambigous with the relavant results.

Table 1. Results of Slant shear test

| Sample condition | Load at crack, kN | Load at failed, kN | Bond strength, MPa | Failure mode |
|---|---|---|---|---|
| Brick aggregate to brick aggregate concrete | | | | |
| C-0 | 120 | 435 | 5.18 | Bond failure |
| C-8 | 440 | 440 | 5.24 | Bond failure |
| C-16 | 467 | 594 | 7.07 | Monolithic failure |
| C-24 | 500 | 604 | 7.20 | Monolithic failure |
| W-24 | 440 | 520 | 6.19 | Monolithic failure |
| As-24 | 412 | 412 | 4.90 | Bond failure |
| Brick aggregate to stone aggregate concrete | | | | |
| C-0 | 200 | 406 | 4.83 | Bond failure |
| C-8 | 222 | 406 | 4.83 | Monolithic failure |
| C-16 | 422 | 422 | 5.03 | Monolithic failure |
| C-24 | 480 | 502 | 5.98 | Monolithic failure |
| W-24 | 147 | 456 | 5.43 | Monolithic failure |
| As-24 | 340 | 340 | 4.05 | Bond failure |

Table 2. Result of Direct shear test

| Sample condition | Load at failed, kN | Bond strength, MPa | Failure mode |
|---|---|---|---|
| Brick aggregate to brick aggregate concrete | | | |
| C-0 | 18 | 2.29 | Bond failure |
| C-8 | 32 | 4.07 | Bond failure |
| C-16 | 34 | 4.33 | Monolithic failure |
| C-24 | 38 | 4.84 | Monolithic failure |
| W-24 | 24 | 3.06 | Monolithic failure |
| As-24 | 23 | 2.93 | Bond failure |
| Brick aggregate to stone aggregate concrete | | | |
| C-0 | 12 | 1.53 | Bond failure |
| C-8 | 18 | 2.29 | Bond failure |
| C-16 | 20 | 2.55 | Bond failure |
| C-24 | 24 | 3.06 | Bond failure |
| W-24 | 22 | 2.80 | Bond failure |
| As-24 | 18 | 2.29 | Bond failure |

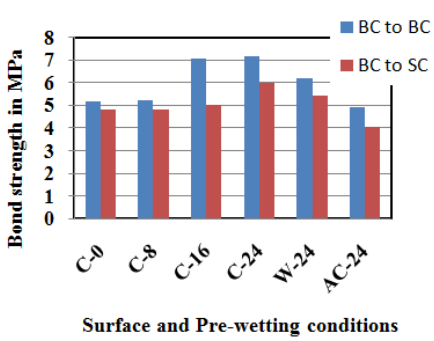


Fig. 6. Bond strength in slant shear test

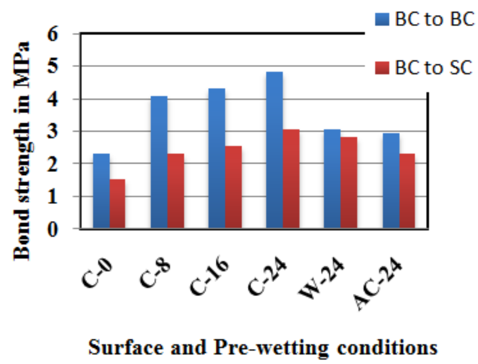


Fig. 7. Bond strength in direct shear test

## 4 Conclusion

From this study the following conclusions can be drawn

1. Bond strength in brick aggregates to brick aggregates found higher than the brick aggregates to stone aggregates concrete because of their similarity in textures and monolithic behavior.
2. Surface treatment with chipping and 24 hrs pre-wetting gives better result.
3. Maximum bond strength is achieved in Slant shear test than direct shear test.
4. In the Direct shear test bond strength is incresed by 105% when roughened by chipping with 24hrs pre wetting and 32.5 % in Slant shear test.



## 5 Recommendations

Following are recommended for the further study to evaluate bond strength between concrete interfaces:

1. The parameters like surface roughness sand blasting, keys, steel connectors, bonding agents etc. may be investigated.
2. The effect of different curing period and concrete compressive strength can be studied.
3. The study is not accounted the shrinkage of substrate and added concrete. therefore, shrinkage impact can be assessed.

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