An Experimental Study on Hardened Properties of Concrete Specimens at Interface of Old and New Concrete

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***Abstract* - An experimental study was performed to evaluate hardened properties of concrete specimens at interface of old and new concrete, using as cast substrate surface and a commercial epoxy resin-based bonding agent under different laboratory tests. Laboratory tests, including compressive strength (bond strength in compression), splitting tensile strength (bond strength in tension), slant shear strength (bond strength in shear) and flexural strength (bond strength in flexure) tests were conducted. The influence of the strength of concrete on the hardened properties of old and new concrete interface, the substrate(old) concrete was kept unchanged with a compressive strength of 20 MPa. On the other hand, two different concrete mixes, with compressive strengths 25 MPa and 30 MPa were used for the new concrete.**

INTRODUCTION

The technique of replacement old concrete by new concrete with efficient bonding agent is part with load in the areas where concrete is carbonated and has to be replaced with new concrete as a measure to deny the further carbonation of concrete.

The quality assurance of bond strength requires test methods that can quantify the bond strength as well as identify the failure mode. There have been numerous investigations led to development of different test methods. The forces which are applied in each test and the failure mode are important in order to choose the proper test. Tests are defined both in laboratory. An interpretive study on test methods is presented which classifies and compares the tests based on the applied force, failure mode and practical importance of each test.

As the failure modes are in compression, in tension, in shear and in flexural. Four test methods are more applicable; four test methods are "compressive strength test, split tensile strength test, slant shear test and flexural strength test ". It can be performed in the lab.

OBJECTIVES OF THE STUDY

This study was aimed at covering the following parameters

- Evaluation of bond strength between old and new concrete at the interface
- Various factors influencing bond strength at the interface of the old and new concrete
- Comparison and discussions of test methods

LITERATURE REVIEW

Magda I Mousa(2015)

The bonding materials used in this study at the interface are modified Styrene Butadiene Rubber Emulsion (SBE), Acrylic Resin (AR), Epoxy Resin (ER), and cement paste (CP). The flexural composite specimen was 100 ×100 ×500 mm with an interface angle of 30°, 45°, and 90° with the horizontal. The split-ting tension composite specimen was cylinder of 150 mm diameter and 300 mm height whilst, the double–L shaped composite specimen was used for direct shear. In order to verify the influence of the strength of repair concrete on the bond strength of old concrete-to-new concrete interface, the substrate concrete was kept unchanged with a compressive strength of 60 MPa. On the other hand, three different concrete mixtures, with compressive strengths 25, 40 and 60 MPa were used for the repair concrete.

Bassam A Tayeh , B H Abu Bakar, M A Megat Johari and Yen Lei Voo(2013)

In recent years premature deterioration of concrete structures due to salt damage has become a serious social problem. Repair and strengthening in order to improve the durability of these structures has become critical. Therefore ultra-high performance concrete (UHPFC) properties in terms of durability and strength are fully exploited in rehabilitation and strengthening. This study was performed to evaluate the bond strength between UHPFC and Normal Concrete (NC) substrate. Slant shear tests were performed to quantify the bond strength in shear, split tests conducted to evaluate the bond strength in indirect tension. The results showed that UHPFC has excellent interlocking with the surface of NC substrate, and then gives bond strength greater than the strength of NC substrate. The bond strength between the UHPFC and substrate depends on the surface treatment increases the bond strength increases .

MIX DESIGN AND EXPERIMENTAL INVESTIGATION

MIX DESIGN OF M20 GRADE CONCRETE: An example of calculating the required quantities of different materials for a considered proportion is given below

Target mean strength = 26.6 N/mm^2
Water cement ratio = 0.52
Cement content = 368.4 kg/m^3
Volume of Concrete = 1 m^3
Volume of Cement = 0.117 m^3
Volume of Water = 0.191 m^3
Volume of Aggregates = 0.682 m^3
Mass of Coarse Aggregate = 1029.01 kg/m^3
Mass of Fine Aggregate = 680.9 kg/m^3

Mix proportions for M20 grade concrete

Cement	Fine Aggregate	Coarse Aggregate	Water
1	1.85	2.79	0.52

M20 grade mix quantity's for compressive strength test in kg/m^3

Type of Mix Proportions	Binder		Fine Aggregate	Coarse Aggregate		Water
	Cement	Fly ash		20 mm	12.5 mm	
SA	368.4	0	681	1029	0	192
SB	368.4	0	681	0	1029	192
SC	294.7	73.68	681	0	1029	192

MIX DESIGN OF M25 GRADE CONCRETE: An example of calculating the required quantities of different materials for a considered proportion is given below

Mix Proportions for M25 Grade Concrete

Cement	Fine Aggregate	Coarse Aggregate	Water
1	1.64	2.79	0.48

MIX DESIGN OF M30 GRADE CONCRETE: An example of calculating the required quantities of different materials for a considered proportion is given below

Mix proportions for M30 grade concrete

Cement	Fine Aggregate	Coarse Aggregate	Water
1	1.40	2.49	0.43

EPOXY RESIN:

The applications for epoxy-based materials are extensive and include coatings, adhesives and composite materials such as those using carbon fiber and fiber glass reinforcements (although polyester, vinyl ester, and other thermosetting resins are also used for glass reinforced plastic). The chemistry of epoxies and the range of commercially available variations allows cure polymers to be produced with a very broad range of properties. In general, epoxies are known for their excellent adhesion, chemical and heat resistance, good-to-excellent mechanical properties and very good electrical insulating properties. The epoxy resin contains two components, they are base and hardener.

Mix Ratio (1 Lt) Base: Hardener	663:337
Coverage	3.5 - 4.0 m2/liter

Compressive strength test (I*S 516:1959):* Casting the substrate concrete cubes of SA type mix of M20 grade concrete using 20 mm coarse aggregates in 100mm x100mm x 100mm size moulds. Curing the substrate concrete cubes for 7days and 28days.After 7 days and 28 days Surface preparation should be done for substrate concrete cubes. Epoxy resin should be applied on the surfaces of substrate concrete cubes. Placing the new concrete over substrate cube of SA type in 150mm x150mm x 150mm. Curing the SA type specimen cube. After completion of 7days and

28days testing should be done for SA type specimen cubes.

Preparation of specimens and testing for compressive strength

Repeat the same procedure for SB type mix of M20 grade concrete using 12.5mm coarse aggregate and tested. Repeat the same procedure for SC type mix of M20 grade concrete using 12.5mm coarse aggregate, cement replaced with 20% fly ash and tested. Few more cubes prepared without epoxy resin by M20 grade concrete in 150mm x 150mm x 150mm size directly and tested under compression

Split tensile strength test *(IS 5816:1999):*

Casting the M20 grade substrate concrete cylinders of size 150mm diameter and 300mm length. Curing the substrate concrete cylinders. After completion of 28days Sawing the substrate concrete cylinders longitudinally in to two halves. After completion of sawing the substrate concrete cylinders longitudinally, Surface preparation should be done.

Preparation of specimens and testing for split tensile strength

Half of the specimens applied Epoxy resin on substrate slant surface and half specimens were left as cast Placing the M25 grade new concrete over substrate half cylinders for one trail and placing the M30 grade new concrete over substrate half cylinders for another trail mix. Curing the cylinders again 28 days and test it. Repeat the process for substrate specimens at age of 56 and 84 days. Few more specimens prepared without epoxy resin and tested

Slant shear test (*ASTM C882:1999):* Casting the M20 grade substrate concrete rectangular prisms of size 150mm x 150mm and 450mm length. Curing the substrate concrete prisms. Sawing the substrate concrete prism at an angle of 30º from vertical or 60º angle from horizontal after 28 days of curing. After sawing Surface preparation should be done. For Half of the specimens applied Epoxy resin on substrate slant surface and half specimens were left as cast.

Preparation of specimens and testing for slant shear strength

Placing the M25 grade new concrete over substrate half specimen for one trail and placing the M30 grade new concrete over substrate half specimen for another trail mix. Curing the prisms again 28days and test it. Repeat the process for substrate specimens at age of 56 and 84 days. Few more specimens prepared without epoxy resin and tested.

Flexural strength test *(IS 516 :1959):* Casting the M20 grade substrate concrete rectangular prism of size 150mm x 150mm and 700mm length. Curing the substrate concrete prism. Sawing the substrate concrete prism at an angle of 90º angle from horizontal after 28 days of curing. After sawing Surface preparation should be done.

Testing specimens for flexural strength

For Half of the specimens applied Epoxy resin on substrate slant surface and half specimens were left as cast. Placing the M25 grade new concrete over substrate half specimen for one trail and placing the M30 grade new concrete over substrate half specimen for another trail mix. Curing the prisms again 28days and test it. Repeat the process for substrate specimens at age of 56 and 84 days. Few more specimens prepared without epoxy resin and tested

RESULTS AND DISCUSSIONS

Compressive strength

Compressive strength test results

	Compressive strength at 7 days(MPa)	Compressive strength at 28 days(MPa)
SA	19.62	28.48
SB	20.93	25.57
SC	19.33	26.74
M20	21.33	28.45

The compressive strength test results shows that there is no much variation of compressive Strength of the specimens tested when compare to control specimens at 7 days and 28 days. The failure of cubes observed was monolithic. A shown in figure 5.1, compressive strength of control specimen is slightly higher than that of the SA, SB, SC for both ages of 7 and 28 days. At 7 days the lowest compressive strength is 19.33 MPa for SC and at 28 days the lowest compressive strength is 25.57 MPa for SB. when fly ash is used in concrete later compressive strength is high but initial compressive strength is low that's why SC specimen 7 days strength is low and 28 days strength is high when compare to SB.

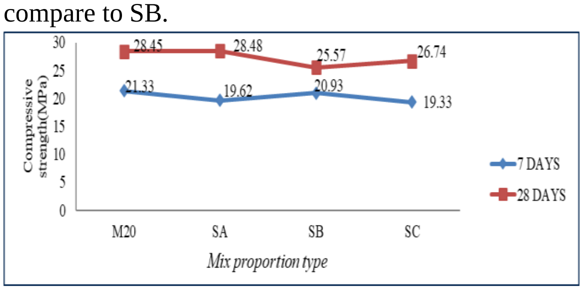
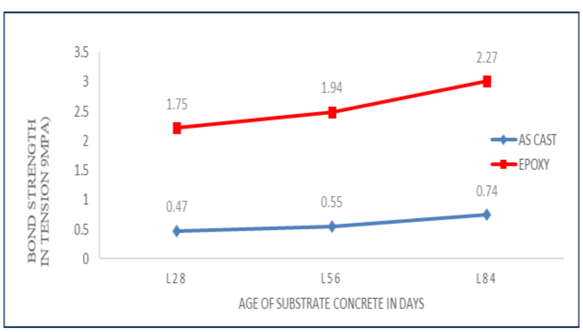


Figure 1 Compressive strength of specimens

Split tensile strength:

Split tensile strength test results

Series	Bond strength in tension(MPa)			
	Epoxy resin		As cast	
	M20:M25	M20:M30	M20:M25	M20:M30
L28	1.89	1.75	0.64	0.47
L56	2.13	1.94	0.88	0.55
L84	2.45	2.27	0.97	0.74



Bond strength for different casting methods of split tensile test M20:M30

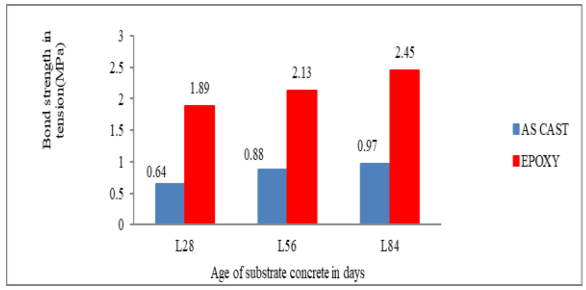


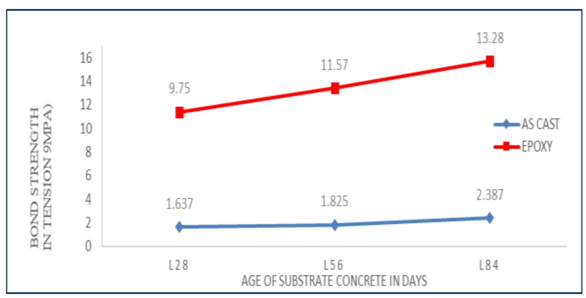
Figure Bond strength for different casting methods of split tensile test M20:M25

Split tensile strength observed that bond strength at interface of M20 and M25 increased 2.6 times, when epoxy resin is used with comparison of as cast specimens. Split tensile strength observed that bond strength at interface of M20 and M30 increased 3.44 times, when epoxy resin is used with comparison of as cast specimens. Bond strength of interface between M20 and M30 increased when compared to M20 and M25 in split tensile strength.

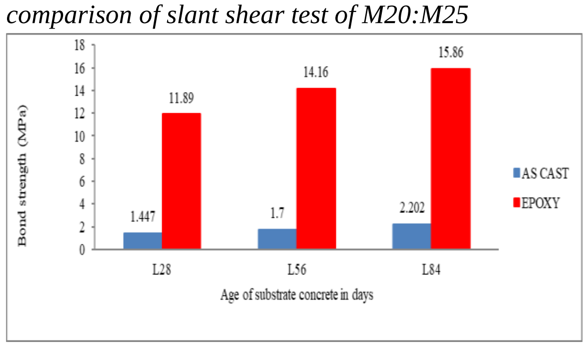
Slant shear strength:

slant shear strength test results

Series	Bond strength in shear(MPa)			
	Epoxy resin		As cast	
	M20:M25	M20:M30	M20:M25	M20:M30
L28	9.75	11.89	1.637	1.447
L56	11.57	14.16	1.825	1.7
L84	13.28	15.86	2.387	2.202



Bond strength for different casting methods comparison of slant shear test of M20:M25



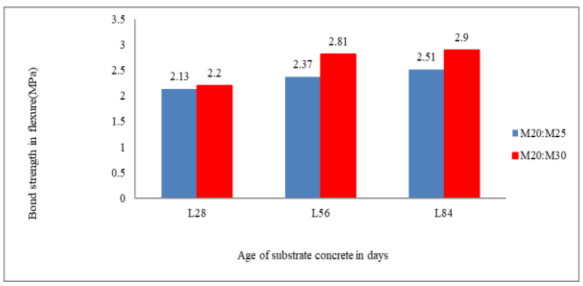
Bond strength for different Casting methods comparison of slant shear test of M20:M30

Slant shear strength observed that bond strength at interface of M20 and M25 increased 5.93 times, when epoxy resin is used with comparison of as cast specimens. Slant shear strength observed that bond strength at interface of M20 and M30 increased 7.92 times, when epoxy resin is used with comparison of as cast specimens. Bond strength of interface between M20 and M30 increased when compared to M20 and M25.

Flexural strength:

Flexural strength test results

Series	Bond strength in flexure(MPa)	
	Epoxy resin	
	M20:M25	M20:M30
L28	2.13	2.2
L56	2.37	2.81
L84	2.51	2.9



Bond strength for difference grade comparison of flexural strength test

Flexural strength observed that bond strength of interface between M20 and M30 increased when compared to M20 and M25.

CONCLUSIONS

- Workability, age difference between specimens, surface roughness were important factors to influencing the bond strength of interface of concrete layers and further study can be required.
- Work can extend to evaluating bond strength between old and new concrete with different binder materials, partial replacements of coarse aggregate and fine aggregate
- Evaluating bond strength of old and new concrete with different fibers and admixtures study can be required.
- Evaluating bond strength of old and new concrete with applying different resins on interface.
- Evaluating bond strength of old and new concrete using of different surface roughness techniques.

Evaluating bond strength of old and new concrete using different curing methods.

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