V－430 Study on Bonding Shear Strength at Interface between New and Old Concrete

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1 Introduction

In concrete-to-concrete repair works, it is essential to ensure good bonding between the new (repair material) and the old concrete in order to achieve durable repair. Most testing methods to measure bonding strength is laboratory test which does not represent the actual condition on site. To date bonding shear strength in-situ is evaluated by bonding tensile strength obtained from pull-out test. However, in many structures such as bridge deck overlay, the main stress acting at the interface is shearing stress. This paper describes the development of a new in-situ testing method to measure bonding shear strength at the interface between new and old concrete and the factors that influence the bonding shear strength.

2 Specimen and Test Method

In this study, torque test is developed as a new testing method to measure bonding shear strength at the interface between new and old concrete. The main instruments are torque meter and an analyzer for recording of torque moment as shown in Fig.1. In the first experiment ,3 rectangular prisms were made from different cement mortar mix characteristics. At the same time cylinder specimens were made from the same mix. Partial cores were cored on the prism and Steel disks were attached to the cores' surface with epoxy. Then torque instrument was attached to the steel disk and force was applied through the torque wrench until failure occurred. The maximum torque moment *Mt* was recorded by the analyzer. The equilibrium equation between maximum shear strength and the torque moment can be obtained by the following equation:

$$\tau_{\max} = \frac{16M_t}{\pi d^3} \qquad \text{Eq. (1)}$$

where d = diameter of core

Compression and tensile tests were carried out on cylinder specimens according to JIS A 1108 and A 1113 to evaluate the shear strength with those results.

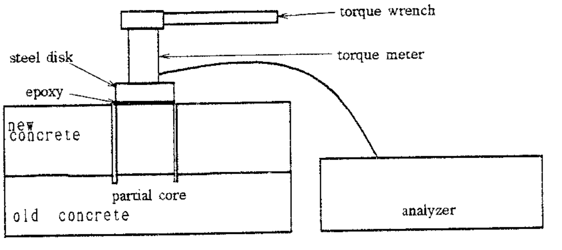

Fig. 1 Torque Test Instrument

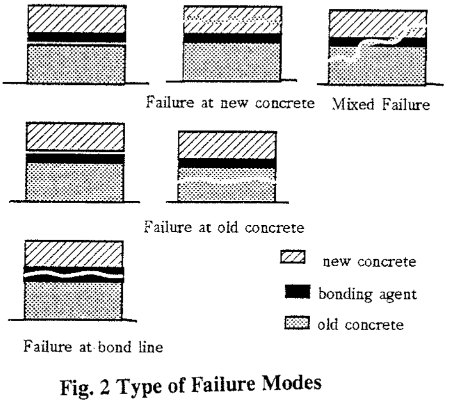

Fig. 2 Type of Failure Modes

In the second experiment, two rectangular prisms made from cement mortar of mix characteristic ratio of cement to sand of 1:3 and water/cement ratio of 0.65 and considered as old concrete. The surface of each prism was divided into 4 parts and different surface treatment were applied to each part as shown in Table 2. Then new layer cement mortar was casted on the prisms and cured. Partial cores were cored on the prisms until they reached to the bonded surface and torque test were carried out. Failure of specimens occurred at the weakest part which could be at the old concrete, new concrete, bonded surface or the combination of these as shown in Fig 2. Pull-out tests were also conducted on the same prisms and results were compared with torque test as shown in Table 2.

3 Test Results and Discussion

In Table 1, τ_{max1} is derived from Eq. 1 using torque moment obtained from the experiment, while τ_{max2} τ_{max3} are estimations from theoretical analysis using Mohr estimation equation and Itoh's empirical equation as shown below:

$$\tau_{max2} = (\sigma_c \times \sigma_t)^{0.5} / 2 \qquad \text{Eq. (2)}$$

$$\tau_{max3} = 0.252\sigma_c - 0.000246\sigma_c^2 \qquad \text{Eq. (3)}$$

From Table 1 it was found that the values of τ_{max1} and τ_{max2} coincide. This indicate that the developed testing method ia an appropriate method to evaluate bonding shearing strength.

From Table 2 in the case without any usage of bonding agent(water was used instead), the chipping treated cores had developed the highest bonding shear strength as compared to hydrodemolition and grinding treated cores as expected because chipping treated cores had the highest degree of surface roughness. Failure modes of chipping treated cores were mixed failures, while the other two were bonded surface failures. This indicates that the higher the degree of surface roughness the higher the bonding shear strength.

Comparing the result of hydrodemolition treated cores without bonding agent and with cement slurry as bonding agent, the bonding shear strength of the later increased over 2 times. For grinding treated cores, the usage of epoxy as bonding agent had increased the bonding shear strength by 4 times. Failure modes of cores using bonding agents were mixed failure as shown in Fig 3. This indicates that bonding agents help to increase bonding shear strength at the interface between new and old concrete.

Looking at the result of shot blast treated cores using cement slurry and epoxy as boding agents, it was found that the values of bonding shear strength were about the same. This indicates that using epoxy as bonding agent does not necessarily give better bonding strength compared to cement slurry although the price of epoxy is generally higher.

The result of pull-out tests showed the same trend as in torque tests as shown in Table 2.

From Fig 4, there is a linear relationship between bonding shear strength and bonding tensile strength.

Table 1 Shear Strength Results

Mortar Mix	Experiment τ_{max1} (kgf/cm²)	Estimation τ_{max2} (kgf/cm²)	Estimation τ_{max3} (kgf/cm²)
Type 1	46.24	57.17	63.24
Type 2	67.72	68.15	63.82
Type 3	54.06	56.85	62.83

Table 2 Result of Torque and Pull-out Tests on Various Surface Treatments (kgf/cm²)

Surface Treatment	Bonding Shear Strength	Bonding Tension Strength
Chipping + water	31.22	16.88
Hydrodemolition + water	14.25	1.81
Grinding + water	9.42	3.49
Hydrodemo+cement slurry	38.57	6.42
Grinding + epoxy	41.35	15.32
Shot blast + cementslurry	42.52	18.9
Shot blast +epoxy	38.44	21.74

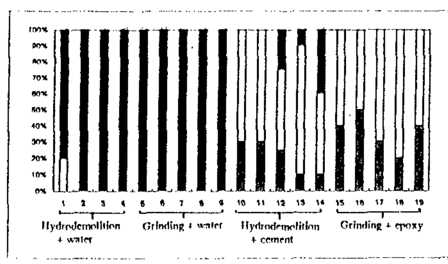

Fig. 3 Failure Mode of Cores with/without Bonding Agent

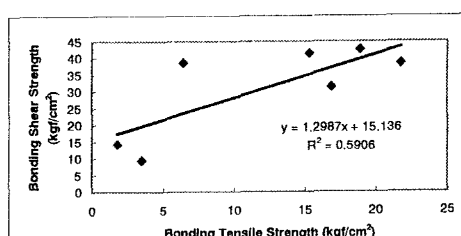

Fig. 4 Bonding Tensile Strength Vs Bonding Shear Strength

4 Conclusion

In this study, a new testing method to measure bonding shear strength by using torque test has been developed. There is a good correlation between shear strength obtained experimentally from torque tests and theoretical estimation. There is a linear relationship between bonding shear strength and bonding tensile strength. The higher the degree of roughness of old concrete surface the higher the bonding shear strength. Applying bonding agent such as cement slurry or epoxy help to increase greatly the bonding shear strength. For fatigue shearing strength, a continuos study should be carried out.