Feasibility of using ultrasonic pulse velocity to measure the bond between new and old concrete

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Abstract

Connecting new and old concrete is required in many practical situations, such as repairing, strengthening or extending existing reinforced concrete buildings or members. In addition to using this technique at construction joints. It is obvious the practical difficulties to measure the bond attained at the interface surface between the new and old concrete. Doing the destructive shear test at the interface surface is not an option in most practical cases due to its destructive character. So, this paper aims to study the feasibility of using the nondestructive ultrasonic pulse velocity to evaluate the bond attained at the interface surface between new and old concrete. An experimental work has been done to 24 specimens of normal and high strength concrete, with and without using an epoxy bonding agent at the interface that connect the two materials. The results of experiments clearly shown that this method can be used to evaluate the acquired bond between the new and old concrete.

Keywords: Concrete, Bond, Ultrasonic Pulse Velocity, Shear Strength, Epoxy Agent

الخلاصة

تظهر الحاجة الى الربط بين الخرسانة الجديدة والقديمة في العديد من التطبيقات العملية، مثل الترميم أو التقوية او تمديد البنايات او العناصر الخرسانية المسلحة، بالاضافة الى استخدامها في المفاصل الانشائية. وتظهر بشكل واضح الصعوبات العملية في كيفية قياس مقدار الربط المتحصل في السطح المشترك بين الخرسانة الجديدة والقديمة. إجراء الفحص الاتلافي للقص على السطح المشترك بين الخرسانة الجديدة والقديمة لا يكون الخيار المناسب في معظم الحالات العملية بسبب طبيعته الاتلافية. لذلك يهدف هذا البحث الى دراسة امكانية استخدام فحص سرعة الموجات فوق الصوتية غير الاتلافي لتقييم الربط المتحصل عند السطح المشترك بين الخرسانة الجديدة والقديمة. تم عمل التجارب المختبرية على 24 نموذجاً من الخرسانة الاعتيادية والعالية المقاومة، وذلك مع أو بدون استخدام عنصر الايبوكسي المحسن للربط بين المادتين. بينت نتائج الفحوصات التجريبية بشكل واضح امكانية استخدام هذه الطريقة لتقييم الربط المتحصل بين الخرسانة الجديدة والقديمة.

الكلمات المفتاحية: الخرسانة، الربط، سرعة الموجات فوق الصوتية، مقاومة القص، محسنات الايبوكسي

1. Introduction

It is very important to evaluate the successful of repairing an existing defected concrete member when adding new concrete to it. Testing the compressive strength of the new concrete is necessary but not sufficient to give an idea about the strength of the joint between the new and old concrete. The bond between the two materials need to be determined to avoid the case of a weak joint .A destructive shear test is required but it is not practical or feasible in most cases.To the researchers’ knowledge,there is no practical method to evaluate the surface bond for such repaired concrete members onsite.

Pu-Woei Chen, Xuli Fu and D.D.L. Chung 1995, used shear tests on laboratory specimens and showed that the bond strength between the old and new concretes was increased up to 89% by addition of short carbon fibers to the new concrete compared to that used admixtures. This effect of fibers addition is attributed to the decrease in drying shrinkage and the resulting decrease in the stress at the interface between the new and old concrete.

S.Ashok Kumar and M.Santhanam 2006, studied the efficiency of using ultrasonic pulse velocity (UPV) method to detect cracks in concrete. They conducted a series of measurements on horizontal and vertical cracks by using UPV on beams and slabs with and without damaging the specimens. The results shown that the UPV method is accurately measure the vertical cracks but the accuracy decreased in measuring horizontal cracks.

Alexandre Lorenzi 2007, investigated the effect of water cement ratio, aggregate type, air incorporator and curing on the strength of concrete and the accuracy of ultrasonic pulse velocity for these variables to estimate the compressive concrete strength. The results shown that the UPV method gave good identification to reflect the effect of these variables on strength of concrete.

H-C. Shin & Z. Wan 2010, used shear tests to study the bonding at the interface surface between new and old concrete. Different moisture conditions (saturated with surface dry and air dry) for old concrete. For new concrete two w/c ratios and a silica fume addition were used. It was found that silica fume in new concrete increases the compressive strength and shear bond strength at the interface between new and old concrete. The low w/c ratio used for new concrete lead to a higher compressive strength but a lower shear bond. The SSD surface of old concrete resulted higher bond strength compared to air dry.

AYSHA H. 2014,studied concrete composite units comprising of two concrete parts. She found that interface readiness and the kind of strengthening(tensile or compressive)impressively impact adequacy.Through a comparison between strengthened and initial specimens, the productivity of the fortifying strategy is assessed.

The present work investigates the efficiency of using Ultrasonic Pulse Velocity (UPV) method to evaluate the surface bond strength between new and old concrete. The shear strength test and ultrasonic pulse velocity (UPV) have been measured for twenty-four specimens by using normal and high compressive strength for old and new concrete in different ways in addition to painting old concrete surface at contact area by epoxy bonding agent for half of the specimens to increase the shear strength.

2. Ultrasonic Pulse Velocity (UPV) Method

The method depends on measuring the velocity of a longitudinal stress wave transmitted through the material. A transducer of an electro-acoustical generation device is held in contact with one surface of concrete member and a signal receiver held in contact with the other opposite surface. The velocity of the transmitted pulse (V) is then calculated by dividing the distance between the transducer and receiver (L) on the elapsed time (T).

3. Experimental Study

3.1 Materials

3.1.1 Concrete

Two types of concrete mix were designed to produce normal and high strength concrete. The used materials were including an ordinary Portland cement (OPC), crushed gravel (G), sand (S), water (W), silica fume (SF) and Superplasticizer (SP). The properties of designed mixes are shown in table 1.

Table 1. Composition and properties of normal and high strength concrete mixtures

Concrete Mix Design	OPC (kg)	G (kg)	S (kg)	W (kg)	SF (kg)	SP (liter)	Slump (mm)	Density (kg/m^3)	Cube Compressive Strength (MPa)	
									7-day	28-day
N	400	1200	800	180	--	--	130	2380	20.1	30.5
H	460	1100	750	120	50	12	135	2440	63.5	78.7

3.1.2 Epoxy Bonding Agent

The Two-Parts Structural Epoxy Bonding Agent (Sikadur-32 LP), shown in fig. 1-a, is used to paint old concrete at joint area (after cleaning it) before attaching the new concrete for 12 specimens. This two-parts bonding agent, based on a combination of epoxy resins and special fillers, designed with a longer pot life or working time for use at temperatures between +20°C and +40°C and used for bonding fresh to hardened concrete. The two parts were mixed together for at least 3 minutes with a mixing spindle attached to a slow speed electric drill (max. 300 rpm) until the material becomes smooth in consistency and a uniform grey color as shown in fig. 1-b.

Fig. 1- Using epoxy agent between new and old concrete

3.2 Specimens details

Two concrete pieces poured first labeled (old concrete) and then after more than 6 months, new concrete piece labeled (new concrete) poured in full attachment with the old concrete. The dimensions of specimens are shown in fig. 2. The two types of test, the UPV and shear test, have been done to the specimens after 28 days curing of the new concrete pieces.

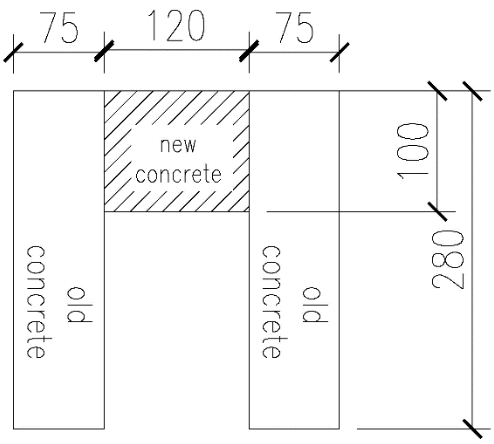

Fig. 2- Specimen dimensions and configuration

Eight groups of different surface bond poured. Each group consists of three specimens that have same conditions of pouring. The details of groups are shown in table2.

Group No.	Type of old concrete	Type of new concrete	Using Epoxy	Symbol
1	Normal strength	Normal strength	No	N-N-N-1
				N-N-N-2
				N-N-N-3
2	Normal strength	Normal strength	Yes	N-H-Y-1
				N-H-Y-2
				N-H-Y-3
3	Normal strength	High strength	No	N-H-N-1
				N-H-N-2
				N-H-N-3
4	Normal strength	High strength	Yes	N-H-Y-1
				N-H-Y-2
				N-H-Y-3
5	High strength	Normal strength	No	H-N-N-1
				H-N-N-2
				H-N-N-3
6	High strength	Normal strength	Yes	H-N-Y-1
				H-N-Y-2
				H-N-Y-3
7	High strength	High strength	No	H-H-N-1
				H-H-N-2
				H-H-N-3
8	High strength	High strength	Yes	H-H-Y-1
				H-H-Y-2
				H-H-Y-3

Table 2- Specimens groups of the study

3.3 Instrumentation and Testing method

The aim of this paper is to show if there is a distinguished relationship between the ultrasonic pulse velocity (UPV) and the strength of the bond between new and old concrete. At first, UPV has been measured for each new and old specimen separately, as shown in fig.3(a,b,c). Then, UPV measured through the assembly of the new and old pieces connected together in a manner that the pulse travel perpendicular to the interface surfaces as shown in fig.3-d. The UPV measured by using Proceq device as shown in fig. 4.

The second stage is conducting the destructive shear strength test by applying monotonic load using computerize Universal Testing Machine as shown in fig. 5. The applied loads were increased successively until specimen failure by shear.

Measure UPV through old concrete piece 1 of specimen

) Measure UPV through old concrete piece 2 of specimen

Measure UPV through new concrete of specimen

) Measure UPV through old and new concrete connected together

Fig. 3 – UPV measurement of the specimens

Fig 4- The Proceq device used in the study

Fig 5- The computerized universal testing machine used in the study

4. Calculations

The UPV device measured the time of transferred wave through the concrete. The specimen is divided into 3 pieces (old-new-old). The time measured for each piece of concrete directly by UPV device and then the speed calculated for old (Vold) and new (Vnew) concrete by dividing the distance of wave (thickness of specimen= 75 mm) by recorded time for each one as shown in figs 2 (a,b,c). Then, the time measured through all connected pieces as shown in fig. 2d, and the speed (Vt) calculated by dividing wave distance (old-new-old thickness = 270 mm) by recorded time. Considering the contribution of each piece of concrete in measuring velocity for UPV through all pieces.

Total wave distance 270 mm = distance (2old= 150 mm + new= 120mm)

Contribution of old concrete (Cold)= distance of old concrete /total distance
= 150/270 = 0.556

Contribution of new concrete(Cnew) = distance of new concrete /total distance = 120/270 =0.444

These contributions were used to determine the average velocity (Vac) from velocities measured separately for each piece.

Vac = Cold *Vold + Cnew* Vnew
= 0.556 * (average of 2 Vold) + 0.444 * Vnew

The comparison between Vt and Vac will give sense if there was a delay in transfer time between the two cases, i.e. when speed is averaged after measuring it separately for each piece and when speed is measured to the integrated specimen. The delay meant that there is a weak in bond between old and new concrete. To quantify the accuracy of this method for different types of bonding, the percentage of difference between Vac and Vt were compared with experimental shear strength test for joint area between old and new concrete for each specimen.

5. Results and discussion

Table 3 shows the results of experimental tests and calculations for shear strength, Vt, Vold, Vnew, Vac and DV (difference percentage of (Vac-Vt)). The results shown that the DV decrease with increase in shear strength for all tested specimen groups and also the values of DV for all specimens of same group are very closed to each other, which reflect the accuracy of this method.

Table 4 shows the percentage of increase in shear strength for group with epoxy agent at interface area compared with same group without epoxy. The results shown that the percentage of increasing in shear strength for normal concrete was more than those of high strength concrete when using epoxy agent but the shear strength for specimens using high strength concrete is greater than those using normal strength concrete.

6. Conclusions

1- Using ultrasonic pulse velocity is very efficient method to evaluate the bond strength between old and new concrete.
2- The determined velocity should consider the contribution percentage of old and new concrete distance which the wave of ultrasonic device transfer through it.
3- Using epoxy agent is very effective method to increase bond strength.
4- The bond strength with using high strength concrete for new concrete increased compared with using normal strength concrete.

Table 3- Measured and calculated variables

Group	Sp.	Symbol.	Shear load	shear Area	Shear stress	Vt	Vold	Vnew	Vac	DV
	No.		N	mm2	Mpa	Km/sec	Km/sec	Km/sec	Km/sec	%
1	1	N-N-N-1	14520	15000	0.968	2.70	3.96	4.18	4.056	50.36
	2	N-N-N-2	14710	15000	0.981	2.72	3.95	4.17	4.050	48.64
	3	N-N-N-3	14020	15000	0.935	2.70	3.92	4.17	4.027	49.30
2	4	N-N-Y-1	40210	15000	2.681	3.52	3.96	4.19	4.061	15.36
	5	N-N-Y-2	41420	15000	2.761	3.55	3.96	4.19	4.064	14.57
	6	N-N-Y-3	39840	15000	2.656	3.50	3.96	4.20	4.066	16.04
3	7	N-H-N-1	25520	15000	1.701	3.68	3.97	5.91	4.831	31.39
	8	N-H-N-2	25040	15000	1.669	3.65	3.96	5.91	4.823	32.22
	9	N-H-N-3	26610	15000	1.774	3.70	3.96	5.93	4.837	30.70
4	10	N-H-Y-1	42700	15000	2.847	4.21	3.97	5.91	4.836	14.76
	11	N-H-Y-2	41850	15000	2.790	4.20	3.97	5.92	4.836	15.12
	12	N-H-Y-3	42690	15000	2.846	4.21	3.99	5.91	4.844	14.97
5	13	H-N-N-1	15800	15000	1.053	3.59	5.97	4.24	5.203	44.93
	14	H-N-N-2	15500	15000	1.033	3.55	5.96	4.23	5.194	46.48
	15	H-N-N-3	14600	15000	0.973	3.59	5.93	4.19	5.158	43.74
6	16	H-N-Y-1	42400	15000	2.827	4.62	5.90	4.18	5.135	11.20
	17	H-N-Y-2	41700	15000	2.780	4.61	5.90	4.21	5.151	11.74
	18	H-N-Y-3	41100	15000	2.740	4.55	5.88	4.18	5.125	12.57
7	19	H-H-N-1	32700	15000	2.180	4.59	5.89	5.97	5.928	29.22
	20	H-H-N-2	31300	15000	2.087	4.56	5.93	5.85	5.897	29.24
	21	H-H-N-3	31140	15000	2.076	4.63	5.90	5.96	5.927	27.88
8	22	H-H-Y-1	75200	15000	5.013	5.61	5.90	5.94	5.919	5.49
	23	H-H-Y-2	76200	15000	5.080	5.64	5.93	5.96	5.943	5.36
	24	H-H-Y-3	75010	15000	5.001	5.53	5.85	5.91	5.880	6.30

Table 4- Shear strength of groups with and without epoxy agent

Group without epoxy	Group with epoxy	Shear strength Increase %
1	2	181
3	4	65
5	6	173
7	8	138

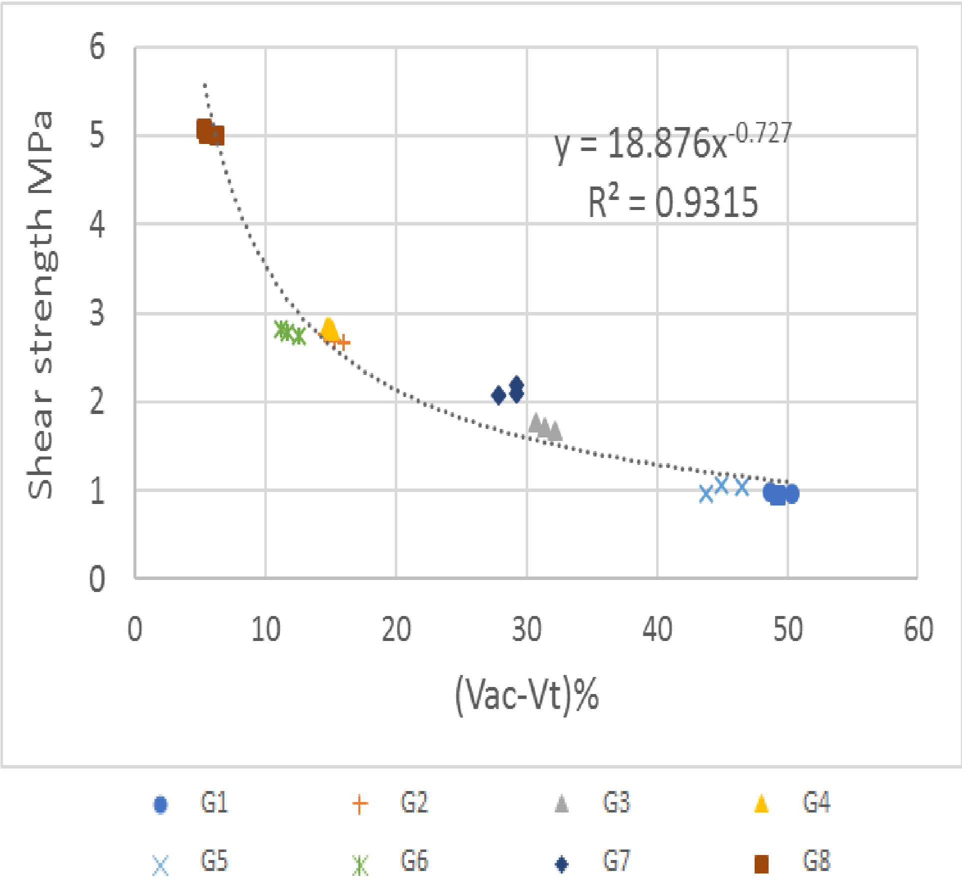

Fig. 3 The relationship between shear strength and DV

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