EFFECTIVENESS OF SCLEROMETER TEST TECHNIQUE ON STRENGTH ASSESSMENT OF HIGH PERFORMANCE CONCRETE

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ABSTRACT

This paper reports the Sclerometric (surface hardness) test using concrete strength Tester (CST) on high performance concrete produced with aggregates available locally. Six different mix proportions of high performance concrete in two series have been made in the form of standard cubes in the laboratory. Destructive and nondestructive test has been carried out on these specimens in 3, 7, 14, 28 and 56 days. The results show that regardless of mix, age and aggregate size, the correlation of the Sclerometric Test and the cube strength is found to be linear. The obtained correlation may be used as a calibration curve of the user of the concrete strength tester using Sclerometric Test for the strength assessment of insitu concrete structure made of high performance concrete.

***Key words**: High Performance Concrete, Sclerometric Test, Rebound Hammer Test, Concrete Strength Assessment*

INTRODUCTION

The Schmidt Rebound Hammer also known as Swiss Hammer was developed in 1948. Impact Hammer or simply Rebound Hammer measures the surface hardness of concrete by releasing a spring loaded plunger which impacts the concrete and measures the rebound distance. This rebound hammer tests only the concrete underneath on relatively small contact area. The results are therefore, sensitive to local variations in the concrete such as the presence of a large hard aggregate, soft paste or voids.

Nondestructive test (NDT) using this technique is not new for the investigation of normal strength concrete [1, 2]. But it is far behind for the testing of high performance concrete. The present method of strength assessment is designed for normal strength concrete. Currently, an equipment called Sclerometric test or simply the concrete strength tester (CST) had been designed to assess concretes having higher grades i.e. high strength concrete. This type of surface hardness test equipment is directly displaying the compressive strength or the surface hardness value in MPa. Details of the application of this equipment on high performance concrete, however, are yet to be established.

Researches on the development of high performance concrete (HPC) have been progressing to a substantial degree. Effects of new constituents had been investigated by Taylor et.al, 1996 and Hassan et.al. 2000, [3, 4], curing effects had been studied by Aitcin et.al. 1994 and Price and Hynes, 1996) [5, 6], mechanical properties had been investigated by Aitcin and Mehta, 1990, and H. Beshr et.al.2003) [7, 8] and durability properties had been documented (Chang et.al, 2001) [9]. However, there has been little research on the evaluation of high performance concrete using nondestructive test techniques especially using surface hardness test techniques. Moreover, none of the national or international standards has proposed any recommendation on the used of surface hardness test on high performance concrete.

It is noted that the test method of rebound hammer and concrete strength tester for normal concrete has been well documented by ASTM C 805 [10], RILEM NDT3 [11] and GOST R 22690 [12]. It is obviously true that the construction industries are moving towards high performance concrete. Therefore, investigation of structural integrity is sought once defects are noticed. In the recent past, research on the HPC by NDT especially using rebound hammer technique have been contributed a little effort by Pascale *et.al,* (2000) [13] and Runkiewicz L. (2000) [14] However, research on HPC by industrial standard NDT still far away to be recognized due to lack of available information. Verification of existing correlation for the HPC with extended form has investigated by Pascale *et.al*, (2000) [13]. They have concluded that combination of rebound test and pulse velocity tests are valid for all grade of concrete. They also have concluded other tests method e.g. pin penetration, pullout test and

Windsor probe implied strength limit reliable up to 80 MPa grade concrete. Further, Roszilah Hamid *et.al.* (2002) [15] have investigated the strength assessment of high performance concrete with fly ash replacement and in different curing environment. They have documented different curing environment did not affect the strength-rebound Index relationship. They also have concluded that rebound hammer method is not a good technique to monitor the strength gain of high performance concrete.

The present investigation aims to find strength correlation between the Sclerometric Test techniques and the actual strength of high performance concrete. The actual strength is given by the results of destructive tests. The high performance concrete is made of locally available materials, including the densified silica fume and superplastisizers.

EXPERIMENTAL WORK

Two series of concrete mixes using different maximum aggregate sizes, namely $A_{12.5}$ and B_{20} are used for this study. Each series had three different mix proportion, designed for different concrete grades of 40, 60 and 80. Series $A_{12.5}$ and series B_{20} comprised of two different sizes of high grade sand stone aggregates namely 12.5 mm (max) and 20mm (max), respectively. The detail of the mix is given in the relevant paragraph.

Material and properties

The cement used was ordinary Portland cement, which complies with the requirements of BS 12 [16]. Fine aggregate (FA) used was washed mining sand and is sourced from Puchong. The crushed coarse aggregate (CA) used was high grade sand stone and is sourced from Hulu Langgat. The grading of fine and coarse aggregate was confirmed with BS 882 [17] and the three mix design in the two series were prepared with coarse aggregate of size 12.5mm (max) and 20mm (max). The silica fume (SF) was a dry powder, called densified silica fume, supplied by Axel Chemie Sdn Bhd. Superplasticiser used was a naphthalene sulphonated polymer-based admixture and complied with BS 5075: part 3 [18].

Concrete mixes

The constituents were proportioned to achieve maximum packing of the particles and thus minimum porosity. In order to achieve this optimum mix design a trial mix for individual mix and series have conducted but not reported here. The detail of design mixes of the two series of the HPC concrete are given in Table 1 and the procedures are given elsewhere [19].

Table 1: Concrete mix proportions

	Cement kg/m^3	water kg/m^3	FA kg/m^3	CA kg/m^3	Silica Fume kg/m^3	Super Plasticizer Liter/m^3	Grade	Slump (mm)	w/b(c+SF) ratio	
Series $A_{12.5}$	391	185	520	1400	0	0	40/20	75	0.47	**Mix1**
	500	169	590	1050	28	10	60/20	125	0.32	**Mix2**
	550	140	645	1043	55	28	80/20	225	0.23	**Mix3**
Series B_{20}	431	194	520	1405	0	0	40/10	80	0.45	**Mix1**
	500	169	580	1050	26	10	60/10	120	0.32	**Mix2**
	500	140	638	1050	55	33.7	80/10	225	0.23	**Mix3**

Test specimens and curing

All tests were done on standard cubes 150mmx 150mm x 150mm and 30 numbers for each mix in each series. Cubes were then cured in water and were removed at about 6hours before the test performed in order to have necessary preparation. Tests were done on 3, 7, 14, 28 and 56 days. Each of the test using the Sclerometric Test was followed by the destructive compression test using a universal compression machine with capacity 3000kN.

Surface Hardness Test

The Sclerometric test technique is similar to the rebound hammer test. However, it is consists of and electronic block and a sclerometer. Connect the sclerometer and the electronic block when test is setout. Switch on the power, the CST-MG4 is ready for operations, then indicator display adjust the test direction by pressing up or down arrow or side accordingly. The main feature of this equipment is an electronic block head is striking on the concrete surface upon releasing the hook. The block head cock the shutter until latch is fixed. The sclerometer must place perpendicular to the test surface by resting on its three points firmly and evenly. Sufficient amount of pressure to be imposed on the sclerometer at the time of test so that when the hook is released the sclerometer does not displace or move. Upon releasing the hook, block head strike on the concrete, the outcome display on the electronic block indicator. Figure 1 shows the details of the sclerometer [20].

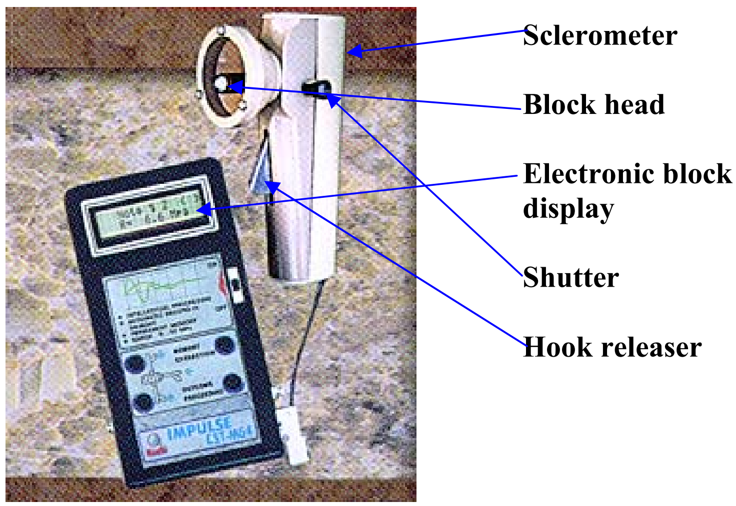

Figure 1: Concrete Strength Tester, CST-MG4

Test procedures were according to the available standards [10, 11, 12] whereby nine points of each molded surface were conducted and hence regards to the spatiality of the equipment each grid points are made 15 numbers of strike by moving the sclerometer 5mm from each sub-points around the grid point. This makes ultimately the whole surface of the cubes are under the impact of the block head. Then these 15 points are calculated automatically by the software programmed in the electronic block (note book) and display the arithmetical mean of the strength of that point. The displayed value of the strength is saved automatically in the memory of the note book. Total of 255 points of the test value can be saved in each test operation. Figure 2 shows the detail of the grid points of the moulded face of the standard cubes.

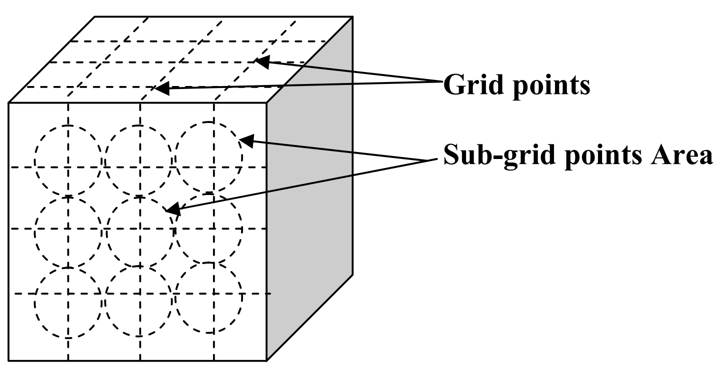

Figure 2: Grid points on the moulded surface of the Standard cube.

RESULTS AND DISCUSSION

Compressive Strength

As mentioned earlier, mix1, mix2 and mix3 in Series $A_{12.5}$ and B_{20} were tested on 3, 7, 14, 28 and 56 days. All the cubes are cured in the water tank by fully submerging them till the testing day. Test results are shown in Figures 3(a)-3(c) for series $A_{12.5}$ and Figures 4(a)-4(c) for series B_{20}.

Concretes in Series $A_{12.5}$ where12.5mm (max) aggregate used, were found to have more scattered results for Mix3 (fig-3c). Concrete in series B_{20} where 20mm (max) size of aggregate were used, were found to be more scattered for Mix1 and Mix3 (fig 4a & 4c). Both of these results indicate that no conclusion can be drawn on the effect of concrete ages on the effectiveness of the concrete strength tester and there is no clear effect of the aggregate sizes on the strength indication of the high performance concrete.

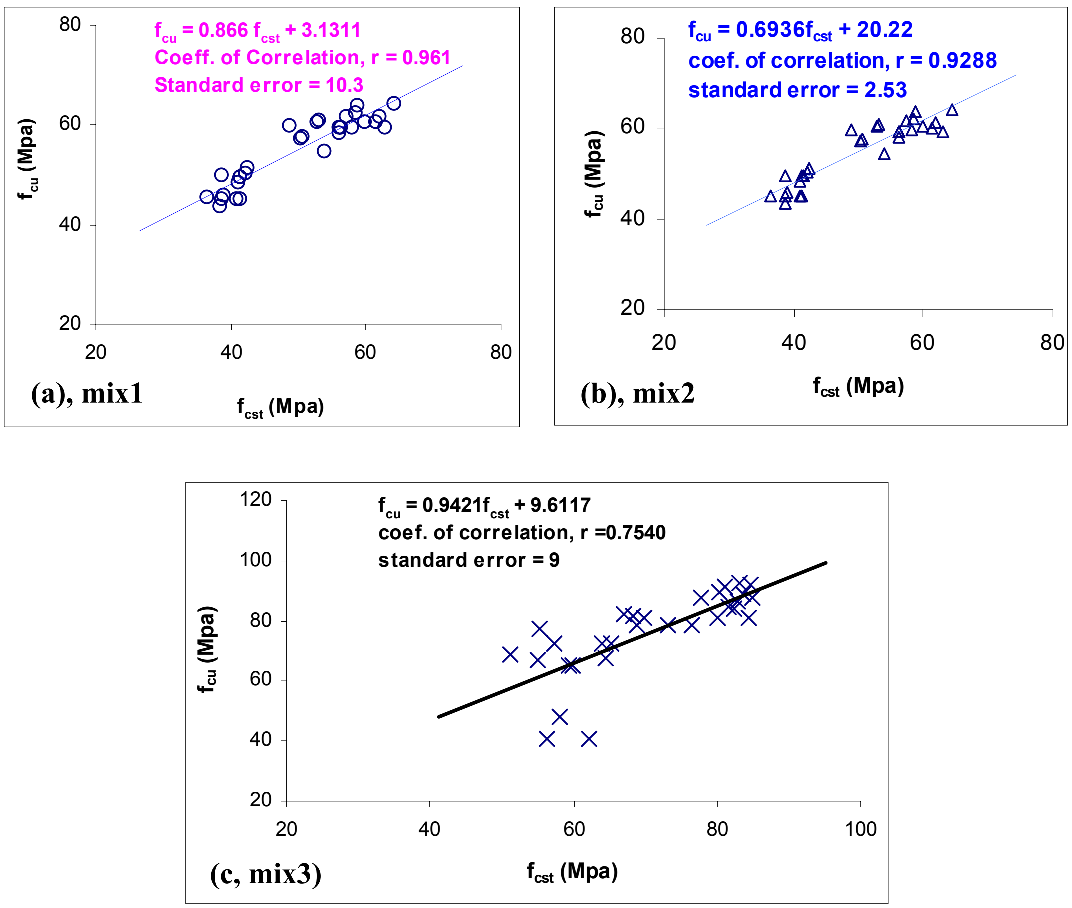

Figure 3: Linear correlation of mean strength by Sclerometric method and cube strength for concrete in series $A_{12.5}$ of 12.5mm (max) aggregate size.

High performance concrete is less sensitive for the NDT technique for the mix 3 partially agreed with the observation made by Pascale et.al.2000 [13]. As mentioned earlier, attempts were made to recommend a single expression to correlate the surface hardness test and the cube strength. Therefore, a correlation was drawn regardless of mix, age and aggregate size (fig 5). It was found that 95% data were having good correlation with the surface hardness test results when they are in the linear regression. This indicates that the correlation between the strength assesment for HPC can be established without the need of another NDT test techniques, as suggested by Pascale et.al. 2000. Therefore, Sclerometric tests technique probably the best NDT technique to predict the concrete strength rather than rebound index.

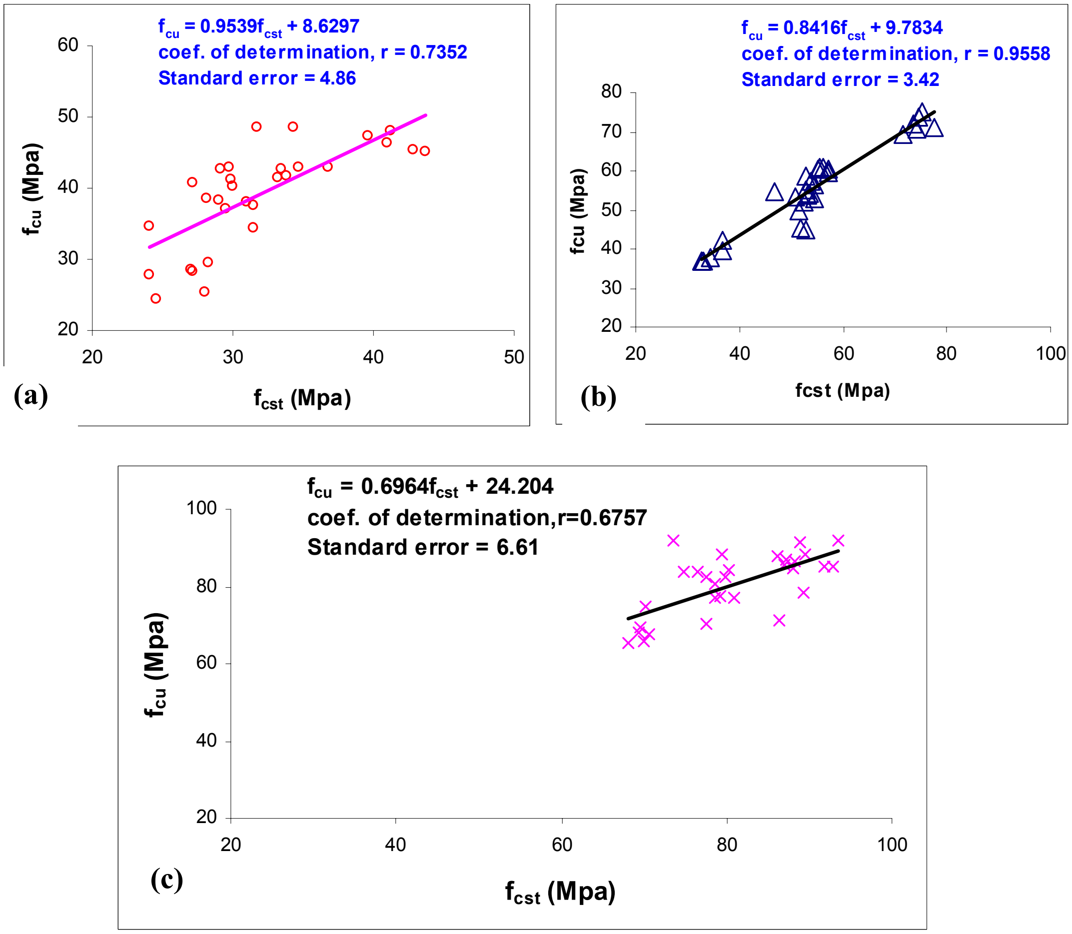

Figure 4: Linear correlation of mean strength by Sclerometric method and cube strength for concrete in series B_{20} of 20mm (max) aggregate size.

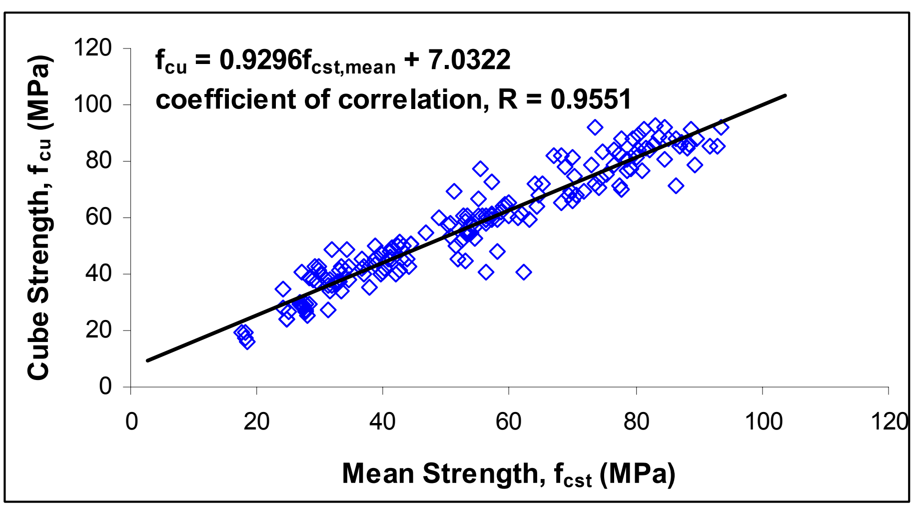

Figure 5: Linear correlation of mean strength by Sclerometric method and cube strength regardless of grade and aggregate size.

CONCLUSION

Based on the results of current studies the following conclusion could be drawn.

- Strength of HPC can be predicted by Sclerometric test regardless of mix proportion, age and sizes of aggregate.
- Linear correlation is the best fit for the strength prediction relationship by using CST surface hardness test.
- Aggregate size has no significant effect on the surface hardness test of HPC.

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