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ScienceDirect

Construction and Building Materials 22 (2008) 981–988

Construction and Building MATERIALS

www.elsevier.com/locate/conbuildmat

Assessing concrete strength by means of small diameter cores

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Received 27 October 2005; received in revised form 27 November 2006; accepted 28 November 2006
Available online 23 January 2007

Abstract

Estimation of concrete strength may be gained from compression tests conducted on cores having a diameter considerably smaller than the recommended one of 100 mm. This paper examines the results of tests applied on the 69 and 46 mm diameter cores. A total number of 2982 cores was tested. The effects of both specimen and aggregate sizes for different length-to-diameter (l/d) ratios on the compressive strength of smaller diameter cores were analysed. The core strengths were compared to those of standard cylinder and cubes. Test results showed that maximum size and type of aggregate significantly affect the strengths of small diameter cores. As the maximum aggregate size increased the strength of core decreased. The strengths of cores removed from crushed aggregate-bearing concrete were somewhat higher than those of ones drilled from natural aggregate-containing concrete. Test results also revealed that the l/d ratio of the specimen is more effective for small diameter cores. The age of concrete was found to be an important factor in the interpretation of the results, the older the concrete the higher the core strength. The coefficient of variation of strength values were noticed to be somewhat higher for 46 mm diameter cores and cores drilled from natural aggregate-containing concrete mixtures. It was indicated that core strength was affected by both specimen and aggregate sizes. Therefore, it was proposed that the size of specimen and aggregate, type of aggregate, age of the specimen should be taken into consideration for the interpretation of the results used to convert the strengths of cores to those of standard cylinders or cubes.

Keywords: Compressive strength; Concrete cores; Evaluation; Testing

1. Introduction

The common way of determining in-situ strength of concrete is to drill and test cores [1–10]. Although the method consists of expensive and time consuming operations, cores give reliable and useful results since they are mechanically tested to destruction [2]. However, the test results should be carefully interpreted because core strengths are affected by a number of factors such as diameter, l/d ratio and moisture condition of the core specimen, the direction of drilling, presence of reinforcement steel bars in the specimen and even the strength level of the concrete [11–16]. The diameter of the core plays an important role in the evaluation of core strength results. Both ASTM and British Standards (BS) specify a minimum core diameter of 100 mm providing that the diameter of the core is at least three times larger than the maximum aggregate size in concrete mixture [17,18]. Turkish Standard TS EN 12504 allows the use of 50 mm diameter cores [19]. However, no correction factors to convert the strength of 50 mm cores to those of cores having larger diameter are given in the standard.

Owing to their easier drilling, handling and storing advantages than larger cores, small diameter cores are usually preferred. During drilling operation, the possibility of cutting reinforcing bars is lower and a smaller hole is left for consequent repair in the case of small diameter cores. Moreover, it is feasible to obtain a relatively large number of small cores, and thus, a larger area can be tested.

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doi:10.1016/j.conbuildmat.2006.11.020

Besides, in some cases where standard core specimens with l/d ratio of 2 are desired, small diameter cores may be the only alternative [12]. In some structural reinforced concrete elements, particularly in pre-stressed units, obtaining 100 mm diameter cores, even with an l/d ratio of 1, is impossible. This may be due to limitations of member dimensions or critical reinforcement locations [11]. For these reasons, the Concrete Society has allowed the use of 50 and 75 mm diameter cores by publishing an addendum to its 1976 report [20].

The most common criticism of small diameter cores is that they are unreliable [11,12]. There are conflicting reports on the effect of core diameter on core strength; some investigators found no effect, while others stating the strength of small cores to be much less than that of larger cores [12]. The principal factors, which may cause differences in behaviour between small and large cores, are the size of the specimen, cutting damage and the relationship between the maximum aggregate size and the diameter of the core [11]. Small cores are also more susceptible to damages during drilling, handling, and storing [12]. The potential influence of drilling damage upon measured strength will be greater with small cores since the ratio of cut surface area to volume increases as the core diameter decreases. Relative size of aggregate with respect to core diameter is more critical for small diameter cores. When the aggregate particles are large in relation to the size of the core, the effects of any aggregate loosened by cutting will be increased. Furthermore, the homogeneity of the material in the test specimen is effectively reduced in comparison with a larger specimen, and this may influence the internal failure characteristics [11].

In this experimental investigation, the effects of aggregate size and type, age of concrete, as well as l/d ratio of the core upon the strength of small diameter cores were studied. The correlations between core strengths and standard cube and cylinder strength were also established for the small cores.

2. Experimental study

A testing program with small diameter cores to investigate the influence of common variables, and also to examine the results in relation to recommended procedures for larger cores was tried. Eight different concrete mixtures were produced using two different types of aggregates possessing four different maximum sizes. An ordinary Portland cement, crushed limestone aggregate and natural aggregates were used in concrete mixtures. Aggregates of 10, 15, 22, and 30 mm maximum sizes were utilized for both types. Mix proportions, some properties and designations of concrete mixtures are given in Table 1.

$250 \times 300 \times 650$ mm concrete beams were cast and moist cured under laboratory conditions until being tested. The cores with diameters of 69 and 46 mm and l/d ratios of 2, 1.75, 1.5, 1.25, 1 and 0.75 were removed from the beams by drilling in the direction perpendicular to that of concrete placement. The l/d ratios mentioned above are values obtained after capping of the specimen. Core specimens were capped with a high early strength cement paste. The compressive strength test results are the average of at least six specimens. Totally, 2982 core specimens were tested in this investigation.

3. Results and discussion

In the present study, the cores with three different diameters and six different l/d ratios were tested and the effects of specimen and aggregate size, aggregate type and concrete age as well as l/d ratios of core on concrete core strengths were examined. The strengths of cores were compared to those of standard cylinder and cube specimens.

The compressive strength developments of cylinder and cube specimens are listed in Table 2. It was found that the standard cylinder and cube strengths of the concretes produced from crushed limestone aggregate were somewhat higher than those of the concretes produced from natural aggregate, although the w/c ratios of the natural aggregate concretes were lower than that of crushed limestone aggregate. It was attributed to the porous structure of the natural aggregate and also to the weaker interfacial transition zone (ITZ) between the aggregate and the cement paste due to the smooth surface of the natural aggregate. At the age of 90 days, the cube compressive strengths were found to be 33 and 30 MPa for crushed limestone and natural aggregate concretes, respectively. The effect of maximum aggregate size was not thought to be significant for the strength of 150×300 mm cylinders and 150 mm cubes.

Table 1
Proportions, some properties and designations of concrete mixtures

Mixture	Mix Proportions (kg/m^3)				Some properties		
	SSD coarse aggregate	SSD fine aggregate	Cement	Water	w/c ratio	Aggregate type	Maximum aggregate size (mm)
MIX-A	696	1043	356	215	0.6	Crushed limestone	10
MIX-B	729	1094	331	200			15
MIX-C	1034	846	315	190			22
MIX-D	1128	752	315	190			30
MIX-E	507	1259	356	195	0.55	Natural aggregate	10
MIX-F	833	994	331	181			15
MIX-G	1158	706	315	173			22
MIX-H	1300	565	315	173			30