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EN 206 conformity testing for concrete strength in compression

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Abstract

Concrete strength in compression is the common characteristic used in the design of concrete structures. However, in general, there are two different types of concrete specimens specified for the determination of concrete strength in compression. They are the standard 150mm diameter by 300mm length cylinders and the standard 150mm cubes. In the case where the maximum size of coarse aggregate is less than 40mm (1½ in.), 100mm diameter by 200mm length cylinders and 100mm cubes may be adopted. Cylinder specimens with aspect ratio (length/diameter) of 2 are likely to be closer to the uniaxial compressive strength as end friction effects at the platens tend to induced a more complex state of stress compared to that of a cubical specimen with aspect ratio of unity. Hence, the two types of test specimens do not provide the same measured strength for the same concrete. For the purpose of conformity testing, the consistency of test results is of greater interest than the magnitude of the measured strength of the concrete specimens. This paper reviews the issues concerning the two types of specimens, (cylinder or cube) and the size of the specimen in relation to maximum size of coarse aggregate used. Some experimental data for compressive strength at 3 strength classes for which slightly over 100 batches produced over several consecutive calendar months were tested. Three types of specimens, 150mm diameter by 300mm cylinders, 150mm cubes and 100mm cubes were adopted for testing at the age of 28-days. Maximum size aggregate of 20mm and CEM I cement were used for strength classes of C32/40, C50/60 and C65/80 achieved with added silica fume. The findings of these test regimes are summarised with recommendations for conformity testing based on EN 206 and its complementary British Standard BS 8500.

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1. Introduction

Concrete strength in compression is the common characteristic used in the design of concrete structures. However, in general, there are two different types of concrete specimens specified for the determination of concrete strength in compression. They are the standard 150 mm diameter by 300 mm length cylinders and the standard 150mm cubes. Traditionally, design codes for concrete structures in different countries may adopt either type of standard specimens. In recent years with the trend towards globalization of construction practice and the promotion of ISO standards to ease international trades, the current European approach in design codes for concrete structure has adopted cylinder compressive strength in the design formulae. However, the conformity assessment of compressive strength may adopt either type of specimens. The corresponding characteristic strength in strength class is stated in terms of both types of specimens, e.g. C40/50 with the first value in cylinder and the second value in cube compressive strength. This paper reports on an a study of three selected strength classes, C32/40, C50/60 and C65/80 with three types of specimens, 150 mm diameter by 300 mm cylinders, 150 mm cubes and 100 mm cubes tested at the age of 28-days. The issues concerning the two types of specimens, (cylinder or cube) and the size of the specimen in relation to maximum size of coarse aggregate used are discussed. The findings of these test regimes are summarized with the recommendation for conformity testing based of EN 206 and its complementary British Standard BS 8500.Structure

2. Background

The design of concrete structures in accordance with BS EN 1992-1-1: 2004[1] adopts the characteristic cylinder compressive strength in its equations. EN 206: 2013[2] provides for conformity testing for concrete strength in compression using 150mm diameter by 300 mm length cylinders or 150 mm cubes only. The complementary standard to EN 206 in UK, BS 8500-2: 2015[3] has added provisions (clause 12.2) for the use of 100 mm cubes for conformity testing. The conformity criteria for 100mm cube specimens are to be the same as those for 150 mm cubes. Both BS EN 1992-1-1: 2004[1] and BS EN 206: 2013[2] provide for equivalent cube compressive strength corresponding to cylinder compressive strength. In general, up to strength class of C55/67, the ratio of 150mm cube compressive strength/150mm cylinder compressive strength is nominally 1.25 (with rounding to nearest 1 MPa). Above strength class of C55/67 up to C100/115, a constant difference of 15 MPa higher for cube compressive strength above that of cylinder compressive strength has been adopted. These relationships are examined at three strength classes, i.e. C32/40, C50/60 and C65/80. In addition, the ratio of 100mm cube compressive strength /150 mm cube compressive strength and the ratio of 100mm cube compressive strength/150 mm cylinder strength at these strength classes are also determined for the same three strength classes. The test results based on three specimens of each shape and size at the age of 28 days after standard curing are analyzed to provide an assessment of their relationships.

2.1. Relationship between cylinder and cube specimens

A From the many studies on the relationship between the two types of specimens in determining the compressive strength of concrete, the general consensus accepts the ratio of 150mm cube compressive strength/150mm cylinder compressive strength is nominally 1.25 in normal range of strength classes. EN 206: 2013[2] puts the limit at C55/67, but for above this strength class and up to C100/115, a constant difference of 15 MPa higher for cube compressive strength above that of cylinder compressive strength has been adopted. This difference has not received as much study, although the trend for the ratio of cube/cylinder strength has been observed to be decreasing with increasing strength classes, e.g. ratio for C60/75 = 1.25 and ratio for C100/115 = 1.15. Neville[3] stated that “in reality, there is no simple relationship between the strengths of specimens of these two shapes”. The difference in the measured strength between the cylinder specimen and the cube specimen is attributed to the difference in aspect ratio in relation to the restraining effect by the steel platen of the testing machine on the “lateral expansion of the concrete in the parts of the specimen near its ends”, estimated to extend to approximately “$\frac{1}{2}d\sqrt{3}$ (where d is the lateral dimension of the specimen)” away from the ends, Neville[3]. Thus, in the case of a cube specimen, there is an overlapping of the affected end zones, but for a cylinder specimen with length/diameter ratio of 2, there is a middle