Oct 31st, 10:45 AM - 12:15 PM

The Effect of Concrete Sample Size in the Compressive Strength Value of Concrete

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Abstract. Concrete is one of the most widely used construction materials. Compressive strength is one of the most important properties of hardened concrete. Different codes use different standards to define the characteristic strength. Albania nowadays is adapting the EN standards, but previously it used to apply the local code KTP. According to KTP standards the concrete samples were cubic specimens of 200mm side length. This study is an attempt to analyze the relation between sample size and compressive strength values of concrete specimens. For this purpose, 4 concrete classes of C8/10, C16/20, C20/25, C30/37 and 5 different cubic sizes of 50, 100, 150, 200, 250mm side length were investigated. The samples were taken according to EN 206-1. Six samples were tested for the determination of the compressive strength value of each class/size combination. According to the compressive strength test results the values increase as the size increases up to 150mm, but as the cube size continues to increase the compressive strength values decrease gradually.

Keywords: Concrete samples, Cube Size, Compressive strength

1 Introduction

The modern construction industry is very much depended on Portland cement Concrete. It has become an indispensable necessity, being the second mostly used material by humankind after water at a rate of 10 billion tons per year [1]. In many countries the ratio of concrete to steel exceeds ten to one. Concrete is a very important material that takes a significant role in our lives. That is why its performance and quality control is crucial for civil engineering professionals [2].

Concrete is an artificial composite material consisting of two phases: the first one is the binding medium, which is the cement paste made of cement water and/or admixtures and the second is composed of aggregate fragments such as fine and coarse aggregate [3].

As concrete is mainly working under compression, compressive strength test is the most commonly used testing method to measure the performance of concrete. The compressive strength test of concrete is mainly performed on cubic and cylindrical specimens, which type, and dimensions may vary from one country to another. Compressive strength testing machine compresses the cube or cylinder until failure occurs. The failure load is divided by cross-sectional area of the specimen giving the compressive strength value of the tested sample. Compressive strength test of concrete specimens is used for experimental work, for quality control or for determining the concrete strength in-place. Strength of concrete is not an absolute value; it may vary from shape and size of specimen. [4].

The compressive strength value of concrete depends on different factors that can be divided into two main groups. The first group includes factors that depend on testing conditions such as: specimen size and its relation with the D_{max}; specimen

moisture content, surface roughness and support type; loading rate etc. Whereas the second group includes factors that depend on the production technology and quality control.

The issue of the effect of shape and size of concrete specimens on the compressive strength test results has attracted the attention of different researchers.

Tokyay and Ozdemir investigated the effect of specimen size on the compressive strengths of high strength concrete of 40, 60, and 75 MPa. They tested different sizes of cylinder and cube specimens It was observed that the strength of the specimens decreases with the increase of the size. Also, in small specimens when its size decreases the strength decreases [5].

Del Viso et al also investigated the size effect in high strength concrete and the differences between cubes and cylinders, their stress-strain curves and failure patterns. They observed that the size effect in cubes is more obvious than in cylinders. The crack pattern resulted to be sensitive to the shape of the specimen, but not to the size [6].

Krishna Rao et. al investigated the effect of size and shape on compressive strength of concrete cubes, cylinders and prisms with different sizes produced with and without additional glass fibres. Compressive strength on 150mm cubes was more than 100mm cubes. Cylinders with diameter 100mm had higher compressive strength than cylinders with 150mm diameter [7].

Table 1. Normal and heavy weight concrete compressive strength classes [8].

Compressive strength class	**Min characteristic cylinder strength $f_{ck.cyl}$ (N/mm^2)**	**Min characteristic cube strength $f_{ck.cube}$ (N/mm^2)**
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C30/37	30	37
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C6075	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

The European standard EN 206-1 specifies the requirements for the constituent materials of concrete, the properties of fresh and hardened concrete and their verification, the limitations for concrete composition, the specification of concrete, the delivery of fresh concrete, the production control procedures, the conformity criteria and evaluation of conformity [8]. According to this standard in order to measure the compressive strength adequately the concrete sample should be taken in

compliance with EN 12390-1 [9] in cubes of 150mm or cylinders of 150/300mm, cured in accordance with EN 12390-2 [10] and tested in compliance with EN 12390-3 [11]. Table 1 shows the characteristic compressive strength of the concrete classes for the two different types of specimen according to EN 206-1.

Since the beginning of concrete and reinforced concrete constructions till 1975, the assessment of concrete compressive strength in Albania was performed on cubic specimens of 200mm side length, even though it was not an officially standardized procedure [12]. Later on, in 1975 the 200mm cubic specimen tested according to KTZ 37-75 [13] was defined in the local codes (KTP). In 2003, the KTZ 37-75 was replaced by national standard S SH EN 206-1 and respectively the cubic specimens of 200mm were replaced by 150mm ones. Taking in consideration that many of the structures built in Albania according to KTP need to be analyzed for their compliance to the modern codes, it is important to be able also to specify the conversion factors for the concrete compressive strength. For that reason, this study is an attempt to analyze the relation between sample size and compressive strength values of concrete specimens and propose conversion factors between different sample sizes.

2 Experimental Program

This study is an attempt to analyse the relation between sample size and compressive strength values of concrete specimens. For this purpose, 4 concrete classes of C8/10, C16/20, C20/25, C30/37 and 5 different cubic sizes of 50, 100, 150, 200, 250mm side length were investigated. Figure 1 shows the moulds prepared for each specimen size

Fig. 1. The moulds prepared for each specimen size

The concrete specimens were taken from ready mix concretes of 4 different classes in a construction site near Tirana. The maximum aggregate size D_{max} for all the concrete classes was chosen as 25mm as this is the most common one used in Albania and also to withdraw it as a factor that may affect the test results. The moulds were filled in three layers and each layer was compacted with the steel rod 25 times. After the placing of concrete, the moulds were covered until the concrete hardened, and then placed for curing in a curing tank until the 28-day test.

Fig. 2. Concrete specimens of 5 different sizes.

Six samples of each concrete class were tested for the determination of the compressive strength value of each class/size combination. Figure 3 shows some of the specimens of different sizes during testing.

Fig. 3. Testing of concrete specimens of different sizes.

3 Results and Discussions

After the evaluation of more than 120 concrete specimen of different sizes and classes the average compressive strength values for each class/size combination were reflected in Table 2 and Figure 4. The concrete class was assessed in compliance with EN 206-1 taking in consideration the 150mm cubic specimen.

Table 2. Average compressive strength values of the four concrete classes for different cube sizes.

	Cubic Sample Size (mm)					
	50	**100**	**150**	**200**	**250**	**150/200 (strength ratio)**
C8/10	7.8	9.7	10.3	10.3	10.0	1.00
C16/20	13.0	17.9	22.1	17.8	17.0	1.24

C20/25	20.6	24.4	27.0	21.1	18.5	1.28
C30/37	**27.0**	**36.8**	**42.4**	**26.7**	**23.2**	**1.59**

The results show that the size of concrete specimen is a very important factor affecting the compressive strength values obtained from the testing of the same concrete mix. For all the four concrete classes part of the investigation it was observed that there is an increase of the strength with the increasing of sample dimensions, then as the dimensions continue to increase the strength value decreases.

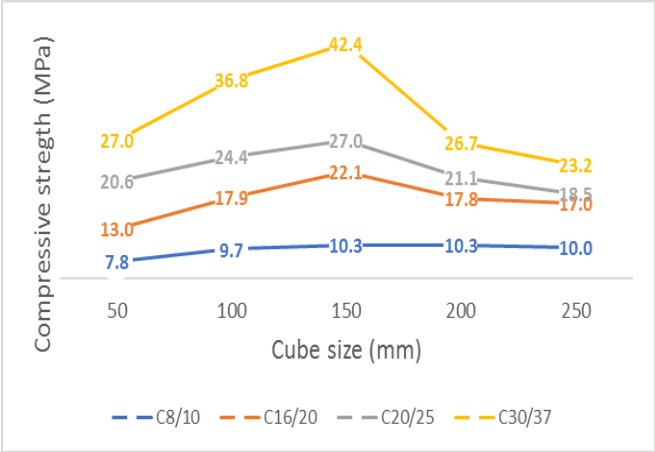

Fig. 4. Compressive strength changes for different cube sizes.

The highest compressive strength values for all four concrete classes were obtained from the 150mm cubic specimens. It was also observed that as the concrete class increases the rate of strength increase and decrease is higher. The results are consistent with literature for larger specimen, on the other hand the smaller specimen vary in different studies. Tokyay and Ozdemir in their investigation obtained similar results, even though their study was focused on high strength concrete [5].

From the comparison between the 150mm and 200mm cubic specimen as shown also in Table 2 the strength ratio between the two specimen sizes increases as the concrete class increases. So in order to obtain the $f_{ck,cube}$ foreseen in the EN standards from the KTZ there should be used different conversion factors for different concrete classes. According to these results the evaluation of compressive strength with 200mm cubes is more conservative that of 150mm cubes, being such on the safe side.

Conclusion

According to the investigation results the following conclusions are drawn:

- The sample size is an important factor in defining the compressive strength of cubic specimen

- The maximum strength is obtained from cubic samples of 150mm side length
- The conversion factors used between different cubic sizes vary depending on the concrete class.
- Further studies should analyse the effect maximum aggregate size, amount of binding material, type of cement etc.

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