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Effects of Size of Coarse Aggregates on the Compressive Strength of Concrete

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Abstract

Concrete is formed by mixing cement, sand, gravel, and water, which then hardens into a robust and long-lasting material. It is extensively utilized in various construction and infrastructure projects due to its strength and durability (Neville, 2011). The strength of concrete is determined by multiple factors, including the size of the aggregates, the porosity, the void ratio, and the proportions in the mix (Mehta and Monteiro, 2005). Two types of aggregates, coarse and fine, are used in the production of concrete (Shetty, 2005). Fine aggregates fill the voids within coarse aggregates, and cement paste fills the voids within fine aggregates, effectively binding the individual aggregates together into a solid structure with the aid of water (Mindess and Young, 2003). The main objective of the study was to examine how the size of coarse aggregate influences the compressive strength of concrete. In pursuit of the research objective, a total of 24 cylinders were tested, each having a diameter of 4 inches and a height of 8 inches. Physical parameters like specific gravity, absorption capacity, and unit weight of both coarse and fine aggregates were evaluated to choose the appropriate aggregate. The Fineness Modulus (F.M) of the coarse aggregate was set at 4.81 and 6.8 to introduce variability in the coarse aggregate composition. The water-cement ratio and other parameters remained constant to observe changes in concrete strength. The mix ratios were 1:1.5:3.0 and 1:2:3.0, with a consistent water-cement ratio of 0.5. From the research it has been observed that the larger the F.M (i.e., the size of the coarse aggregate) the lower the compressive strength of concrete. In this research the compressive strength of concrete having F.M 4.81 of coarse aggregate and mix ratio 1:1.5:3 has found 3.86 % higher in 7 days, 3.0 % higher in 14 days and 3.12 % higher in 28 days as compared to aggregate having F.M 6.8. For the same concrete having mix ratio of 1:2:3, the compressive strength of concrete for F.M of coarse aggregate has found 5.71 % higher in 7 days, 1.30 % higher in 14 days and 2.42 % higher in 28 days. Our study revealed that aggregates with a Fineness Modulus (F.M) of 4.81 exhibited greater strength compared to those with an F.M of 6.8, indicating that smaller aggregate sizes contribute to higher strength.

Keywords: Coarse aggregate, Compressive strength, Fineness Modulus (F.M), Mix ratio.

1. Introduction

The strength characteristics of concrete are influenced by several factors, including the amount of cement used, the ratio of water to cement, the type and quality of aggregates employed, the duration of curing, setting times, and the inclusion of various admixtures and additives (Wang and Zhang, 2019). Coarse aggregate makes up approximately 50-60% of the concrete volume, impacting its strength and durability significantly (Smith and Johnson, 2020). Even though aggregate is commonly seen as passive filler, it plays a critical role in determining concrete's thermal and elastic characteristics, as well as its dimensional stability (Soroushian and Mirza, 1999). Research has demonstrated that modifying the size, grade, and type of coarse aggregate can alter both the strength and fracture characteristics of concrete (Brown and Davis, 2018). Aggregate is divided into two main types: coarse and fine. Coarse aggregate generally consists of particles larger than 4.75 mm while fine aggregate consists of particles smaller than 4.75 mm (Malhotra and Mehta, 2006). Concrete mixes with larger aggregate particles generally demand less mixing water than those with smaller aggregates, while smaller aggregate sizes provide increased surface area for bonding with the mortar matrix (Whitney and Kosmatka, 2002). In concrete mixtures, coarse aggregates not only impact the workability and water requirements but also play crucial roles in the development of strength and long-term durability (Kosmatka, 2006). Studies suggest that a well-graded mix of aggregates, characterized by a balanced distribution of particle sizes, can significantly enhance both the workability and compressive strength of concrete (Chen and Liu, 2019). This optimized aggregate distribution enhances particle packing efficiency, leading to minimized voids and improved interlocking between aggregates and the cement paste. Consequently, concrete demonstrates enhanced mechanical strength, increased durability, and improved resistance against environmental factors, thereby extending the lifespan of concrete structures (Mindess, Young and Darwin, 2003). The size of coarse aggregates plays a crucial role in influencing the compressive strength and durability of concrete, highlighting its pivotal significance in construction and engineering applications (Lee and Park, 2017).

2. Objectives

1. To evaluate the change of compressive strength of concrete due to change of size of coarse aggregate.
2. To compare the compressive strength of concrete having different size of aggregates with different mix ratio.

3. Methodology

3.1 Selection of materials

The study examined the influence of coarse aggregates on concrete strength using brick aggregates with fineness moduli of 6.8 and 4.81. Physical parameters including specific gravity, unit weight, and absorption capacity were evaluated. Fine aggregates comprised a blend of Sylhet sand and local sand in a 1:1 ratio.

3.2 Preparation of concrete cylinder sample

With a constant water-to-cement ratio (W/C) of 0.50, 24 cylindrical specimens with a diameter of 4 inches and height 8 inches were prepared for each ratio. The ratio of mixes was taken 1:1.5:3 and 1:2:3. For each mix ratio 24 cylinders were prepared using coarse aggregate having F.M 6.8 and other 24 cylinders were prepared using coarse aggregate having F.M 4.81. Sylhet sand and local sand were combined to produce a total of 48 cylinders for testing purposes. The cylindrical specimens were 4 inches in diameter and 8 inches in height.

3.3 Curing of concrete

After preparation, the cylindrical specimens were submerged in water for curing. Water curing, specifically ponding, was employed for this purpose. The pond was constructed using plain concrete and was thoroughly cleaned prior to curing the specimens.

3.4 Testing of specimens

At intervals of 7, 14, and 28 days, the samples underwent a drying period of 4 hours before being subjected to crushing using a Universal Testing Machine (UTM). During this process, compressive loads were applied to each sample, and the compressive strengths and failure patterns were meticulously documented.

4. Results

4.1 Sieve analysis of Aggregate

The sieve analysis of two types of aggregate (larger and smaller) and the sand (Sylhet and local sand, ratio 1:1) were executed and F.M of the coarse aggregate were found 6.8 and 4.81 and the combined F.M of the sand was found 2.11.

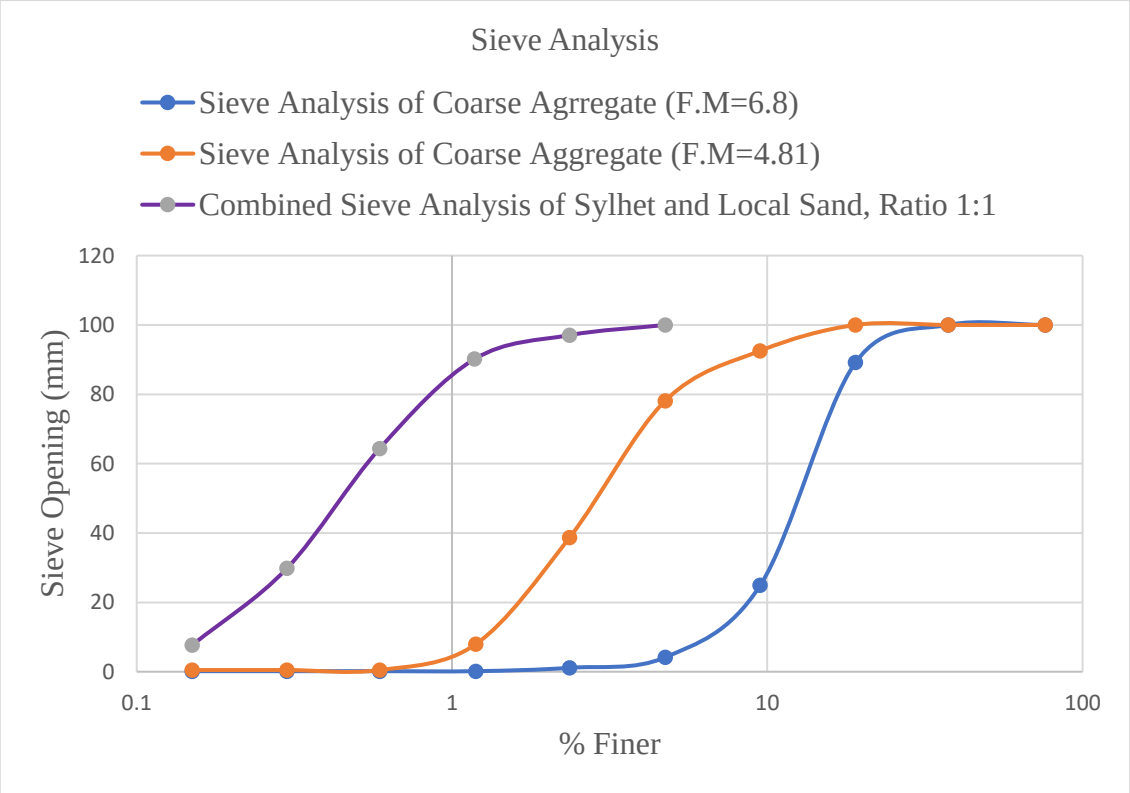

Figure 1 : Gradation curve of the coarse and fine aggregate

4.2 Properties of aggregate

The bulk specific gravity of the coarse and fine aggregate in both Saturated Surface Dry (SSD) and Oven Dry (OD) condition, apparent specific gravity, absorption capacity, unit weight in SSD and void ratio was examined in laboratory. In preparation of cylinder specimen all these properties were same with F.M of coarse aggregate varying 6.8 and 4.81. The properties of aggregate is shown in the table below:

Table 1: Properties of coarse and fine aggregate.

Properties of aggregate	Coarse aggregate (F.M 6.8)	Coarse aggregate (F.M 4.81)	Sylhet sand	Local sand
Bulk Sp. Gravity (SSD)	1.66	1.63	2.6	2.58
Bulk Sp. Gravity (OD)	1.40	1.32	2.52	2.53
Apparent Sp. Gravity	1.89	1.90	2.73	2.68
Absorption (%)	18.67	20.74	2.96	2.26
Unit weight, SSD (Kg/m^3)	1441	1380	1728	33
Void ratio (%)	19	15	1637	37

4.3 Compressive strength of concrete

The compressive strength of concrete for each mix ratio (1:1.5:3 & 1:2:3) and F.M (6.8 & 4.81) was examined after 7, 14 and 28 days. For each day total 4 samples were tested and the average results has represented in figure 2. From the figure it has been observed that the for both the mix ratio, the highest compressive strength has achieved for the F.M of 4.81 i.e., for smaller sizes of aggregate.

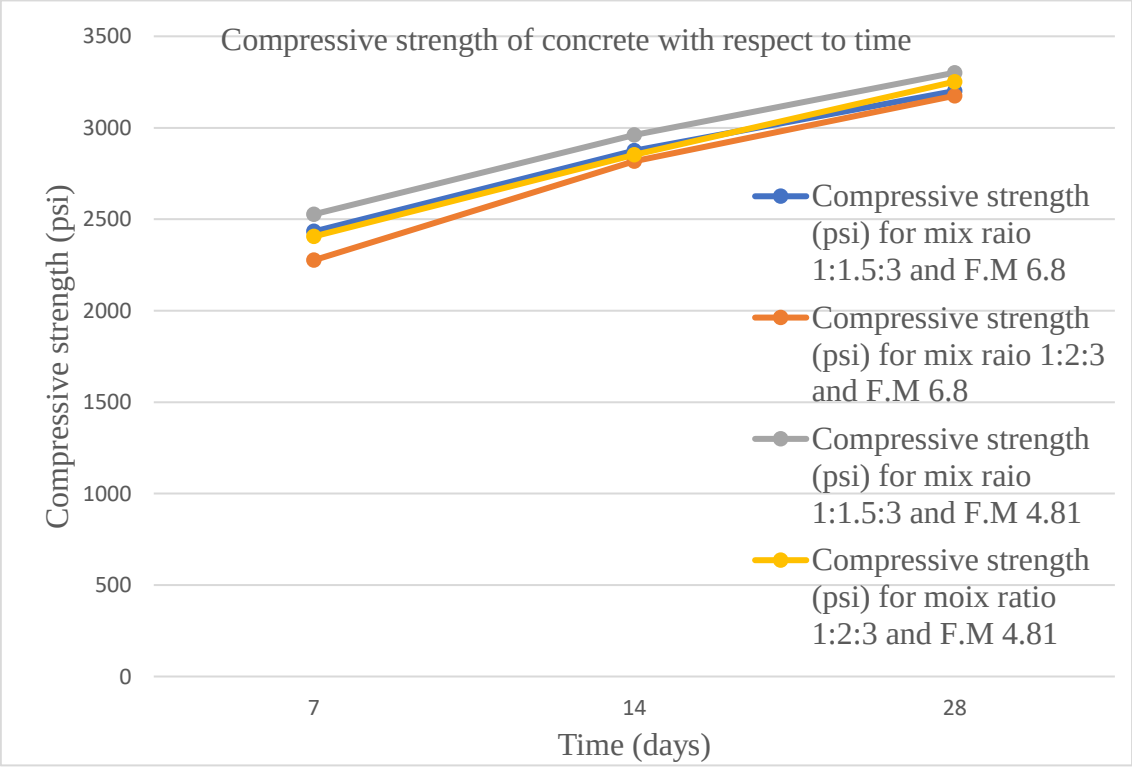

Figure 2: Comparison of compressive strength of concrete with respect to time, mix ratio and F.M

5. Conclusions

The results of the experiment indicate that the compressive strength of concrete is influenced by various factors, including the mix ratio and the size of coarse and fine aggregates. In this study, the size of the

coarse aggregate was varied, with Fineness Modulus (F.M) of 6.8 and 4.81, while all other parameters remained constant. It was observed that the highest compressive strength was achieved with coarse aggregate having an F.M of 4.81 for both mix ratios, suggesting that smaller aggregate sizes yield higher strength compared to larger ones. Additionally, the mix ratio of 1:1.5:3 produced higher compressive strength than the mix ratio of 1:2:3, indicating that an increase in cement content leads to greater compressive strength in concrete.

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