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Effect of river and crushed gravel, and well and river water on the compressive strength of concrete in Helmand province of Afghanistan

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Abstract

The durability and compressive strength of concrete under various loads depend on the quantity and quality of the ingredients of the concrete mix. Water, cement, sand, and gravel are the most essential components of the mix. Selection of the right amount of cementitious material results in a correct and standard concrete mix. By controlling the quantity and quality of each component, we will not only achieve a standard mix, but also the desired compressive strength expected in the design stage of structures. So, this plays an important and significant role in realizing the required strength of a structural concrete element defined during the design process. In this study, the effect of altering water quality and type of gravel on the strength of concrete has been investigated. In the meantime, the effects of applying river and crushed gravel, along with river and well water on the strength of concrete have been investigated experimentally using 14 concrete specimens. Among these standard-sized concrete cylindrical specimens, 6 were made using crushed gravel while the remaining 8 specimens were made usinged river gravel. Half of either category of the specimens used ordinary well water while the rest used water from Helmand River, Afghanistan. All the specimens were cured under standard conditions in laboratory for 28 days. After completing the period, all the specimens were tested using a Schmidt Hammer as well as by the universal testing machine. The results indicate that the compressive strength of the concrete specimens made from crushed gravel is higher than those made from the river gravel. The results also show a slight increase in compressive strength of the specimens made with river water in comparison with well water.

Keywords: river gravel, crushed gravel, water quality, compressive strength, structural concrete

1. Introduction

Concrete is a mixture of cement, water and aggregate in a given proportion. They are inert grains bound together by means of a binder called cement. Aggregate helps to reduce shrinkage and heat dissipation during hardening and also contributes to the increase in the mechanical strength of concrete. Cement generally represents 12-14% of concrete weight. It plays an active part in the mixture by ensuring cohesion between aggregate grains and, in doing so, it introduces a decisive contribution to concrete mechanical strengths. During the hardening process, it generates shrinkage and heat dissipation phenomena which lead to material cracking. Water occupies 6-8% of the composition of fresh concrete. It provides hydration for cement and workability for the fresh concrete mixture. When in excess, it determinately affects concrete porosity and mechanical strengths (Mbadike, 2011) [13]. Annual global production of concrete is about 5 billion cubic yards according to the Cement Association of Canada. Twice as much concrete is used in construction around the world than the total amount of all other building material, including wood, steel, plastic and aluminum (Chat, 2015) [8]. It is currently one of the most widely used construction material in Afghanistan, especially in the state of Helmand, where its ingredients are is easily accessible. Unfortunately, concrete compressive strength and other quality control tests are rarely carried out in Afghanistan, particularly in Helmand state that is resulting intopoor quality buildings and other concrete structures.

Concrete is similar to artificial stone and is used for the construction of bridges, roads, footpaths, buildings and dams. Concrete is also selected in the industrial structures as a construction material, owing to its specific characteristics (i.e. durability, stability, ease of construction, availability and aesthetic look). Concrete is the result of a chemical reaction between cement and water. For many years, concrete has been used more than any other construction material. Thus, for achieving better characteristics (for instance higher compressive strength) research on the concrete ingredients is updated from time to time. Fagbenle, *et al*. (2018) have demonstrated that the quality of concrete is affected by the choice of coarse aggregate used in its production. Aggregate account for about 60-75% of the total volume of concrete mix and 70-85% of weight with coarse aggregate contributing to about 45-55% of the total mass. Various other factors, like water-cement ratio, aggregate material, and texture, curing mechanism, transportation and finishing processes, affect the compressive strength of concrete. Since dealing with all of these characteristics is not possible in a single article, we have focused herein on the effect of the water type and aggregate texture. Water is an essential component of concrete. The cement paste glues the aggregate together, fills voids within it, and allows it to flow more freely. Less water in the cement paste will yield a stronger, more durable concrete; more water will give a freer-flowing concrete with a higher slump, (Olugbenga, 2014) [12]

1.1 Background:

Due to land restrictions and population growth in cities, high-rise buildings have recently become popular in Afghanistan. Therefore, researchers, are more eager to investigate all the factors that control the strength of concrete. In order to provide an appropriate concrete mix that fulfills this demand, all of the characteristics of its ingredients (for instance the quality of cement paste and interface transition zone) should be investigated. In normal strength concrete, compression failure is mostly often caused by the separation of cement paste from the aggregate. One of the main causes of this separation is the nature of the texture of aggregate which is one of the main concerns of this article. Moreover, other properties of concrete, such as aggregate shape, size, density, relative density and toughness, can affect strength of the concrete ASTM (2010) [6], ACI (2008) [5]. Finally, the effect of water type and aggregate texture is considered on strength of concrete.

2. Material and Methods

The current investigation was conducted in the city of Lashkargah, Afghanistan. The concrete components used in this study are cement, sand, sandy or crushed gravel, and river or well water. From the graph in Figure (1), a water-cement ratio of w / c = 0.75 corresponding to a 15 MPa compressive strength is selected.

We prepared 14 concrete cylinders. Eight out of the 14 concrete cylinders were made from the concrete with river gravel as in Figure (2), while the remaining six were made from concrete with crushed gravel as in Figure (3). Each of the fourteen concrete specimens had a volume of 0.0265m^3 and a mixing ratio of 1: 2: 4. The quantities of different cementitious materials for the 4 specimens of concrete were calculated as following:

Cement = 0. 0212 (1/10) * 1.54 * 1440 = 4.8 kg

Sand = 0. 0212 * (3/10) * 1.54 * 1550 = 15.2 kg

Gravel = 0. 0265 * (6/10) * 1.54 * 1600 = 31.4 kg

Water = 0.75 * 4.5 = 3.43 kg

All the ingredients were weighed using a digital scale. The percentage used to calculate the gradation of the river gravel are presented in Table (1).

The quantities of material for the three specimens made from concrete with crushed gravel are calculated as following:

Cement = 0. 016 (1/10) * 1.54 * 1440 = 3.6 kg

Sand = 0. 016 * (3/10) * 1.54 * 1550 = 11.5 kg

Gravel = 0. 016 * (6/10) * 1.54 * 1600 = 23.7 kg

Water = 0.75 * 3.6 = 2.7 kg

All of these ingredients were also weighed using a digital scale. The percentages used to calculate the gradation of the crushed gravel are demonstrated in Table (2).

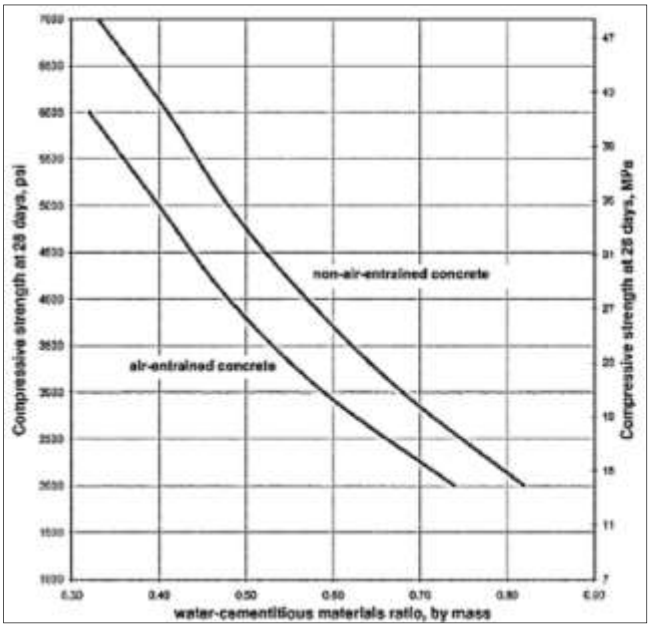

Fig 1: Water-cement ratios corresponding to different compressive strength values of concrete (ACI 211.3 R-02).

Table 1: Percentage of river gravel in concrete mix for making of 8 concrete specimens

Gravel Diameter (mm)	**16**	**13-12**	**10**	**5**
Percent	5 %	50 %	38 %	7 %
Amount (Kg)	3.2	31.4	24	4.4

Table 2: Percentage of crushed gravel in concrete mix for making of 6 concrete specimens

Gravel Diameter (mm)	**16**	**13-12**	***10***	***8-5***
Percent (%)	5 %	50 %	38 %	7 %
Amount (Kg)	2.4	23.7	18.13	3.12

Fig 2: Helmand River gravel used for the concrete mix

Fig 3: crushed gravel (a course and b fine) used for the concrete mix

2.1 Methodology

Concrete was prepared using crushed aggregate and river gravel having similar gradation, mix ratio of (1:2:4) and water-cement ratio of (0.75), respectively. Then, fourteen cylindrical specimens are casted. After demolding, the specimens are cured for 28 days in laboratory. The curing is performed in an environment illustrated in Figure (4).

Fig 4: Curing pots in the laboratory

The compressive strength of the concrete specimens was tested by the Schmidt hammer. The result of the average compressive strength was almost identical to the results of the experimental tests. The process of testing the concrete specimens by the Schmidt hammer is illustrated in Figure (5).

Fig 5: Cylindrical specimen test conditions by the Schmidt hammer

Furthermore, the concrete specimens were tested by the universal compressive machine. The specimens had a size of 300mmx150mm and were divided into four categories. Each of the first two categories included four specimens using river gravel. While the first category was prepared with river water, the second used well water. Each of the second two categories was composed of three specimens made of crushed gravel. Likewise, river water was used in the third category, and well water for the fourth. The compressive load was calculated using equation (1). All the specimens were crushed as in Figure (6). The results are summarized in Tables (3) and (4).

$$\text{Compressive Strength} = \frac{crushing\ load\ \ N}{\text{Area of cube}\ \ \text{mm2}} \dots\dots 1$$

Fig 6: Crushing of the cylindrical specimens using the universal compressive testing machine

3. Results

Material and their characteristics were discussed in detail in the previous sections. However, here we are setting the results of the conducted experiments. The results obtained from all the laboratory experiments are summarized in this section. In Table (3), the laboratory results of eight specimens made of concrete with river gravel are presented. In Table (4), the laboratory results of the six specimens made from concrete with crushed gravel are demonstrated.

Table 3: Results of specimens made from concrete with crushed gravel

Compressive Load kN	Compressive Strength N/mm²	Average Compressive Strength N/mm²	Curing Time days	Water Content	Slump (mm)	Gravel Maximum Size (mm)
231.56	13.8	14.4	28	River	30	18
239.07	14.4					
247	14.5					
216.2	12.5	12		Well		
210	12					
208	11					

Table 4: Results of specimens made from concrete with river gravel

Compressive Load kN	Compressive Strength N/mm²	Average Compressive Strength N/mm²	Curing Timedays	Water Content	Slump (mm)	Gravel Maximum size(mm)
165	10	10	28	River	25	18
160	9.5					
160	9.5					
167	10					
139	8	8.7	28	Well	25	18
132	8					
148	8.9					
148	8.4					

3.1 Discussion

The compressive strength of concrete made with river gravel and crushed aggregate are presented in Table (3) and (4); respectively. Effect of the type of the aggregate used in making of concrete is evaluated. The results indicate that the Schmidt Hammer test and type of water actually have less effect on the experimental results.

The total number of specimens used in this study were fourteen. Eight of them were made from river gravel. In the first column of Table (3) the loads that have been applied by the machine onto the specimens are displayed. The rest of the columns represent the compressive strength, average compressive strength, curing period, type of water content, slump and large aggregate size, respectively. According to Table (3), the average compressive strength of specimens made of concrete with crushed gravel and river water is 14.5 MPa. However, the average compressive strength of the specimens made using well water is 12 MPa. Likewise, the laboratory results of the specimens made from concrete with river gravel are presented in Table (4). The average value obtained from the specimens made from concrete with river gravel is 10 MPa, while the average value obtained from the four samples using well water is 8.7 MPa. The difference between these two is 1.3 MPa. This difference leads us to the conclusion that using crushed gravel has a direct effect on the compressive strength of concrete. In other words, the crushed gravel increases the strength of concrete, compared to the river gravel. This is because the smooth and round shaped surface of the river gravel and the cement-aggregate bond on the smooth surface is weaker than that of the angular surface, like crushed aggregate. Lastly, it is concluded that the concrete compressive strength, made from crushed gravel is approximately 21% higher than that made from river gravel.

4. Conclusion

The results of the investigation are based on compressive testing of 14-cylinder specimens, made from concrete with either crushed or river gravel using two types of water. The following are the key finding of this study:

- Fourteen concrete specimens were used in this experimental study. Among them, 6 specimens were made of crushed aggregate while the remaining 8 were made of river gravel.
- In the experiments performed, except for the quality of water and aggregate texture, all the concrete specimens were made of the same type of components and under similar circumstances.
- The average compressive strength of the eight specimens made from river gravel is 12 MPa while the average compressive strength of the specimens made of crushed gravel is 14.4 MPa.
- The compressive strength of concrete cylinders made from concrete with crushed gravel was 2.4 MPa higher than the compressive strength of concrete cylinders made from concrete with river gravel. This indicates that the concrete strength of specimens made from crushed gravel is 21% higher than those made from river gravel.
- In this study the effect of the water type was also investigated. It was found that the compressive strength of the specimens made from river water, was approximately 1.2 MPa higher than those made from well water.
- For reliability of the destructive tests, non-destructive experiments were also conducted using Schmidt hammer. The results of the destructive and non-destructive experiments were almost in close proximity.
- It is concluded that usage of crushed gravel in construction work will increase the compressive strength of structures effecting the durability factor of concrete structures in Afghanistan, particularly in Helmand Province.

5. Recommendations

The gravel used in the construction works in Lashkargah city of Helmand Province and in the nearby areas, all the related resources from which the aggregate contents are retrieved needs a thorough investigation. The long-term and short-term effects on the concrete compression strength are to be considered important in construction of concrete buildings in this region. It is recommended that usage of crush gravel come into practice rather than the current usage of river gravel; however, it is also important to investigate the cost comparison of both types of gravel in addition to their structural performance which is currently beyond the scope of this study. To better clarify the effect of water type on the concrete strength, the results should be assessed with large number of tests. Such investigations contribute greatly to the selection of economical, durable, and stable concrete for construction of structures in Helmand and other parts of Afghanistan.

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