Experimental Investigation of Concrete Properties using Locally available Coarse Aggregates in Punjab, Pakistan

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Abstract

Concrete is the most widely used construction material worldwide. The concrete mainly consists of cement, water, fine aggregate (FA), and coarse aggregate (CA). CA is the main constituent of concrete in terms of weight and volume. The properties of CA can affect the fresh and mechanical properties of concrete. In the present study, CA from three different sources (Sargodha, Mangla, and Margalla) are used in three different mixes of grade M-20 (1:1.5:3) concrete. The FA aggregate source (Chenab) is kept the same in all three mixes with constant w/c=0.5. It is observed that the fresh properties of concrete with Margalla and Sargodha CA are better compared to the Mangla source aggregate. This is because the CA of both the sources is relatively smooth in shape compared to the Mangla source that improves the flowability of concrete. While the lesser flowability of the Mangla source concrete is due to CA used is flaky, elongated, and has high absorption. The mixes with Margalla and Sargodha aggregate also performed slightly better in terms of mechanical properties. But overall, a significant difference occurred in the fresh properties of mixes compared to mechanical properties. Hence, it can be said that in normal strength concrete the different sources of aggregate mainly affect the fresh properties of concrete.

Keywords: Fresh properties, Coarse aggregate, Mechanical properties, Sources of aggregate.

Introduction

Concrete is the most commonly used human-made material on earth [1,2]. It is used in different types of work like bridges, dams, buildings, and roads. It is a heterogeneous material consists of fine and coarse aggregate bonded together with a cement paste that hardens over time. In the past, several researches have been carried out on concrete related topics such as self compacting concrete [3,4], incorporation of different natural [5] and artificial fibers [6], nanomaterials [7], waste materials [8–10] etc. Apart from water and binder, aggregate also governs the properties of concrete [11]. The aggregate petrological, petrographical, and mineralogical characteristics play a key role in deciding the properties of concrete such as workability, strength, and durability [12–14]. Many properties of aggregate such as mineral composition, specific gravity, porosity, and absorption capacity depend on parent rock [15,16]. Therefore, it is necessary to have sufficient knowledge about the origin of the aggregate before using it in concrete.

In concrete usually coarse aggregate (CA) covers one-third volume [17]. CA physical and mechanical properties both influence concrete properties. Concrete properties vary using different aggregates from different sources. Even if the source is the same, particle shape and size can also affect the properties of concrete [18–20]. Therefore, one must be very careful while selecting aggregates for concrete [21]. In the developed world tremendous amount of work is available on CA properties and plays a huge contribution to the construction industry. But unfortunately, there is very insignificant research available on locally available coarse aggregates properties in the developing world. The main reason is the researchers in the developing world mostly engage in work that only benefits the developed world. Working on locally available things is either not novel or insufficient data is available to start work. However, now there is a trend shift, and research on locally available materials is gaining importance.

In the province of Punjab, Pakistan, the three locally abundantly coarse aggregate sources for concrete are Sargodha, Marglla, and Mangla [11]. Sargodha aggregates are obtained from the hills of Sargodha. The color of aggregates is greenish/dark gray [22]. Mangla crush is found in the beds of the river and doesn't need blasting or mining costs. However, they require proper processing before use in the construction industry. Margalla aggregates are obtained from the hills of Margalla, Islamabad. These are usually irregular and rough in texture.

In the current study, coarse aggregate from three different sources (Sargodha, Margalla & Mangla) is used to assess the concrete fresh and mechanical properties. Three different formulations of grade M-20 concrete are made at w/c=0.5. The fine aggregate from Chenab, river bed is used in all three mixes.

Methodology

Materials

Ordinary Portland Cement (OPC) Type-I conforming ASTM C-150 is used. The physical properties of OPC are listed in Table-1. Aggregates from Margalla, Mangla, and Sargodha quarries as shown in Figure 1 are used. The physical properties of Margalla, Mangla, and Sargodha aggregates are shown in Table-2. The fine aggregate used is obtained from the Chenab river bed and its physical properties are listed in Table-2. The impact values of Margalla and Sargodha quarry sites are comparatively low that indicates better mechanical performance in concrete.

Table 1. Physical Ordinary Portland Cement (OPC) Type-I

Properties	Parameter	Testing Standard
Specific Gravity	3.15	-
Blain Finess (cm^2/gm)	3450	ASTM C204
Consistency (%)	27	ASTM C187
Initial Setting Time (minute)	107	ASTM C191
Final Setting Time (minute)	131	ASTM C191
Soundness (mm)	6	ASTM C189

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Table 2. Physical properties of coarse aggregates obtained from Margalla, Mangla, and Sargodha quarries

Properties	Margalla	Mangla	Sargodha	Sand
Bulk Specific Gravity	2.75	2.44	2.75	2.64
Water Absorption(%)	1.32	1.47	1	1.4
Bulk density (lbs/ft^3)	100.28	99.18	99.69	-
Aggregate impact value (%)	13.20	16.50	11.60	-

Figure 1. Google Map displaying the location of Margalla, Mangla, and Sargodha quarries.

Table 3. Concrete formulations mix proportions per batch of concrete

Designation	Cement (kg)	Sand (kg)	Aggregates (kg)			Water (kg)
			Sargodha	Mangla	Margalla	
Mix 1	11.76	17.76	35.28	0	0	5.88
Mix 2	11.76	17.76	0	35.28	0	5.88
Mix 3	11.76	17.76	0	0	35.28	5.88

Mix Proportion Formulations

Three sets of concrete mix with Margalla, Mangla, and Sargodha aggregates are studied. The mix ratio is set at 1.1.5:3 having a constant w/c ratio =0.5. The details of all the formulations are given in Table-3.

Mixing Regime, Casting, and Curing

Concrete quality can also be influenced by the mixing procedure and placing techniques. Therefore, a standard mixing approach as per standard is recommended. In the present work, first cement, sand, and crush were mixed dry in a mixer for 1 minute, then water was added slowly and mixed for 2 minutes. After mixing fresh property such as consistency of concrete is determined through a slump test. After that concrete cylinders and prisms are cast. After 24 hours concrete specimens are de-molded and cured in a water tank till the testing date.

Experimental Program

The fresh properties of all three mixes are determined through the slump test. This test is used to determine the consistency of concrete. It is a very simple test and is widely used in laboratories and fields. This test was performed as per ASTM C143 for all three mixes. Total 27 cylinders (150 x 300) mm are cast for compression test for all three mixes. The compression test is conducted as per ASTM C39 at age of 3, 7, and 28 days. The flexural strength is determined as per the center loading method. For flexural strength 6 prisms size 150 x 150 x 750 mm were castes. The flexural strength is determined on 28 days. The samples of compression and flexural tests are shown in Figure-2.

Results and Discussions

Slump Test

Figure 3 shows the slump value for all three mixes. The consistency of mix-2 (Mangla) is relatively low compared to other mixes. The lack of flowability in mix-2 is contributed by the flaky, porous, and elongated coarse aggregate used in the mix. The particles of aggregate have a key role in flow properties. If the particles of aggregate are smooth and rounded then it will facilitate the flow of the resultant concrete. On the other hand, flaky, rough, and elongated particles cause hindrance in the flow of concrete.

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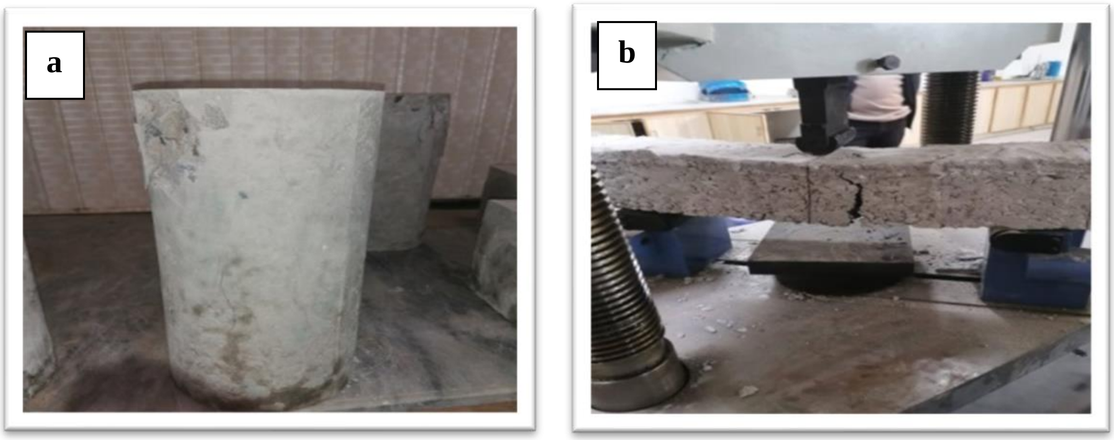

Figure 1. The Concrete Specimens prepared for mechanical testing: (a) 150 mm x 300 mm concrete cylinder cast for a compression test, (b) Concrete prism placed in the flexural machine for determining the flexural strength.

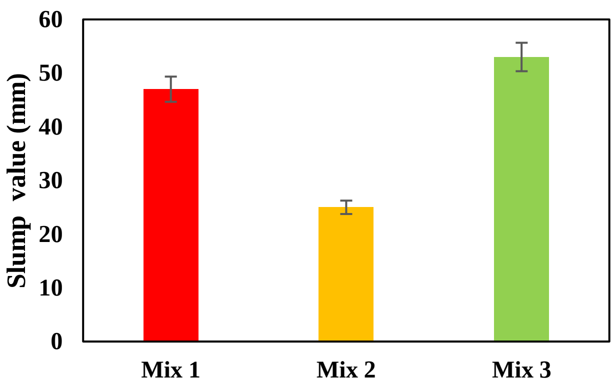

Figure 3. Slump values of concrete mix formulations after mixing.

Compressive strength results on hardened concrete

Figure 4 shows the compressive strength of all three mixes at age of 7, 14, and 28 days. There is a minor difference in the compressive strength of all the formulations. A little improvement in the strength of mix-1 and mix-2 is due to better packing of particles which is not relatively good in Mangla mix. However, the difference is very minor because in low and normal strength concrete the strength is controlled by cement paste and failure occurs mostly at the paste phase unless coarse aggregates are very weak.

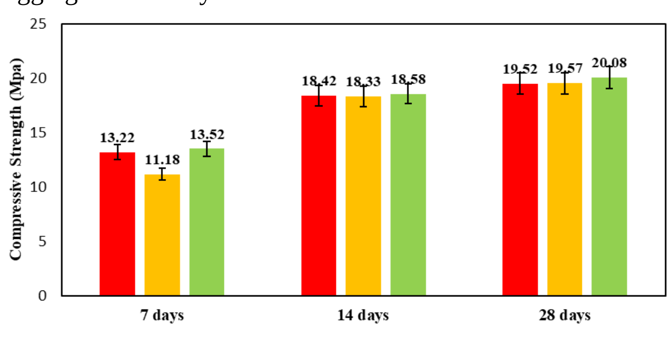

Figure 4. Compressive strength of all the three mixes at age of 7, 14, and 28 days.

Flexural strength of concrete

Figure 5 shows the flexural strength results. A similar trend as observed in the compression test is observed in flexural. The better performance of mix-1 (Sargodha) and 3(Margalla) in flexural is due to low aggregate impact value.

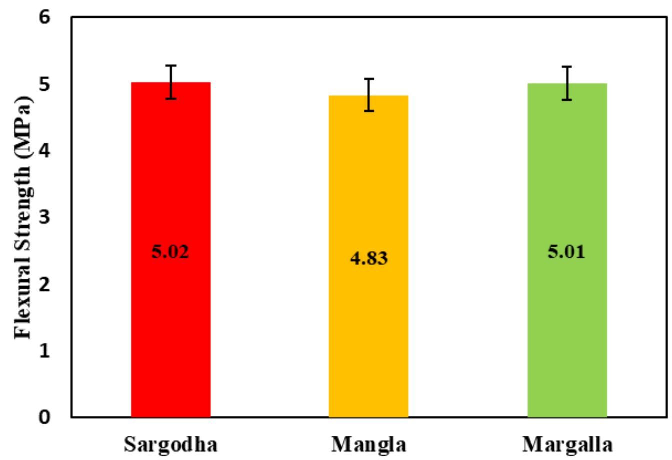

Figure 5. Flexural strength of all the three formulations at age of 28 days.

Conclusion

The present research is carried out to assess the fresh and mechanical properties of the concrete base on the coarse aggregate source. The following concluding remarks are made on the current study.

- The absorption capacity of Mangla base coarse aggregates(CA) is comparatively high to Margalla and Sargodha quarry sites aggregate. Also, the unit weight of Mangal's CA is low that is depicted in the high impact value of aggregate.
- The consistency mix-2 concrete is relatively low compared to Margalla and Sargodha source aggregate concrete. This is due to the fact the Mangla source aggregates are collected from river sites and are not well-graded, flaky, and elongated that can cause hindrance to flow.

- The mechanical properties of mix-1 and mix-3 performed slightly well. But overall the difference in mechanical performance is not significant. Therefore, it can be confidently claimed that in low and normal strength concrete the mechanical properties of concrete will varies slightly and remain almost constant.

It is highly recommended to evaluate the properties of high-strength concrete made with Mangala, Margalla, and Sargodha sources coarse aggregate.

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