

A Review paper on the Effect of different types of coarse aggregate on Concrete

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Abstract. The strength of concrete mix is dependent on many parameters like cement type, coarse aggregate and the interface between aggregate and mortar. However, generally the coarse aggregate is treated as an inert material and only its physical properties like shape, size, water absorption and specific gravity are studied. Whereas, as we increase the quality of mortar mix, the strength of coarse aggregate also comes into picture. In case of high performance concrete, the type of coarse aggregate used has a great influence on the strength and elasticity modulus of concrete. For high strength concrete with compressive strength above 40 MPa, which are generally cast with water-cement ratio less than or equal to 0.4, the strength of mortar and the interfacial bond strength may be comparable to the strength of aggregate. This paper presents a comprehensive review of the past research work done on the effect of using different types of coarse aggregate on various properties of concrete mix like its compressive strength, tensile strength and elasticity modulus.

1. Introduction

With the rapid growth in infrastructure of the country, construction industry is booming and thus the demand for building materials has increased manifolds. The demand for high rise buildings has increased due to space constraints, rapid urbanization and growth in population. The increase in demand of high rise buildings has led to increase in demand for better performing materials like high performance/strength concrete and its composites. Thus, this new interest has encouraged many researchers to study the efficiency of concrete's constituent materials. The performance of the structural concrete is dependent on its strength and durability which in turn is dependent on the characteristics of the mortar, aggregate and mortar-aggregate bond. For same quality of mortar mix, the type, texture and mineralogy of coarse aggregate affects the various parameters of concrete in its hardened and fresh state. The effect of coarse aggregate type is more prominent in high strength concrete due to limitation on water/cement ratio. In case of water/cement ratio of 0.4 and less, the strength of bond between mortar and aggregate is equivalent to the strength of aggregate itself. Hence, the full potential of the coarse aggregate should be



explored prior to its use as a raw material as it will not only affect the strength but also the modulus of elasticity of concrete. Thus, a proper investigation should be conducted for coarse aggregate to enhance the mechanical properties of concrete. Generally, as the coarse aggregate occupies around 70% of the volume of concrete mix, its role in affecting the strength and durability parameters of the concrete is paramount.

Different properties of aggregate like its size, shape, texture, petrography, mineralogy etc. have an effect on the properties and behavior of the interfacial transition zone. A lot of study has been done on the bond strength due to the shape and surface texture of the aggregate however the type of aggregate also attributes to the bond that aggregate makes with mortar. The mineral constituents of the aggregate can lead to chemical reaction between cement and aggregate thereby strengthening or weakening the bond. The primary cause of micro cracks development is the difference in modulus of elasticity of the aggregate and cement mix. The differential shrinkage in the two regions because of difference in modulus of elasticity is a big reason behind low tensile strength of concrete. Hence the quality of ITZ plays a important role in the tensile strength of concrete specifically for high strength concrete. The compressive strength of concrete is primarily controlled by the quality of mortar and the bond properties of aggregate. However, the influence of aggregate type is relevant in high strength concrete as the quality of mortar improves in them. Apart from the properties discussed above, modulus of elasticity of concrete is also a matter of concern from the design and strength perspective. The scientist has significantly improved on the strength of concrete but much less emphasis has been laid on the modulus of elasticity. The use high strength concrete has helped in reducing the dead load of the structure due to use of thinner sections to carry load so therefore the requirement of higher modulus of elasticity has increased. The modulus of elasticity of concrete is directly related to the type of aggregate. Thus, the type and mineralogy of aggregate affects various properties of concrete and hence it should not be treated as an inert material. A careful petrographic study of the aggregate should be conducted before its use in high performance concrete.

In this paper, the effects of different type of coarse aggregate on the various properties of concrete are reviewed. Based on numerous papers on the subject a try was made to identify the effect type of aggregate on the various mechanical properties like compressive strength, modulus of elasticity, tensile strength, flexural strength and the mortar-aggregate bond.

2. Parameters studies

Based on the study various past work conducted on the topic, following properties have been studied.

2.1 Compressive strength

F.P. Zhou et al. [1] experimented high performance concrete with low water/cement ratio and fixed mortar mix with six different types of aggregates of constant volume. A mix of M90 was casted in which the water/cement ratio was kept at 0.29 and the cement was replaced with 10% of silica fume. Superplasticizer was used as the admixture to maintain workability and the coarse aggregate volume was kept as 0.425 for all the six different types (Table 1). The compressive strength of the sample were measured at 7, 28 and 91 days. It was observed that concrete with expanded clay aggregates had 28 day strength of about 30% of that of mortar and corresponding value for sintered fly ash aggregate was 80%. The limestone when used gave similar results as mortar whereas the cube strength for glass bead was higher. The steel bead aggregate showed lower strength than mortar. It was concluded that as the porosity of aggregates increased, the cube strength decreased. Also, the minimum cube strength was achieved with the stiffest aggregates.

Table 1: Properties of coarse aggregate used

Aggregate	Shape	Maximum size (mm)	24 hour water absorption
Expanded clay	spherical	10	17.5
Sintered fly ash	spherical	6	13.6
Limestone	angular	10	2
Gravel	rounded	10	2
Glass beads	spherical	10	0
Steel	spherical	3	0

T. Ozturan et al. [2] studied the effect of three different types of coarse aggregate namely basalt, limestone and gravel on 28 day compressive strength. Three different mix M30, M60 and M90 were casted with water/cement ratio as 0.58, 0.40 and 0.30 respectively. Water curing for all the specimens were done for the first seven days followed by air curing till 28 days. It was observed that in high strength concrete (target strength of 60 MPa) basalt and limestone gave higher strength than gravel. The 28 day compressive strength was 10 to 20 % lower for concrete with gravel as coarse aggregate as compared to concrete made with limestone and basalt as coarse aggregate. However, in mix with target strength 30 MPa both gravel and basalt showed similar strength. It was concluded that the influence of the type of coarse aggregate is more prevalent in high strength concrete as compared to normal strength.

Ke-Ru Wu et al. [6] studies the 28 day strength for mix casted using crushed quartzite, crushed granite, limestone, and marble coarse aggregate as coarse aggregate. The mix were casted with a target strength of 30, 60 and 90 MPa to check the effect of aggregate type on strength of concrete. Cube of size 100mm x 100mm x 100 mm were casted and cured for 28 day strength for evaluating its strength. The mix were casted for three different water/cement of 0.26, 0.44 and 0.55 and with the reduction in water cement ratio and increasing the coarse aggregate strength, the strength of concrete improved specifically for high strength concrete. However, the effect of type of coarse aggregate on the compressive strength of normal concrete was insignificant. Aggregates play a very important role in high strength concrete as the cement aggregate bond is significantly increased utilizing the full potential of coarse aggregate.

H Beshr et al. [7] evaluated the effect of use of four types of coarse aggregate namely calcareous, dolomitic, quartzitic limestone, and steel slag. The water/cement ratio for all the mix was kept at 0.35. On testing it was found that the mix prepared with steel slag gave the highest compressive strength whereas the mix with calcareous limestone produced lowest strength. It was concluded that in high strength mix with low water/cement ratio and a high cement content, the compressive strength is greatly influenced by the quality of coarse aggregate. The strength parameter is dependent on the aggregate strength rather than the cement paste and the failure in such mix happens due to cracking of aggregates. The compressive strength result supported the above stated conclusion which was further quantified by conducting an abrasion test on aggregate to test its strength.

H. Marzouk et al. [9] studied the effect of alkali-aggregate reactivity on the compressive strength of high and normal strength concrete. High strength and normal strength concrete was cast using highly reactive aggregates and moderately reactive aggregates. After the initial curing of 28 days the samples were equally divided and submerged into a curing tank with either sodium hydroxide or de-ionised water at 80 degree C for 12 weeks. It was observed that in normal strength concrete mix prepared with highly reactive aggregate reduction of 24% for sample placed in sodium hydroxide and an increase of 14% for sample kept in de-ionized water due to elevated temperature which led to accelerated hydration. For samples containing moderately reactive aggregate the compressive strength remained same in sodium hydroxide and a slight increase with time was seen in de-ionised water. Whereas, due to improvement of

microstructure in high strength concrete the compressive strength of all the samples increased with maturity of samples.

A.A. Jimoh et al. [14] studied the influence of aggregate type and size on the compressive strength. Sample of 1:2:4 proportion was casted using sand, quarry dust, granite and gravel as the aggregate of 20 and 28 mm size coarse aggregate. The mix casted with quarry dust and granite of 20 mm size performed the best. It was concluded that with the increase in size of coarse aggregate its strength reduced.

Mohammed Seddik Meddah et al. [18] reported the mechanical properties of concrete casted using phyllite and granite as coarse aggregate. Five different mix with target strength of 20, 25, 30, 35 and 40 MPa were casted and tested at various days of curing. The result showed that though the strength development pattern was same for both the aggregates but phyllite concrete mix achieved 15-20% low strength compared to granite concrete. This can be attributed to lower class of phyllite as compared to granite in terms of aggregate properties and characteristics.

Abdullahi. M [19] studied the effect of using quartzite, granite and gravel as coarse aggregate in normal strength concrete. Highest compressive strength was observed in quartzite sample followed by gravel and granite. A linear polynomial numerical model was also developed to account for variability in compressive strength with age of curing.

Theophilus Yisa Tsado [21] studied the effect of using igneous, sedimentary and metamorphic rock as aggregate in normal strength concrete. The aggregates used from each category were granite, limestone and marble. During the testing it was observed that granite concrete showed the best performance whereas marble aggregate concrete showed the least strength owing to the weakness in inherent properties of the metamorphic rock as compared with igneous and sedimentary rocks used in the study.

2.2. Modulus of Elasticity

The modulus of elasticity as studied by Ke-Ru Wu et al. [6] is affected by the elastic properties of its constituent material and interfacial zone between aggregate and paste. Due to the large volume occupied by coarse aggregate and its stiff characteristics it influences the most. Not only the physical characteristics but also its type and chemical properties also effect the modulus of elasticity. The influence of aggregate type increases on the elastic modulus with the increase in strength of concrete. High strength concrete of low brittleness can be made using high strength aggregate with low brittleness.

H Beshr et al. [7] recommended softer aggregates result in lower modulus of elasticity and hence more ductile failure of concrete. Significant difference in elastic modulus and hysteresis loop were observed in high strength concrete prepared with different type of aggregates. The static modulus was higher for concrete made with steel and quarzitic aggregate that calcareous and dolomitic limestone aggregate. It was seen that the effect of coarse aggregate type is more significant on elastic modulus than compressive strength.

J. M. chi et. Al. [8] proved that for aggregate volume fraction of 18 %, the compressive strength and elastic modulus are independent of aggregate type and are influenced by water/cement ratio.

F.P. Zhou et al. [1] studied various theoretical models like voigt, reuss, Hirsch, counto, Pcounto and BNC were used to predict the modulus of elasticity and compared with the experimental results. Compared with the experimental results all the models gave result within less than 10% of the experimental results except for shale and steel beads. It was found that strong aggregates produce concrete with higher modulus of elasticity.

2.3. *Splitting tensile strength*

T. Ozturan et al. [2] observed that the tensile strength measured using flexure and splitting tests showed that the tensile strength was higher for basalt and limestone as compared to gravel aggregate. However with the reduction in target mean strength of concrete, the difference in tensile strength with the different type of coarse aggregate became insignificant. The tensile strength of the concrete was mainly dependent on the strength of mortar and interfacial bond strength between mortar and aggregate. Ke-Ru Wu et al. [6] concluded that the split tensile strength of concrete is not significantly influenced by the splitting tensile strength of aggregates. The tensile strength is also dependent on the size of aggregate and the reduction in tensile strength with the increase in aggregate size becomes higher in high strength concrete as recommended by T. Akçaoğlu et. al. [12]

3. Conclusion

From the extensive literature review done on the topic following conclusions can be drawn about the parameters studied:

- 1) In high strength concrete the compressive strength is affected by the type of aggregate used whereas in normal strength concrete, compressive strength is independent of aggregate type.
- 2) Stiffer aggregates will produce stiffer concrete mix.
- 3) Modulus of elasticity is mainly dependent on the mortar aggregate interface which is further dependent of the strength of aggregate for high strength concrete
- 4) Tensile strength of aggregate is independent of the type of aggregate used and is significantly affected by the surface characteristic of the aggregates.

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