The Study of Relationships between Aggregates Properties and Concrete Strength

Javad Sharifi[1], Mohammad Reza Nikudel[1]

[1] Department of Engineering Geology, Tarbiat Modares University, Tehran, Iran

ABSTRACT: This paper presents an experimental investigation for the mechanical behavior of concrete specimens made with different types of aggregates. Crushed aggregates were selected with different petrographic, but similar grading curves. The main objective of this research is to investigate the effect of aggregate on the mechanical properties of fresh and hardened concrete, as well as identified the relationship between aggregates properties and concrete strength. Concrete mixtures with water/cement ratios of 0.44 were designed and all the parameters were the same and constant. The hardened concrete tests consisted of cubic and cylindrical specimens at different curing ages in accordance to the relevant standards. Afterwards, the effect of aggregate type on the behavior of the concrete was investigated and the results were analyzed and presented in the study. The results of the study showed considerable effect of the type of the used aggregate on the mechanical behavior of the specimens.

1 INTRODUCTION

Strength performance remains the most important property of structural concrete, from an engineering viewpoint. The relation between concrete composition and mechanical properties has long been a matter of research interest (Wu et al.; 2001). The concrete strength and other properties depend heavily on its microstructure. The microstructure of concrete depends upon a number of parameters such as type, amount and structure of constituent materials. Constituent materials for concrete include fine and coarse aggregates and mortar (Yashar et al.; 2004). Aggregate is produced by crushing a large parent mass of rock. Thus, many aggregate properties depend on the properties of the parent rock (e.g., chemical and mineralogical composition, petrographic classification, specific gravity, hardness, strength, physical and chemical stability, pore structure and color). Some properties such as shape and size of particles and surface texture of crushed aggregates are not seen in the parent rock, while other properties such as absorption can change due to the crushing. The shape depends on the nature and the degree of stratification of rock deposit, the type of crushing plant used and the size reduction ratio. All these properties have an important influence on the quality of fresh and hardened concrete (Neville & Brooks; 1993). The technical and economical aspects regarding the durability, workability and strength characteristic of aggregates have been reported by many earlier researchers. The main objective of this research is to provide information about the effects of mineralogical characteristics of aggregates on hardened properties of concrete. These aggregates include ingénues, metamorphism and sedimentary rocks. With this aim, two aspects were analyzed, the influence of the mineralogical source of the crushed aggregates, and the determination of relationship between aggregates properties and concrete strength. To evaluate the influence of the mineralogical source of the crushed aggregates, ten concrete mixtures were designed. For the same strength level concrete mixture, the mixture proportions of all aggregates were the same. The results show that the aggregates used in concrete have the most advantages in strength as the following order: Marble, Dolomite, Tuff, Granite, Genasis, Basalt, Andesite, Lumashele, SandStone and Diorite.

2 EXPERIMENTAL WORK

2.1 Raw materials

2.1.1 Cement

ASTM type IV cement produced in Tehran cement factory was used in this study. The cement, which was equivalent to ASTM Standard, is commercially available in Iran.

2.1.2 Aggregate

It was also noted that aggregates were selected with different petrographic characteristics but similar grading curves, the difference was only related to the aggregates type. In all crushed aggregates, dust content is higher than the limit proposed (7%) by the ASTM C 33 Standard, but lower than that proposed by the BS 882 Standard (16%). The assessment of engineering properties of the aggregate was carried out in compliance with the standard testing method recommended by the International Society for Rock Mechanics, Standard of the American Society for Testing and Materials and British Standards.

2.1.3 Admixture

In this research, Superplasticizer and silica fume was not used.

2.2 Mixture proportions

Ten concrete mixtures were designed with the same Proportions; the aim of the study was to obtain compressive strength of 25 MPa at 28 days and the slump value of 3 cm of workability of mixing calculation in produced concrete. These mixtures were designed with a w/c of 0.44, medium cement content (336 kg/m^3) and similar slump. In order to investigate the effect of aggregate on the mechanical properties of concrete, all parameter were same and constant. Maximum size of the coarse aggregate was 12.5 mm.

2.3 Preparation of specimens

Concrete cube moulds were used for compression tests and cylindrical moulds for indirect tensile tests, were manufactured from the broken parts of the notched tests. Mixing was done using an electrically operated concrete (drum) mixer. First of all, the total cement and aggregates were dryly mixed for 10 second. Then the total amount of water was added and mixed for 3 min. The moulds of concrete specimens had a size of 150 × 150 × 150 mm and 50×100 mm.

2.4 Testing procedures

Characterization of concretes produced was performed by the physical and mechanical tests at different days of age. Physical tests were carried out on fresh and hardened concrete specimens to evaluate their mechanical properties in conformance to British Standards. For the purpose of determining any relationships between aggregates properties and concrete strength, concrete properties were investigated and the effects of mineralogy and strength of rock on the concrete strength were determined. Also characterization of produced concretes was performed by the physical and mechanical tests at different days of age. The testing of engineering properties of the aggregate was carried out in compliance with the methods recommended by the aggregate standards testing. Physical tests were carried out on fresh and hardened concrete specimens to evaluate their mechanical properties in conformance to common Standards. Testing of mechanical properties of concrete was carried out in accordance with ASTM C 39 for compressive and tensile strengths.

3 RESULTS AND ANALYSIS

Some physical and mechanical properties of 200 different concrete were investigated. The numerical results of slump, water absorption of aggregates, unit weight, ultrasound pulse velocity, compressive strength, tensile strength, Aggregate crushing value and Aggregate impact value are analyzed in the following subsections.

The maximum slump obtained was 27 mm which occurred in granite aggregate as compared to the slump of 30 mm of the control mix. In general, it can be concluded that the addition of aggregate such as granite, gneiss and basalt improves the workability of the concrete mix, primarily due to the smooth glassy surface texture and low frictional force of the igneous and some metamorphism aggregates. Smooth surface and moisture acts as lubricant between the solid particles, reducing the inter-particle frictional force.

The effect of water absorption on the compressive strength of concrete was evaluated by testing concrete specimens. Fig. 1 reports the results for Influence of pores and water adsorption on compressive strength of concrete. As expected, the compressive strength increased with reduction of pores in all the concrete specimens. Further, the data in Fig. 1 indicate that the type of aggregate has a significant effect on the compressive strength of concrete.

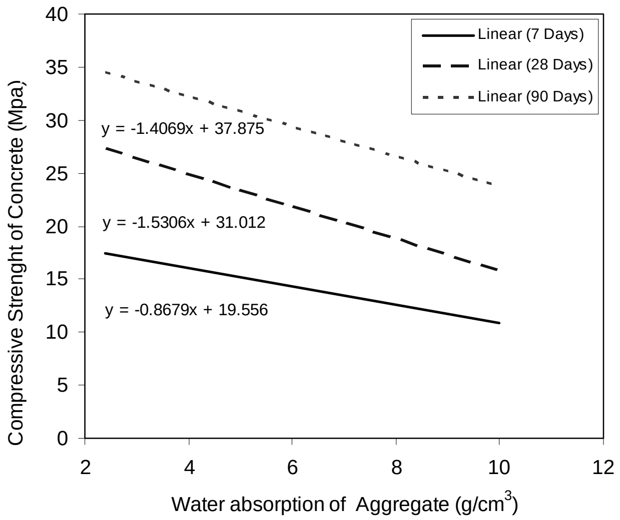

Figure 1. The relationship between water absorption of aggregates and compressive strength of concrete.

The effects of aggregate density on compressive and tensile strength are shown in fig. 2. As absorption of aggregates is lowered, the strength of concrete is enhanced with increasing strength of density of aggregates. Considering of the density presented in this figure, it is clear that all the crushed aggregates have produced concrete with a lower density than the basalt aggregate concrete.

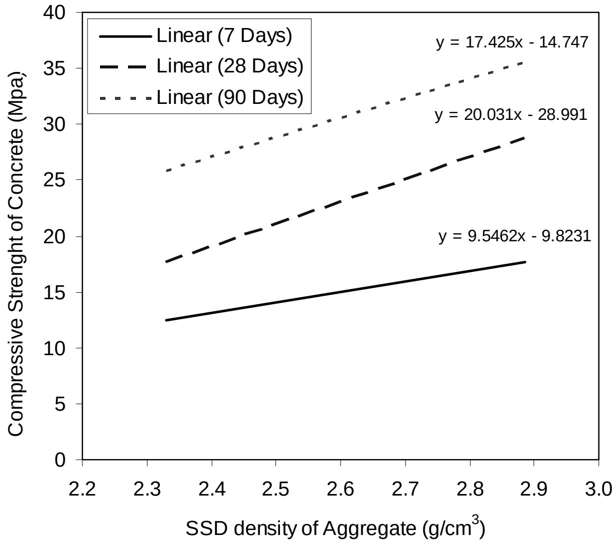

Figure 2. Effect of density of aggregates on compressive strength of concrete.

Effect of compressive wave velocity of aggregates on mechanical properties of concrete was determinate. Figure 3 show the compressive strength of concrete versus compressive wave velocity of aggregates. It can be observed that concrete has a higher strength, corresponding at aggregates with high wave velocity.

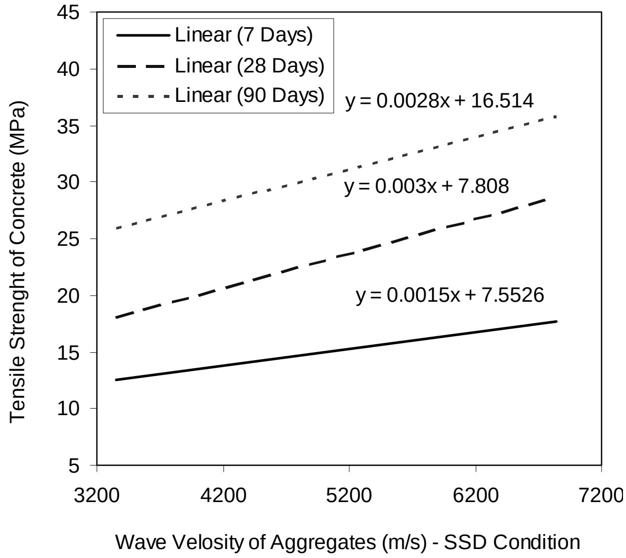

Figure 3. Effect of density of aggregates on compressive strength of concrete.

In Fig. 4, the compressive strength of concrete was displayed as a function of compressive strength of aggregate for three different curing ages. As aggregate strength is lowered, the strength of concrete is enhanced with decreasing strength of aggregate. Nevertheless, the increasing behavior of strength in concrete constant at 35 MPa, after this point, increasing in concrete strength affected by strength of aggregate – cement paste interface. This explained by the fact that the rigidity of concrete has been reduced (Nadeau; 2003). In contrast to the compressive strength results, the results of the splitting tensile tests show that the splitting tensile strength of concrete is influenced by the splitting tensile strength of aggregates to a small extent (See fig. 5).

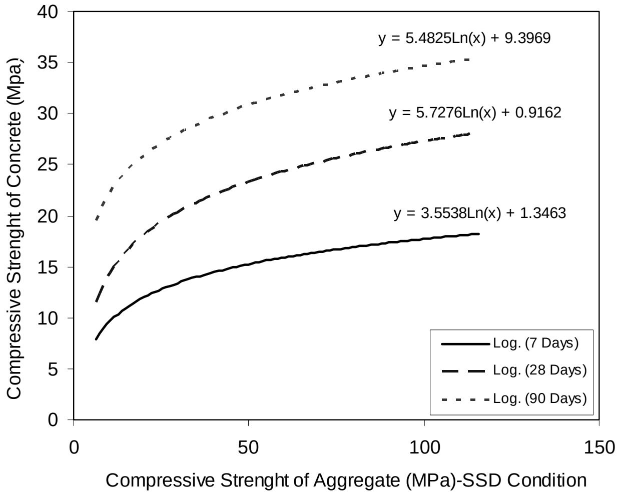

Figure 4. The relationship between UCS of aggregate and compressive strength of concrete.

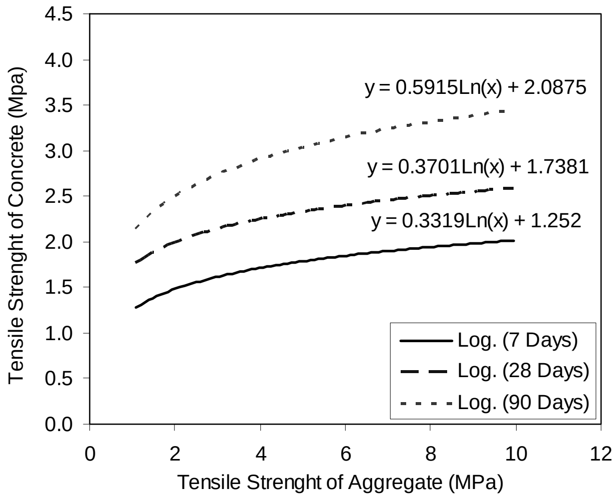

Figure 5. The relationship between tensile strength of aggregate and tensile strength of concrete.

Aggregate crushing value (ACV) test is a useful guide when dealing with aggregates of unknown performance. For this reason, the Aggregate crushing value for each aggregate was plotted against compressive strength of concrete for 7, 28 and 90 days and is shown in fig. 6. As can be observed, the concrete strength increases with decreasing aggregate crushing value for any given aggregate type. It may be due to the fact the mechanical properties of the aggregates, other properties, such as the particle form, the mineralogy, and the roughness of the surface of the aggregates, may have effects on the mechanical properties. Also fig. 7 shows the adverse effects of Aggregate impact value (AIV) on compressive strength of concrete, but the compressive strength of concrete is improved. This behavior could be attributed to particle strength and to the different surface textures and shapes of particles failure. Toughness can be defined as the resistance of aggregate to failure by impact, and it is usual to determine the aggregate impact value of bulk aggregate.

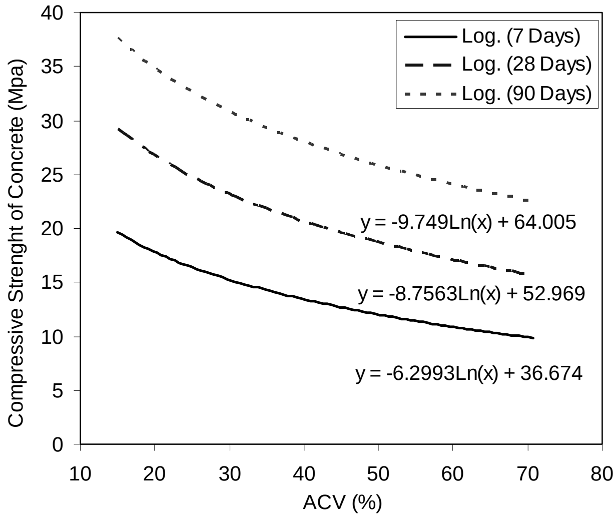

Figure 6. The relationship between ACV of aggregate and compressive strength of concrete.

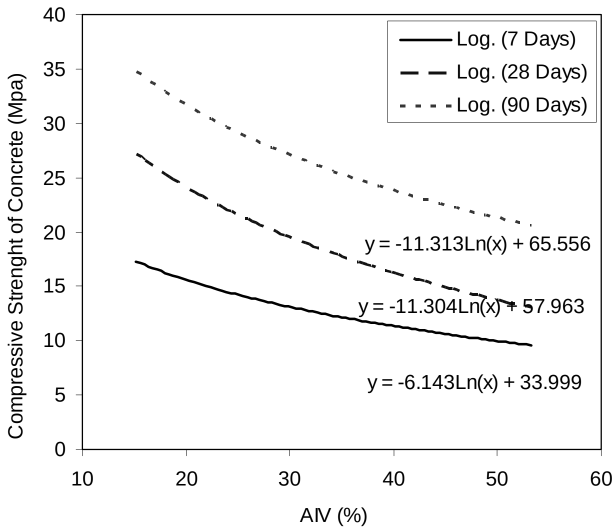

Figure 7. The relationship between AIV of aggregate and compressive strength of concrete.

3.1.1 Conclusions

In conclusions and recommendations section, it was focused on that hardened properties of concrete with different type of aggregates.
As expected from the low alkali content of the host cement, the concentrations of the alkali ions in the pore solutions of the control specimens were low; also as expected, the chemical tests demonstrates that the aggregate with high chemical reaction are not seen in the sample until 180 days of curing ages.

Reviewing density presented in aggregates, it is clear that all the crushed aggregates have produced concrete with a lower density than the basalt aggregate concrete. Relatively higher density of the basalt concrete may be related to the proportions of Fe_2O_3 particles in the basalt rock, this is observed in the chemical analysis tests. Therefore, chemical analysis tests are necessary to detect light weighted aggregate. Aggregate density constitutes a very important parameter for lightweight concrete, which is influenced by variations in the density of the pores materials. The result shows that if light weighted aggregate such as lumashele and diorite were used, dead load of structures would be decreased.

Due to the very high durability of igneous origin, the use of high abrasion value rock as aggregate in concrete pavements offers a more economical solution than the other ones.

Abrasion resistance of igneous and metamorphism aggregates is better than the sedimentary with all the type of concrete. The abrasion resistance of aggregates increases with increasing compressive strength.

In the concrete with different aggregate type, high strength properties of concrete were found when aggregates have good abrasion; also the results showed high strength of concrete was not related to high strength of aggregates. However, suitable relations are found between strength of concrete and physical and mechanical properties of aggregates.

Dolomite crushed aggregates appears as the most advantageous for building purpose. It was also found for the specimens in this study, there exited a significant common trend in the variation of the aggregate composition during the aggregates quarry detection process

4 ACKNOWLEDGMENTS

This work has been funded by Tarbiat Modares University, Iran. Authors wish to thank Dr. M. Khamehchiyan for his assistance during the experiments.

5 REFERENCES

ACI Committee 221R-308-363, 1996. *American Concrete Institute*, USA: Michigan.

ASTM, American Society for Testing Materials, *Annual Book of ASTM*, 2000. USA: Philadelphia, PA.

BS, British Standard Institution, BS 1881: Part 116-121-208, 1996. UK: London.

El-Dash, KM, and Ramadan, MO. 2006. Effect of aggregate on the performance of confined concrete, *Cement and Concrete Research*, 36: 599 – 605.

Elices, M, and Rocco, CG, 2008. Effect of aggregate size on the fracture and mechanical properties of a simple concrete, *Engineering Fracture Mechanics*, 75: 3839–3851.

ISRM, Brown, ET, 1981. *Rock Characterization Testing and Monitoring-ISRM Suggested Methods*, Oxford, Pergamon.

Nadeau, JC, 2003. A multiscale model for effective moduli of concrete incorporating ITZ water–cement ratio gradients, aggregate size distributions, and entrapped voids. *Cement and Concrete Research*, 33: 103– 113.

Neville, A, Brooks, J, Concrete Technology, 1993. England: Longman.

Wu, K, Chen, B, Yao, W, and Zhang, D. 2001. Effect of coarse aggregate type on mechanical properties of high-performance concrete. *Cement and Concrete Research*, 31: 1421–1425.

Yashar, E, Erdogan, Y, Kılıc, A. 2004. Effect of limestone aggregate type and water–cement ratio on concrete strength, *Materials Letters*, 58:772– 777.

Zhang, G, Song, J, Yang, J, and Liua, X. 2006. Performance of mortar and concrete made with a fine aggregate of desert sand, *Building and Environment*, 4: 1478–1481.