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Properties of Diyarbakir Basalt for Concrete Mix

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Abstract Concrete is the most common structural material used in construction of buildings etc. in the world. the chemical and physical properties of aggregates have a great importance in concrete design with respect to strength and durability of concrete structures. In this study, as a concrete aggregate, basalt which is common around Diyarbakır province and mineral additives which are waste materials together with cement are used as binding material. This paper has come into prominence as it aims to determine proper admixture levels and usability of Diyarbakır basalt in concrete admixture following the mechanical, physical and chemical properties.

Keywords Concrete mix, Basalt aggregate, mineral addititives

1. Introduction

Aggregates are the main material in concrete with an average volume of approximately 70-80% in concrete mix. On the other hand the mechanical properties of aggregates have a dominant effect on concrete design with respect to strength and durability of concrete structures. Among the commonly preferred concrete aggregates are limestone and dolomite. However, given that concrete is the commonly used building material in the world, it is necessary to make use of alternative rocks.

Concrete production as a composite material made of aggregate, cement and water is easy and possible around the world. Besides these, concrete production has phases such as calculation mixing, transportation, compaction and curing. Material choice and wrong applications for concrete directly effects on concrete strength [1]. Concrete strength is an important factor for structural analysis. This factor directly effects on analyses. Concrete classes determining by compressive strengths, using cube and cylinder samples [2]. There are various theoretical and experimental studies investigating the strength and strain capacities of concrete including mineral additions, retrofitting concrete elements and various techniques to examine the performance of concrete structures in structural engineering [3-10]. The results of such studies obviously indicate that provides significant increase in failure stress and strain of the confined concrete.

Basalt is the most common type of igneous rock at the Earth's surface. Having been used successfully in old structures for long years, basalt, stiff material abound on earth with a high strength, may be preferred as an alternative of concrete aggregate [11]. In order for basalt to be used as aggregate, it should be resistant to granulometry, abrasion and frost and should not cause chemical degradation in concrete. In addition, it should not contain noxious substances such as clay and silt which can potentially affect concrete and bond strength [12]

Some studies were done on basalt aggregate concretes in the middle of 20th century, results of which revealed that basalt rocks were superior compared to other rocks. Thermal expansion coefficient, conduction and conduction velocity of basalt are low. Neither temperature rise nor crack formation during the cooling was observed [13-15]. During the compression test, it was determined that basalt aggregate concretes had higher compression strength, that compression strength of basalt rock was higher than that of limestone and that water absorption and voids had low values [16]. Some studies dealing with basalt has been concluded that basaltic aggregates increase the quality of concrete [17-19].

Formed mainly from feldspar under the natural stones classification and dark grey and black in colour in the nature, basalt is a stiff and durable volcanic rock. In order to meet the raw material aggregate requirement of the concrete sector, basalt which is known with high strength and widely available on the earth can be used. It is commonly found in various properties in Diyarbakır province and its neighborhood, East and Central Anatolia and Thrace Region in Turkey. Basalt is more cost-effective in comparison to other aggregates inasmuch as it is abundant in the region with lower processing costs due to advance in today’s technology [20-21].

Being locally as thick as 150 metres in Diyarbakır and its neighbourhood, Karacadağ basalt deposits cover an area of 10000 kilometre square in Southeast Anatolia, Turkey and occur half metre below the soilcover or as a surface cover. The creeping basalt flow from Karacadağ volcano that forms these basalt rocks is common notably in Diyarbakır. Wide basalt plateaus are found across 120 to 130 km in Diyarbakır-Şanlıurfa to the west, Diyarbakır-Elazıg to the north and Diyarbakır-Mardin highway to the east. Figure 1 illustrated as formation samples of basalt rock in central parts of Diyarbakır.

Figure 1: Distribution of basalt samples in Diyarbakır

Physical, Chemical and Mechanic Properties of Basalt Rock

Diyarbakır Karacadağ basalt rock is usually in dark grey or black colour. Some other basalt rocks may weather to lighter colours. They may weather to brown colour following oxidation of ferrous minerals [22]. Diyarbakır basalt has two types as porous and non-porous basalt with density varying from region to region. It has values of 2.66-2.79 g/cm3 in the west, 2.91-2.93 g/cm3 in the north and 2.45-2.47 g/cm^3 in the east respectively [23].

Uniaxial strength mean of Diyarbakır basalt rock of 5 samples with a diameter of 42 mm and height of 102 mm is 51.76 Mpa for the porous and 89.10 Mpa for the non-porous [21]. Comparison of physical and mechanic properties of basalt with the limestone, yet another rock, is shown in Table 1 [24].

Table 1: Comparison of physical and mechanic properties of basalt with the limestone

Some properties		Basalt	Limestone
Compressive Strength (Mpa)	Dry	97.60	17.80
	Saturated	83.20	14.65
Flexural Strength (Mpa)	Dry	16.20	4.90
	Saturated	13.90	4.16
Schmidt (Mpa)	Dry	75.00	21.00
	Saturated	67.50	15.80
Compressive Strength after frost (Mpa)		83.90	16.30
Elasticity Modulus (Gpa)		68.50	14.00
Poisson Ratio		0.25	0.31
Water absorption by weight (%)		0.81	8.40
Water absorption by volume (%)		2.17	19.22
Water absorption (g/cm^2)		0.022	0.174
Capillary Abrosption ($cm/sn^{0.5}$)		1.52	1.23
Unit Weight (g/cm^3)		2.69	2.08
Density gap amount (%)		6.80	19.22
LA Abrasion loss ($cm^3/50\ cm^2$)		18.75	27.76
Freeze-thaw loss (%)		6.90	0.07
Thermal conductivity (W/m.K)		1.74	1.42

Properties of Diyarbakır-Karacadağ basalt such as high abrasion strength, low thermal conductivity and acid and frost resistance have diversified the areas of its use and led to an increase in the number of studies related to the material today [20]. Basic element chemical analyses of samples taken from various spots close to the summit of Karacadağ, results obtained through X-ray florescence spectrometry (XRF) at Earthquake Research Institute of University of Tokyo as well as chemical analysis results of testing basalt obtained from Diyarbakır- Elazığ at Dicle University labs are shown in Table 2.

Table 2: Chemical analyses of Diyarbakır basalt aggregate (%)

Components	Sample 1	Sample 2	Sample 3	Sample 4	TEST SAMPLE
SiO_2	46.04	48.70	46.79	45.88	50.28
TiO_2	3.18	2.62	2.94	2.86	1.00
Al_2O_3	13.89	14.05	14.18	13.68	22.60
Fe_2O_3	4.89	4.32	4.62	4.69	3.24
FeO	8.80	7.78	8.31	8.44	-
MnO	0.15	0.15	0.16	0.16	-
MgO	8.76	8.57	9.19	8.82	4.55
CaO	9.12	8.67	8.77	9.32	5.76
Na_2O	3.64	3.23	3.18	3.78	6.00
K_2O	1.04	1.36	1.30	1.63	1.50
P_2O_5	0.44	0.48	0.51	0.69	0.50

Alkali-Silica Reaction (ASR) in Concrete

Alkali silica reaction (ASR) is a concrete degradation occurring as a result of available reactive reaction SiO_2 in aggregates used in concrete admixtures leading to a reaction with Na_2O and K_2O (alkali) components that form the cement [22]. ASR-based deterioration in concrete was first observed in 1940s in the world and in 1995 in Turkey around İzmir region at some highways and bridges nearby [25].

Reaction caused by ASR occur in two steps: [24]

Alkali + Reactive Silica → Alkali Silica Gels (I)

Alkali Silica Gels + Moisture → Expansion (II)

Product of Alkali silica reaction is a highly hydrophilic alkali silica gel [26-27]. As alkali silica gel absorbs the moisture, the concrete expands up to 2-3% in volume. Having expanded due to moisture, alkali silica gel forms fractures and cracks in and on the surface of the concrete in unreinforced mass concretes, coating concretes as a result of exceed in tensile strength, leading to loss in durability [28]. The deterioration occurring on the bridge (İzmir-Hilal) in which sand obtained from Gediz Delta [29]. was used is represented in Figure 2.

International Union of Geological Sciences (IUGS) has reported that the rock whose SiO_2 amount and total of Na_2O+K_2O alkaline do not exceed 45-52% and 5% respectively according to the systematic of igneous rocks features basic and that its use in concrete does not lead to ASR [22]. According to [29], where SiO_2 content in basalts is more than 50%, it acts like andesite and features a reactive aggregate to the potential ASR. It is noted that the intensity of the damage given by types of volcanic rock to a structure under the influence of ASR, it is clearly understood that andesite is the most reactive rock and andesite is the type of rock that most intensely impairs the concrete as ASR, and that dacite and rhyolite give least harm. On the other hand it was identified cements whose Na_2O amount is 0.50% as low alkali and cements with 1.04% amount as high alkali. Where highly reactive rocks to ASR and low alkali cements are used, ASR impact has been identified to be reduced.

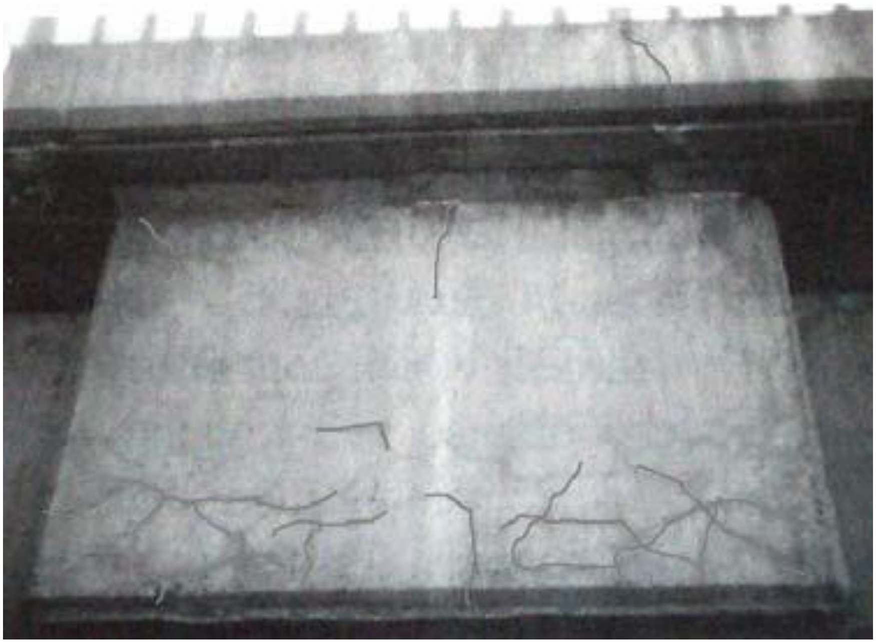

Figure 2: ASR impact on concrete

In accelerated mortar bar tests conducted in accordance with ASTM C 1260 standard, it was identified that basalt is the most nonaggressive aggregate that forms ASR compared to sedimentary rocks such as opal, chert and chalcedony [30].Considering chemical results belonging to Diyarbakır basalt samples within Table 2, it is realized that according to [22] it is basic and according to [29] it is not reactive to ASR as SiO_2 content is less than 50%. It was observed that ASR products generally are located in voids, in-between cracks of aggregates and aggregate-cement paste. Having different morphological structures, massive ASR products were able to be clearly seen in Figure 2with images zoomed in by 35 (Figure 3a.) and 650 (Figure 3b.) [31].

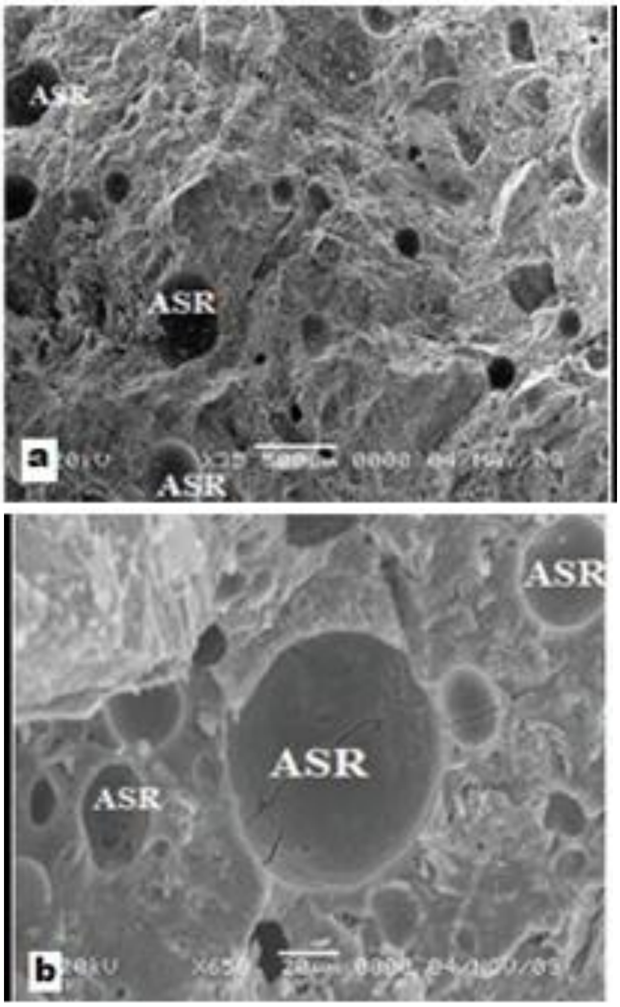

Figure 3: ASR products monitored via SEM

In Figure 3, ASR via SEM images was monitored in form of black void in the concrete. SEM images related to concrete samples prepared with Diyarbakır basalt are given in Figure 5 and 6 for samples exposed to hydropathy and for samples exposed to sulphate solution respectively. Accordingly, no ASR voids were observed in samples.

Conclusion

The images of the SEM observations indicate that the chemical structure of Diyarbakır basalt can not be classified as reactive to ASR. On the other hand the microstructure in SEM images did not change and the products related to alkali-silica reaction did not occur. As it was identified also based on strength results Diyarbakır basalt have no negative effect of ASR. Therefore the Diyarbakır basalt can be classified as a suitable aggregate material for concrete mix due to ASR reactions.

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