IMPACT OF AGGREGATE CONTENT CONTAINS BASALT AND NORMAL STRENGTH CONCRETE

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ABSTRACT

The aim of this study was to determine the impact of mechanical properties of aggregates on ordinary and high performance concretes with these aggregates. Research included aggregate crushing resistance and mechanical properties of 24 concretes with: basalts, granites, granodiorite, dolomite, quartzite, and gravels from 13 Polish and Ukrainian mines. Properties of concretes are consistent with aggregate strength. The strongest impact of aggregate crushing resistance on concrete modulus of elasticity was found. A similar strong impact applies to tensile strength of concretes, while effect of crushing resistance on compressive strength of concretes was just moderate. The samples were exposed to water curing and 100g/L sulphate solution to determine the loss in weight of the concrete cubes and compressive strength was examined at the end of 7, 28 and 360 days of the specimens. Analysis of the microstructure and cracks that influence durability, were also performed to determine effects of sulphate attacks alkali-silica reactions on the specimens using scanning electron microscopy (SEM). A loss in weight of the concrete cubes and compressive strength was distinctly evident at the end of 56 and 90 days in both acids.

Keywords: *Concrete, Elastic modulus, Splitting tensile strength, Compressive strength, Stress-strain relationship, Coarse aggregate, Crushing value, Crushing resistance, Basalt aggregates, Sulphate attack.*

INTRODUCTION

Basalt is the most common type of igneous rock on the Earth's surface. Having been used successfully in old structures for long years, basalt, a stiff and durable material abundant on arth with a high strength, may be preferred as an alternative of concrete aggregate. 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. One of the most important factors shaping the strength and deformation properties of concrete is the microstructure and properties of the aggregate-cement paste interfacial transition zone, which is responsible for the aggregate-cement paste bond strength. The adhesion of aggregate and cement paste causes concentration of internal stress in the transition zone of the interface paste. Due to the locally higher porosity and layered microstructure of the interfacial paste, they are the weakest areas in concrete. The formation of stress transfer through aggregate in concrete is possible due to the adhesion of the cement paste to the aggregate. The adhesion depends on its own mineral composition, micro and macro roughness, smoothness or ability to overlap with the paste. The formation of even the smallest micro-cracks facilitates the mutual movement of broken parts of the material. The formation of any micro-cracks in concrete reduces its elastic properties. Any cracking of aggregate grains, even in small quantities, e.g. weak grains, will also have a significant direct impact on elastic strains.

This aggregate feature is considered by testing its crushing strength, and the measure is the aggregate crushing value (ACV). Nowadays among all fibres, the basalt material is gaining much more significance due to its extraordinary properties like corrosion resistance and low thermal conductivity. Additionally the basalt fibre has, heat and sound properties, vibration resistance and thermal stability etc. It is noticed that there is also an improvement such as tensile strength, flexural strength and toughness property of concrete. Basalt fiber is in the category of high performance non-metallic made from the basalt rock which is melted due to high temperature. The basalt fibre has a fine grained texture composition which is obtained due to the quick cooling process of molten rock. Moreover, basalt fibers are eco-friendly, non-toxic, anti-corrosive, and non-magnetic properties, acid resistance and alkali resistance etc.

LITERATURE REVIEW

Altan Yılmaz (2022) In this study, it is aimed to increase the level of knowledge about the physical and mechanical properties of basalt aggregates which is produced as crushed-stone in quarries. For this purpose, an experimental study was carried out on aggregates and test results were compared with the current specifications in force. As a result of the initial tests, it was determined that the impact resistance, abrasion resistance and freeze-thaw durability of basalt aggregate were quite good. However, the water absorption and flakiness index of basalt aggregate was observed partially high. Based on the test results, it is observed that the findings obtained by single-graded and static test methods that are widely used for granular materials do not provide sufficient information about the performance of materials.

Ibrahim Baran Karasin (2022) In this study, basalt, which is common around Diyarbakır province (Turkey), is used as concrete aggregate, waste materials as mineral additives and Portland cement as binding material to prepare concrete mixes. This paper aims to determine the proper admixture levels and usability of Diyarbakır basalt in concrete mixtures based on mechanical, physical and chemical tests. Thus, in order to determine the strength and durability performance of concrete mixtures with Diyarbakır basalt as aggregate, 72 sample cubes of 150 mm were prepared in three groups: mineral-free admixture (MFA), 10% of cement amount substituted for silica fume (SFS) and 20% for fly ash (FAS) as waste material.

Adam Stolarski (2022) In this work, we present an analysis of natural fine aggregates' influence on the properties of ultra-high-strength concrete. The reference concrete mix was made of natural sand with the addition of fly ash and micro-silica. It was assumed to obtain concrete with a very high strength without the addition of fibers and without special curing conditions, ensuring the required workability of the concrete mix corresponding to the consistency of class S3. The reference concrete mix was modified by replacing sand with granite and basalt aggregate in the same fractions. Five series of concrete mixes made with CEM I 52.5R cement were tested. A comparative analysis of the obtained results indicated significant improvement in the concrete strength after the use of basalt aggregate.

Susan Tighe (2020) Quantitative analysis was conducted in this study using a threedimensional field microscope, scanning electron microscope, energy dispersive spectroscopy, and molecular simulation to investigate the surface and interface adhesive properties of three fine aggregate asphalt mixtures (FAM): basalt, steel slag, and andesite. The roughness of the aggregate and the contact angle of the asphalt on the aggregate surfaces also were analyzed quantitatively. Molecular dynamics simulations were carried out to evaluate the adhesive properties, molecular diffusion, and interfacial failure mechanisms of the basalt-, steel slag-, and andesite-based FAM. The asphaltenes and resins contributed to the asphalt's increased adhesion to the aggregate particles.

The use of basalt fiber products in construction

Alkali-resistant sizings KV-13, KV-42 and KV-41 for Basfiber® were developed specifically for construction applications. These sizings provide excellent alkali resistance and good compatibility with concrete and different resins used for production of rebar and other composite products in construction industry. Besides high alkali resistance these products have much higher mechanical properties than E-glass and much lower price compared to all other alkali resistant fibers. All the above mentioned advantages make these product an excellent and affordable alternative to alkali-resistant fibers which are currently used on the market.

Applications

Kamenny Vek offers a wide range of products for building and road construction:

- Wet or dry chopped strand for premix technology
- Special roving for Spray-Up technology
- High strength roving for production of rebar and pultruded profiles
- Basalt mats and fabrics for concrete reinforcement and buildings thermo insulation
- Reinforcing mesh for roads and buildings construction
- Scrims

In comparison to steel:

- **High strength to weight ratio:** Basalt fiber is 3 times lighter and up to 2.5 times stronger in tensile strength than steel.
- **Chemical and corrosion resistance:** Basalt fiber doesn't rust and is resistant to the action of salt ions, chemicals, and the alkalinity inherent in concrete.
- **Low thermal conductivity:** Basalt fiber has extremely low coefficient of heat conductivity compared to steel. This advantage helps to reduce heat transfer from building interiors to exteriors and significantly improves energy efficiency
- **Zero electrical and magnetic conduction:** Basalt fiber has much higher electrical resistance compared to steel and doesn't interfere in the operation of sensitive electronic devices

In comparison to E-glass:

- **Tensile strength and modulus:** Basfiber® shows 25% higher tensile strength and 15% higher tensile modulus compared to E-glass.
- **Chemical resistance:** Basalt fiber shows much better chemical resistance compared to E-glass.

- **Heat and fire resistance:** Melting point of basalt fiber is 150°C higher compared to E-glass.

COARSE AGGREGATE

Generally, natural mineral aggregates are being extensively used for making different types of concrete. The normal weight, light-weight and heavy weight natural mineral aggregates are being used to produce normal weight concrete, light weight and heavy weight concrete respectively. Also, synthetic aggregates such as expanded clay and shale to produce light weight aggregates. Further, industrial byproducts such as blast furnace slag and fly ash are also being used to produce aggregates.

Cutting

The cutting machine used in this cutting was a SCQ-300 automatic cutting machine as shown in Figure 3b, the saw blade adopted a diamond blade, and the cutting speed was 5 mm/min. Figure 3c,d show the concrete cubic after coring and the concrete cylinders, respectively.

Polishing

When the cutting of the specimens finished, the specimens were coarse. The specimens' surface was polished until smooth, in order to ensure these specimens were standard and thus increased the security in the later experiment.

RESEARCH METHODOLOGY

Compared with traditional concrete, basalt fiber-reinforced concrete has the advantages of higher tensile strength and less cracking. The main mechanism is that after basalt fiber is added, basalt fiber exerts its high tensile strength characteristics, and then shows the overall strength of basalt fiber-reinforced concrete. At the same time, basalt fiber-reinforced concrete has better anti-cracking advantages compared with traditional concrete, and its thermal and chemical properties are also different from traditional concrete. In addition, as mentioned in the literature section, i.e., introduction section, concrete has been used in many scenarios with high temperatures in modern society. Thus, this study focused on the development of a fiber-reinforced concrete, and then the proposed fiber-reinforced concrete was tested with high temperatures, cooling methods, and dynamic loading to obtain its thermal and dynamic behaviors. To investigate the influence of the type of aggregate on the physical and mechanical properties of high-strength concrete, first the composition of the primary SC1 mix based on sand was developed. The main aim during the design of the SC1 mix was to obtain high strength parameters while maintaining the required consistency class of the mix. The required consistency class was determined as plastic, which corresponded to class S3 according to the slump test. Micro-silica in proportion of ms/c = 13.3 was used to improve the tightness of concrete and increases its strength.

RESULTS

Compressive Strength Test Results (M 50)

This test was performed according to the British Standard (B.S. 1881, part 3).Table5 to table 8 and the results of the compressive strength tests that were conducted on the trial mixes containing 0%,25%, 50%,75% and 100%basalt, respectively. In general, the compressive Strength increased as the percentage of basalt content in the mix is increased.

TABLE 1.Curing days for compressive strength test results for M 50 grade concrete mix in N/mm^2

S.No:	Curing Days	Compressive strength (N/mm2)				
		0 % of basalt	25 % of basalt	50 % of basalt	75 % of basalt	100 % of basalt
1	3	29.81	33.39	36.10	39.88	42.18
2	7	40.86	41.58	42.35	43.09	45.3
3	28	60.75	63.46	64.94	65.56	66.33
4	56	62.01	64.72	66.2	66.82	69.79

SPLIT TENSILE STRENGTH (M 50)

Tensile testing, also known as tension testing, is a fundamental materials science and engineering test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics.

TABLE.2.Curing days for Spilt Tensile strength test results for M 50 grade concrete mix in N/mm^2

S.No:	Curing Days	Spilt Tensile strength test strength (N/mm2)				
		0 % of basalt	25	50 % of basalt	75 % of basalt	100 % of basalt
1	3	3.21	3.81	4.55	5.83	6.64
2	7	4.21	4.81	5.56	6.83	7.36
3	28	4.77	5.56	6.55	7.83	8.36
4	56	5.77	6.56	7.55	8.36	9.20

COMPRESSIVE STRENGTH TEST RESULTS (M 60)

Compression tests are used to demonstrate how a material will respond to compression. They can be used to assess a material's plastic flow behavior and ductile fracture limits. They also determine how a material responds to crushing loads. Compression tests are crucial for assessing the elastic and compressive fracture characteristics of brittle or low-ductility materials.

TABLE.3.Curing days for compressive strength test results for M 60 grade concrete mix in N/mm^2

S.No:	Curing Days	Compressive strength (N/mm2)				
		0% of basalt	25% of basalt	50% of basalt	75% of basalt	100 % of basalt
1	3	34.63	36.50	37.44	39.88	43.84
2	7	45.58	48.48	49.23	51.02	53.62
3	28	68.84	70.06	74.58	76.08	79.59
4	56	72.20	73.39	76.00	79.35	79.98

SPLITTENSILE STRENGTH RESULTS (M 60)

TABLE.4. Curing days Spilt Tensile strength test results for M 60 grade concrete mix in N/mm^2

S.No:	Curing Days	Spilt Tensile strength test strength (N/mm2)				
		0% of basalt	25 % of basalt	50% of basalt	75 % of basalt	100 % of basalt
1	3	3.43	3.88	4.55	6.00	6.64
2	7	4.38	5.00	5.72	6.83	7.58
3	28	5.00	5.66	6.62	7.86	8.53
4	56	5.77	6.62	7.68	8.49	9.16

CONCLUSIONS

The laboratory test results in compressive strength, tensile strength and modulus of rupture seem to indicate that the increase in basalt percentage enhances the mix strength over the conventional limestone mix. This is due to the fact that basalt is denser and more durable and less water absorbing than limestone. Tests results also show an improvement in permeability and thermal conductivity with the increase in basalt aggregate content. In general, it is clear that the increase in basalt content in the concrete mix tends to enhance the properties of the mix. On the other hand, the use of waste minerals such as fly ash with appropriate proportions of cement replacement in concrete mix saves both the energy consumed for cement production and carbon emissions, addressing an important environmental issue. As it is noted the samples produced with Diyarbakır basalt aggregate did not show any volumetric cracks after 90 days of curing and were not reactive to ASR as the microstructure seen in SEM images did not change and products related to alkali-silica reaction were not observed. The chemical analyses of all five samples revealed that there is no objection in terms of ASR for the use of Diyarbakir basalt as concrete aggregate. Additionally, the mineral admixtures such as FA can improve the microstructure as well as the compressive strength reducing the mass loss of concrete.

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