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The effects of different sandstone aggregates on concrete strength

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HIGHLIGHTS

- ▶ Sandstones vary in composition and may cause different concrete strength.
- ▶ We examine the influence of different sandstone aggregates on concrete strength.
- ▶ Subarkose and arkose cemented with clay cause lower concrete strength.

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ABSTRACT

Sandstones vary in composition and consequently when used in concrete as aggregate may cause different concrete strengths. However, there are few data about correlating the effects of different sandstone aggregates. In this work we have highlighted some mechanical aspects concerning the use of different sandstones as concrete aggregate. The sandstone samples were first tested to determine their petrographic characteristics and aggregate properties. Then, concretes were prepared by using these aggregates, and fresh and hardened concrete properties were determined. The influence of different sandstone aggregates on the strength of the concrete was evaluated. According to the results obtained, subarkose–arkose, sublitharenite–litharenite and arkose aggregates which have clay cement caused approximately a 40–50% reduction in concrete strength when compared to subarkose, quartz sandstone and arkose aggregates which have carbonate cement, because these aggregates result in weaker bonding between aggregate and cement than others.

1. Introduction

Aggregates are the major constituents of concrete and typically occupy between 60% and 80% of the concrete volume [1]. Properties of both fresh and hardened concrete are mainly influenced by the quality of aggregate, including its long-term durability and resistance to cracking [2–4]. It is well known that the inhomogeneous structure of concrete can be described as a three-phase system consisting of hardened cement paste, aggregate and the interface between aggregate particles and cement paste [5]. Due to the relatively high differences of stiffness of between aggregate and hardened cement paste, stress concentrations are formed around the aggregate particles in the interfacial zone. Therefore, the bond strength that maintains the stresses distribution at the interfacial zone influences highly the compressive strength of concrete composite [3,5].

Strength performance remains the most important property of structural concrete, from an engineering viewpoint [6]. The relation between concrete composition and mechanical properties has long been a matter of research interest [7–9]. The strength of the concrete is determined by the characteristics of the cement, coarse aggregate, mixture proportions including w/c and the interface [3]. For the same quality cement, different types of coarse aggregate with different shape, texture, mineralogy and strength may result in different concrete strengths. However, the limitation of the water/cement ratio (W/C) concept is becoming more apparent with the development of high-performance concrete, in which the aggregate plays a more important role [10].

Sandstone is a widespread aggregate resource and is increasingly being used in concrete construction around the world [11]. The geological properties of this sedimentary rock are fairly diverse such as quartzite, arkose, subarkose and greywacke aggregate that may produce a range of hardened concrete properties. Therefore, it is important that the aggregate can be easily characterized to obtain predictable concrete properties.

The aim of this study was to evaluate the composition, physical and mechanical properties of different sandstone aggregates on the strength of concrete. To date, many researchers [1,2,5,6,8–11] have attempted to investigate the effect of different types of aggregates but there is little information about correlating different types of sandstone aggregates on concrete strength.

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Sandstones used in this study are widespread in both sides of Istanbul in Turkey. The samples were taken as being representative of different sandstones. They were fresh or slightly weathered. A total of seven different sandstones was sampled and subjected to the laboratory studies.

2. Description of the selected sandstones

Petrographical characteristics of the sandstones collected from the Omerli, Ayazağa and Cebeciköy regions in Istanbul were determined by thin section studies. According to these studies, mineralogical composition, cement and particle size of the different sandstones were determined and classified (Table 1).

3. Laboratory analysis

3.1. Aggregate properties

The studied sandstone samples were broken into smaller pieces by hammer. Aggregate fractions were prepared from the smaller pieces using a laboratory jaw crusher. The aggregate tests undertaken included percentage of fine materials, methylene blue test, sand equivalent test, relative density, water absorption, Los Angeles test, Micro-Deval test, flakiness index and magnesium sulfate ($MgSO_4$) test. The results of these tests are given in Table 2. Tests were performed in accordance with European Standards (EN). Each test was performed at least three times.

3.2. Cement properties

The cement type used in this study was CEM II 42.5 R which was checked which conformed to EN 197-1 (2000). The chemical, physical and mechanical features of this cement are given in Table 3.

3.3. Preparation of concrete specimens

In order to investigate the effects of different sandstone aggregates on the strength of concrete, seven concrete mixtures were designed. Tests were performed in accordance with TS 802 (1985) standard. The mixture proportions of testing concretes are given in Table 4. As seen in this table; all mixtures were designed

Table 1
Petrographical characteristics of studied sandstones.

Sample code	Composition	Cement	Particle size	Classification [12]
KM1	Quartz, feldspar, serizite, muscovite, rock fragments (schist, quartzite, silicious sedimentary rock fragments)	Few clay	Fine–medium	Subarkose/arkose
KM4	Quartz, feldspar, rock fragments (quartzite, schist, phyllite), serizite, muscovite, opaque min.	Clay	Coarse	Sublitharenite–litharenite
KM5	Quartz, feldspar, clay, muscovite, rock fragments	Clay	Very fine–fine–medium	Arkose
K3	Quartz, feldspar, muscovite, serizite	Carbonate	Fine	Arkose
K4	Quartz, feldspar, muscovite, calcite, opaque min.	Carbonate and very few clay	Fine–medium	Quartz sandstone
AKT	Quartz, feldispar, muscovite	Carbonate and very few clay	Fine–medium	Subarkose
CBKT	Quartz, feldispar, muscovite, rock fragments	Very few carbonate	Fine	Subarkose

Table 2
Results of aggregate tests.

Aggregate tests	KM1	KM4	KM5	K3	K4	AKT	CBKT
Fine materials (%) (0–4 mm)							
EN 933-1 (1997)	11.7	7.3	12	10.0	9.3	7.2	6.5
Methylene blue absorption (gr/kg)							
EN 933-9 (2009)	2.25	2.5	4	1.25	0.50	1.2	1.4
Sand equivalent (%)							
EN 933-8 (1999)	30	53	35	38	65	36	65
Saturated surface dried relative density (gr/cm^3)							
EN 1097-6 (2000)							
0–4 mm	2.75	2.70	2.77	2.70	2.70	2.68	2.68
4–11.2 mm	2.70	2.65	2.64	2.73	2.71	2.71	2.70
11.2–22.4 mm	2.69	2.62	2.66	2.73	2.73	2.72	2.71
Water absorption (%)							
EN 1097-6 (2000)							
0–4 mm	2.63	2.21	3.75	2.45	1.82	1.6	1.6
4–11.2 mm	2.19	2.17	3.65	0.89	0.48	0.7	0.7
11.2–22.4 mm	2.03	2.19	3.62	0.45	0.37	0.7	0.5
Los Angeles coefficient (%)							
EN 1097-2 (2010)	26	34	29	13	14	20	22
Micro-Deval coefficient (%)							
EN 1097-1 (2011)	46	65	86	40	15	19	18
$MgSO_4$ value (%)							
EN 1367-2 (2009)	65	87	82	36	12	10	12
Flakiness indices (%)							
EN 933-3 (1997)							
4–11.2 mm	46	48	63	37	33	19	20
11.2–22.4 mm	31	26	35	13	10	11	12