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Adequacy of carbonate aggregates as an alternative for chert aggregates in concrete manufacture

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HIGHLIGHTS

- Diagenesis controls the physical and mechanical properties of carbonate rocks.
- Chert intact rock have higher strength than carbonate intact rock.
- Angularity and porosity of carbonate aggregates increase the concrete strength.
- Chemical deterioration of carbonate aggregates decreases their concrete durability.

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ABSTRACT

Carbonate and chert aggregates are extensively used in concrete manufacture. The present study assesses the effectiveness of both aggregates in different concrete mixtures. The diagenetic processes control the dissolution of carbonate aggregates and their physical and mechanical properties. Although the mechanical properties of the chert aggregates increase the concrete strength, the physical properties of the carbonate aggregates benefit largely the concrete strength. Sewer water is more effective than the rain and tap water in carbonate dissolution, so the chemical deterioration of the carbonate aggregates could decrease the concrete durability.

1. Introduction

Aggregates constitute the fundamental component in the concrete that used in diverse engineering applications. The demand for aggregates increases day by day due to extensively use of concrete in the world [1]. The aggregates must be clean, sound, durable, hard and resistant to abrasion; uniform in quality, properties and free of friable, thin, elongated or laminated pieces, disintegrated materials, alkalis substances [2]. Petrology, texture, particle shape, porosity, rock materials control the mechanical degradation of aggregates [3]. The naturally fragmented sources of these aggregates are clastic alluvial sediments, whereas artificially fragmented sources include crushed sedimentary, igneous, and metamorphic rocks [4].

Natural coarse chert aggregates and quartz sand are quarried from the Oligocene and Miocene rock units around the Greater Cairo area (Egypt), which are composed of cherty gravels and quartz sand (Fig. 1). After more than 150 years of quarrying, the depletion of chert aggregates has motivated construction agencies to opt for artificial sources. Popular amongst these are the crushed carbonate aggregates, widely exposed in the North Egypt (Fig. 1), they are cheaper than chert aggregates. Consequently, the demand for carbonate aggregates has increased progressively with time. The carbonate aggregates are commonly derived from the Middle Eocene outcrops, east of Greater Cairo at Jabal Ataqa (Fig. 1). These outcrops consist mainly of hard, massive limestone, dolomitic limestone, dolomite and siliceous limestone beds, with chert bands. Argillaceous limestone and chalky limestone appear higher in the stratigraphic sections of the Middle Eocene unit.

The aim of the present contribution is to determine the chemical and mechanical disadvantages of chert and carbonate aggregates and their effects on concrete strength and deterioration. This study reports the petrographic characteristics of the carbonate aggregates, and explores the dissolution effects of rain, sewer and tap waters on the carbonate aggregates to evaluate their chemical stability.

In order to investigate the properties of the coarse carbonate and chert aggregates in experimental concrete mixtures, representative samples were collected from Ataqa area and from Cairo-Suez

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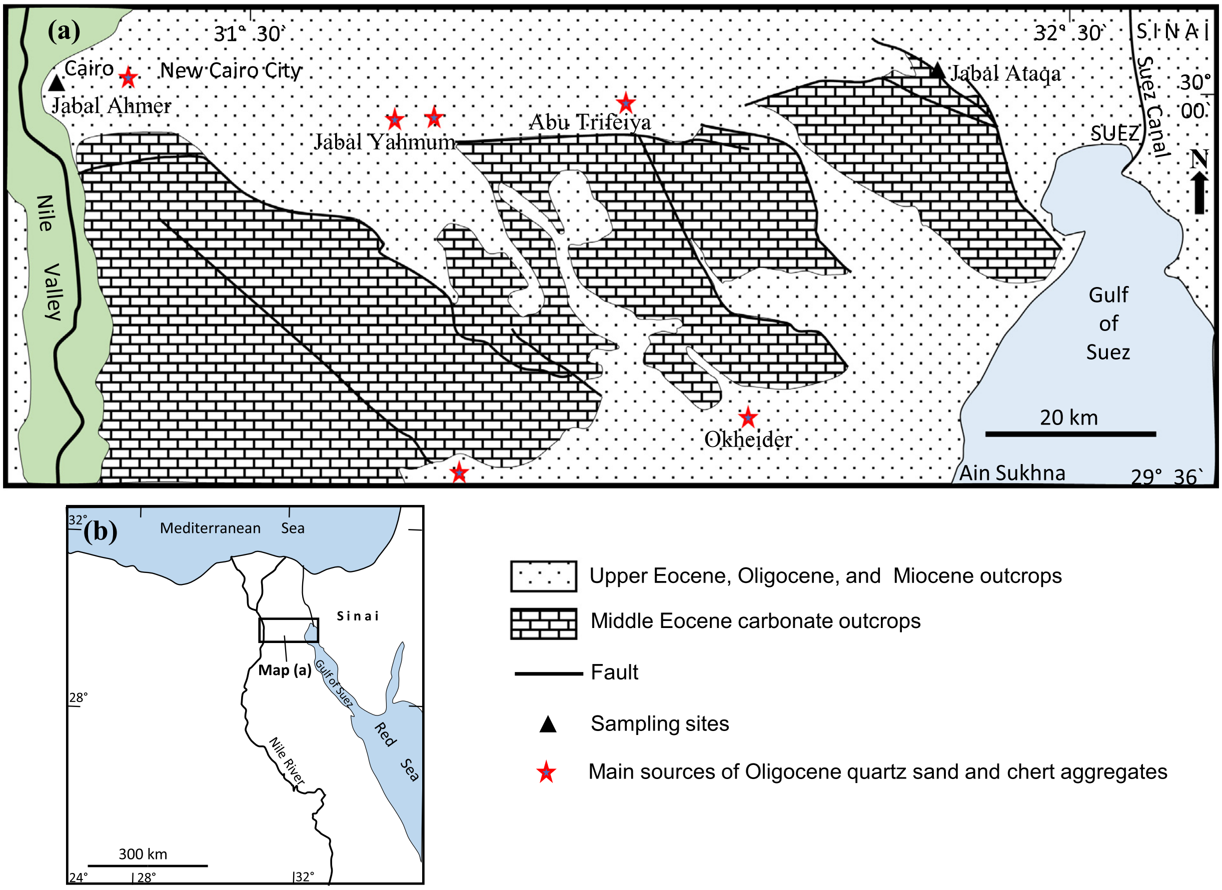

Fig. 1. (a) Simple geologic map of the Cairo-Suez district showing the outcrops of coarse and fine aggregates, as well as the sampling sites (Jabal Ataqa for carbonate aggregates). Oligocene sediments are the source of natural fine sand and coarse chert aggregates. (b) Location of map (a) in Egypt.

district, respectively. In addition, quartz sands as fine aggregates that were collected from Jabal Ahmer area.

2. Materials and methods

2.1. Materials and sources

Primary megascopic investigation of the carbonate rocks at Jabal Ataqa revealed the presence of four carbonate types that are recorded also in the aggregates products. For measuring the physical (density, effective porosity, aggregates shape) and mechanical (strengths, hardness, abrasion, p-wave velocity) properties of aggregates, four samples (about ½ m^3, each) of coarse carbonate aggregate were collected from the Ataqa area (two samples) and the client stockpiles (two samples), as well as four coarse chert samples (about ½ m^3, each) were collected from the client stockpiles. Four samples (about ½ m^3, each) of quartz sand were collected from a stockpile derived from Jabal Ahmer (Fig. 1). The sand samples were mixed together and then split into two large samples for using in experimental concrete mixtures.

2.2. Properties and tests of aggregates

The carbonate and chert aggregates were investigated in hand specimen and in thin sections. The thin sections were examined using polarizing microscope before and after staining the carbonate with Alizarin Red-S. The grain size distribution in the aggregates was determined using sieve analysis. Materials less than 5 mm are termed as fine aggregates, while those more than 5 mm are coarse aggregates. The fractions were washed to remove fine sand, silt and dust. The physical and mechanical properties of the aggregate materials were tested using mainly the ASTM techniques and methods. X-ray diffraction analysis was conducted on the bulk samples using a Philips diffractometer (model PW/1840) with Ni filter, Cu–Kα radiation (λ = 1.542 Å). Instrument settings were 40 Kv and 30 mA potential, scanning speed of 0.02°/second and 2θ ranged between 2° and 60°. The various mineral species were identified using ASTM index and files. Their proportions were semi-quantitatively determined, based on the intensities of the strongest diffraction peaks.

Rain, sewer and tap water were collected to study their possible dissolution effects on the carbonate aggregates. Three batches of aggregates, each about 10 g, representing different types of carbonate rock, were immersed separately into 500 ml of these three water types for 14 months. The water was then chemically analyzed, and the aggregate particles were dried and weighed to calculate the weight loss due to dissolution. Chemical analyses of the carbonate aggregates and water samples were performed using SP-ICP and ICP-OES, respectively.

2.3. Properties and tests of concrete

Concrete mixtures (8000 cm^3 for each test) were separately prepared for chert and carbonate aggregates. The coarse aggregate to fine aggregate ratio of the mixtures was measured as a volume ratio. For each aggregate type, three water/cement ratios (w/c) were used in these mixtures. Water/cement ratio is measured in ml/g, and the three ratios used were 0.3, 0.4, and 0.5 w/c. Portland