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Sulfate Resistance of Filler Cement Mortars

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Abstract: *Cheap fillers are added to concrete mixes to improve sustainability. Durability of such mixes is investigated. In this paper the sulfate resistance of mortar mixes containing crushed limestone and crushed dolomite fillers is investigated and compared to that of conventional mortar. Mortar mixtures with different ratios of dolomite or limestone of 10, 20, and 30%, introduced as partial cement replacement by weight,were tested to evaluate the effect of sulfate attack according to ASTM C 1012. Six prisms of each mix were exposed to sulfate for 10 weeks. It was concluded that the introduction of lime filler greatly reduces sulfate resistancewhile mixes containing dolomite fillers have almost the same sulfate resistance as conventional mixes.*

I. Introduction

Portland cement is one of the most polluting materials with low sustainability as the cement industry is heavily energy consuming and it results in the release of a huge amount of carbon dioxide (CO_2) which is one of the greenhouse gases. The world annual production of Portland cement is about 3 billion tons. The production of one ton of cement results in the release about 0.9 ton of CO_2 into the environment. Greenhouse gases are the main cause of the currently experienced global warming. Due to its deleterious effects, it is necessary to reduce the CO_2 release into environment.

Several methods to reduce cement utilization have been investigated. One of those methods is the partial replacement of Portland cement with a ‘green’ material (El Mostafa, 2013). The utilization of some types of fillers is gaining popularity as a method to achieve a cheaper, more sustainable concrete, especially with high strength concrete with low water to cement ratio, where no enough water or space are available for full cement hydration. Limestone is the most common type of filler while Dolomite is another relatively new promising type of filler, locally available in Kuwait. Both types are considered in this study.

The use of limestone fillers has been thoroughly investigated by many researchers. Portland Limestone cement (PLC) may be defined as cement that containing ground limestone as a partial replacement for Portland cement (PC). It is produced by blending Portland cement and limestone or intergrinding Portland cement clinker, limestone, and calcium sulfate (Thomas, 2010). The performance of Portland limestone cement is almost similar to Portland cement. The ASTM and CSA specifications both limit the amount of limestone in Portland Limestone Cement to 15%. The purpose of using limestone is to reduce the amount of cement clinker, to reduce the consumption of raw materials, and to achieve sustainable concrete (Ramezanianpour, 2012), (Bonavetti et al, 2013).

Dolomite and limestone are considered carbonate rock. They are sedimentary rocks which can be grinded and used as a partial replacement for cement. Using dolomite as a partial replacement of cement to produce Portland Dolomite Cement (PDC) decreases the amount of cement which in turn reduce the CO_2 emissions (Preethi and Prince, 2015).Its use is not as common as limestone and research studies on the properties of dolomite as a partial cement replacement are limited (Scybilski and Nocuń-Wczelik, 2015).

Deterioration and loss of durability is the main cause of premature loss of serviceability and termination of service life of buildings and structures in Kuwait. Sulfate attack is one of the common types of deterioration in Kuwait due the special characteristics of weather. The weather in Kuwait is characterized as hot marine environment. The very high temperature leads to much faster rate of deterioration. The investigation of sulfate resistance is, therefore, of great importance. The scope of this researchis to investigate the sulfate resistance of mortars produced with 0, 10, 20 and 30% of crushed limestone and crushed dolomite introduced as partial replacement of cement by weight.

II. Materials And Mix Designs

Portland cement Type Iwas provided by Kuwait cement company (KCC). This type of cement is produced in accordance with the Kuwaiti standards specifications (KSS 381-383), and the American specifications (ASTM C150). Coarse aggregate of Limestone with size (3/8 inches) was provided by KuwaitiBritish Ready Mix Company (KBRC). The specific gravity of coarselimestone used in this study was 2.37 % and the absorption was 0.3%. The limestone used was ground. Fine Ground dolomite was obtained from National Industries Company of Kuwait (NIC). The chemical composition ranges of the acquired type of dolomite are shown in Table 1. Particle size distributions of cement, limestone and dolomite are shown in Figure1.

Table 1: Chemical composition ranges of dolomite

Chemical Composition	Percentage (range)
Silicon Dioxide	2-3
Aluminum Oxide	0.1-0.15
Ferric Oxide	0.2-0.25
Calcium Oxide	25-30
Magnesium Oxide	15-20
Carbon Dioxide	45-50
Calcium Carbonate	65-80

Fine Aggregates are natural sand, acquired from local quarries in Kuwait. Physical properties of fine aggregate are shown in Table 2.

Constituent materials for mortars were proportioned according to ASTM C 1012 requirements such that the water to cement ratio was 0.485 and the sand to cement ratio was 2.75. Cement was partially replaced by crushed limestone and crushed dolomite at ratios of 0%, 10%, 20% and 30% , by weight,rendering seven different mortar mixes.

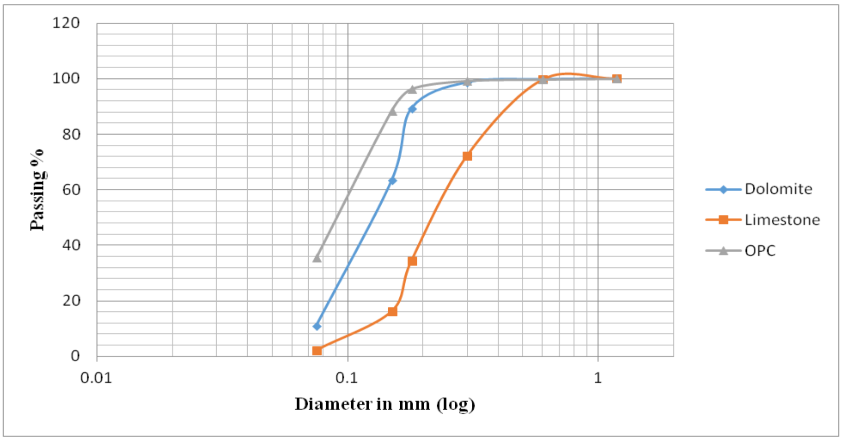

Figure 1: Particle Size Distribution for OPC, Limestone and Dolomite

Table 2: Physical properties of fine aggregates

Properties	**Observed values**
Bulk Specific Gravity(SSD)	2.59
Bulk Specific Gravity(OD)	2.57
Absorption (%)	1.13
Moisture Content (%)	0.91
Fineness Modulus	2.46

Mixing and samples preparation:

For each of the seven mixes, six mortar bars of sizes 25x25x280mm and three cubes of sizes 50x50x50mmwere cast. Mortar cubes were cast and tested according to ASTM C 109 (Standard Test Method for Compressive Strength of Hydraulic Cement Mortars). Mortars were mixed in small mixer, covered properly by plasticand placed in curing room at 35ºC. After 24 hours, specimens were demoulded and stored in a water curing tank at 21±2ºC.

Figure 2: Mortar bars immersed in Na_2SO_4 solution

III. Testing And Properties

Mortar cubes were tested for compressive strength. The average compressive strengths for the seven mixes are shown in table 3.

Solution of Na_2SO_4 was prepared by dissolving 50 g of Na_2SO_4 in 1000 mL of distilled water; such that the volume proportions of the solution was 4 times the volume of mortar bars. Bars were then placed in the solution and kept at 21±2ºC as shown in Figure 2. Length change measurements were performed at 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 weeks after immersion in sulfate solution.

According to ASTM C1012, when the maximum expansion of mortar bars exposed to sulfate solution for 6 months is less than 0.1%, then the cement can be considered as moderate sulfate resistance, while it can be classified as highly sulfate resistance when it reaches less than 0.05% after 6 months or reaches less than 0.1% after 12 months of exposure. Due to time restrictions, however, and as only a comparative study between conventional and filler mortars is required, samples were immersed for only 10 weeks.The variations of average expansions and time for the seven mortars are shown in figures 3,4 and 5.

Table 3: Average Compressive Strength for mortar cubes

Mixture	Designation	Avg. Compressive Strength (Mpa)
M1	OPC 100%	33.24
M2	PDC 30S	18.87
M3	PDC 20S	20.26
M4	PDC 10S	24.53
M5	PLC 30S	18.24
M6	PLC 20S	19.71
M7	PLC 10S	24.18

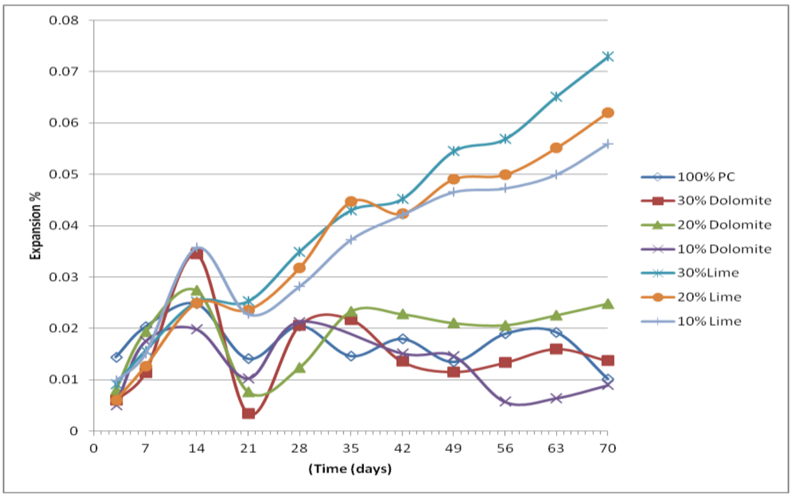

Figure 3: Average expansion due to sulfate attack during 70 days at 20ºC

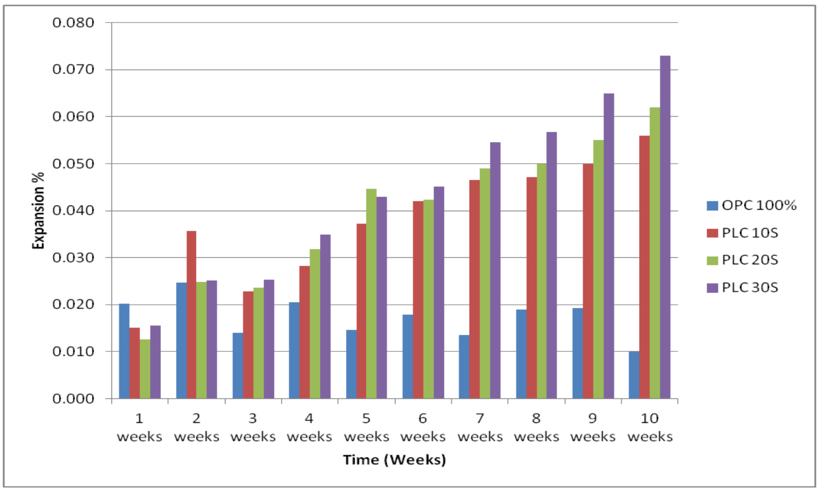

Figure 4: Average Expansion length of 10 weeks of Portland Limestone Mixtures

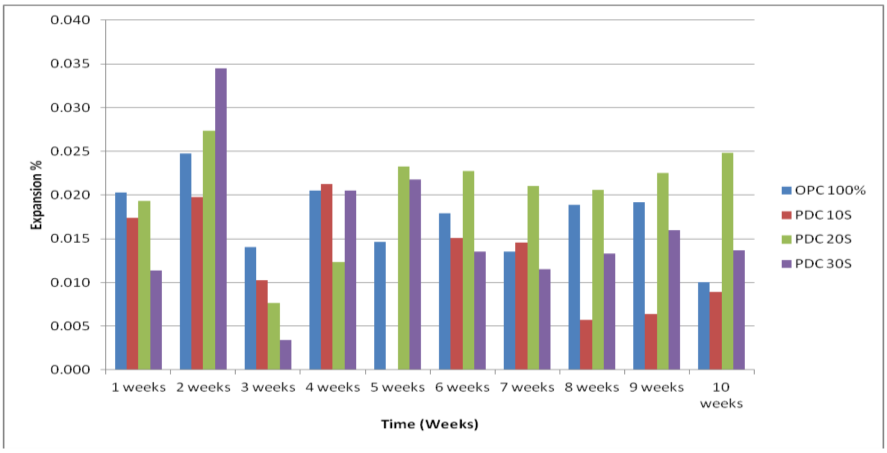

Figure 5: Average Expansion length of 10 weeks of Portland Dolomite Mixtures

IV. Discussion And Analysis

As shown in figures all samples experience expansion due to immersion in sulfate solution. The expansion increase with the immersion duration. The average expansion due to sulfate attack is much higher for mortars containing limestone than for conventional concrete. The average expansion for mortar prisms containing 10, 20 and 30% limestone as cement replacement after 10 weeks of immersion were 460, 520 and 630%, respectively, higher than that for conventional mortar. Results may be improved by increasing the limestone fineness. The fineness of the used limestone is higher than that of cement, and according to Dhir et al (2005) the fineness of limestone cement has to be 100-120 m^2/Kg more than OPC to render similar properties. The type of limestone used in this study was selected due to its availability in the Kuwaiti market.

The sulfate resistance for mortars containing crushed dolomite filler is almost the same as that for conventional mortar. The average expansions for dolomite filler mortars are 150% and 40% higher than normal mortar for 20 and 30% dolomite, respectively, after 10 weeks of immersion. For 10% dolomite mortar, however, the expansion was 10% lower than that of conventional mortar. Sulfate resistance for dolomite filler mortars may also be improved by increasing crushed dolomite fineness.

V. Conclusions

In this paper, the sulfate resistance for mortars and concrete incorporating either crushed limestone or crushed dolomite filler as partial replacement of cement were investigated. The following were concluded:

- The introduction of ground dolomite as a concrete filler resulted in concrete with analogues sulfate resistance to conventional concrete. The use of 10% dolomite as cement replacement increased resistance to sulafte attacks.
- The utilization of crushed limestone filler as partial replacement of cement resulted in great reduction in concrete resistance to sulfate attacks. In case of sulfatepresence other means to increase sulfate resistance suchas using sulfate resistance concrete or pozzolanic materials should be considered.
- Materials available in market were used in this investigation. Increasing the fineness of either dolomite or limestone is expected to improve sulfate resistance of concrete.
- The use of fillers as partial cement replacement has great effect on concrete sustainability. Fillers reduces energy consumption in cement production and CO_2 emission by the same ratio. Concrete sustainability also improve due to the increased service life resulting from increased durability.
- Addition work is required to investigate the effect of the dolomite fineness on the properties and durability of resulting concrete.

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