Effect of Nano Calcium Carbonate on Mechanical Strength and Permeability of Roller-Compacted Concrete

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Extended Abstract

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Introduction

Nanostructured materials have gained increasing attention of industry and the academia in recent decades, due to their prominent behaviors. In this regard, the building industry is considered to be the major consumer of nanostructured materials in terms of its needs, including strength, resistance, durability and high performance. Studies on nanoscale behavior of cement and concrete to develop new building materials and their applications are of high importance. A typical method for the development of high performance concrete (HPC) often contains various parameters, including the mix of conventional concrete with different types of additives. Nano-Calcium carbonate (Nano-Precipitated Calcium Carbonate) is a nano-sized filler which is used in this research. The results indicate that the higher the optimal content of nano-precipitated calcium carbonate powder, the higher the initial heat of the roller-compacted concrete; also, the resistance of the samples significantly increases over time. However, the level of permeability of roller-compacted concrete decreases by optimal increase of nano-calcium carbonate powder due to its fine grains, filling properties, and high specific level. The results of this study show that the adequate use of this material improves some properties of roller-compacted concrete.

Material and methods

In this study, the content of Nano-calcium carbonate used was selected at 0, 1, 2, 3 and 4 percent replacing a volume of cement consumed in concrete. Type II Portland cement, crushed fluvial sand, and crushed coarse aggregates with a maximum size of 19 mm were used. The aggregates' grading range in the mix has been selected according to the ACI325-10R. The chemical formula of Nano-calcium carbonate powder is $CaCo_3$ and the average particle size is between 15-40 nm

According to the roller-compacted concrete specifications, 5 mix designs have been used with different proportions of stone materials in preparing of concrete. The samples were made on a vibrating table and in the cylindrical molds of 15 × 30 cm according to ASTM C1176 standard.

By increasing the cement grade, the slope of the Vebe curve increases, which means an increase in speed and reduction in efficiency over time in higher grades. Increasing the cement grade from 275 to 300 kg/m^3 leads to increased Vebe time. In other words, it can be said that the efficiency is reduced at a lower rate in lower grades of new roller-compacted concrete mix. The Vebe time of the roller-compacted concrete pavement should be between 30-40 s to achieve optimal efficiency. According to the results of Vebe time, the efficiency of the roller-compacted concrete with the grade of 300 kg/m^3 has a better functionality than other mixtures and lasted more than others in the 30 to 40 second range. Accordingly, concrete with a grade of 300 kg/m^3, is the compressive strength according to this design.

Determining the compressive strength of cylindrical concrete samples of different ages is done according to the ASTM C39/C39M standard. For permeability test, the BS EN 12390-8: 2009 was used in which the sample should be put under pressure of (0.5±)5 for 72 hours immediately after molding. Determining the tensile strength of concrete cylindrical samples at different ages is done according to the ASTM C496 standard. The peak is obtained using the XRD analysis of the crystallite size by determining the width of the peaks. In interpreting the XRD data, a list of peak resolution and their intensities is observed. To determine the elemental composition of materials, a non-destructive analytical technique is used by X-ray which is so-called XRF (X-ray fluorescence). A scanning electron microscope is a powerful magnification tool and is used to distinguish elements.

Results and discussion

The results indicate that the increased Vebe time occurs by an increase in the percentage of nano-calcium carbonate. In terms of the compressive strength of cylindrical roller-compacted concrete samples, 2% of nano-calcium carbonate at the ages of 7, 28, and 90 days has been effective in increasing compressive strength in higher ages. Such that, at the ages of 28 and 90 days, it is increased by 12% and 15 % compared to the control sample, respectively. The nano content increases over 15% causes decreased compressive strength and thus had negative effects on the rheological properties of the roller-compacted concrete. In terms of tensile strength of the cylindrical roller-compacted concrete samples, 2% of nano-calcium carbonate at the ages of 7, 28 and 90 days has been effective in increasing compressive strength in higher ages, such that at the ages of 7, 28 and 90 days, it has been increased by 25%, 30% and 30 % compared to the control sample, respectively. However, it can also be concluded that the excessive increase has partly reduced the tensile strength.

The variation of the permeability coefficient is a function of concrete porosity and water penetration in the roller-compacted concrete. Also, there are significant changes in the concrete permeability coefficient by adding different percentages of nano-calcium carbonate to concrete.

Adding nano-calcium carbonate up to 2% of cement weight to the roller-compacted concrete reduces the permeability coefficient of the roller-compacted concrete. One of the reasons for this phenomenon is capillary interstice filling in the roller-compacted concrete. Moreover, the nano-calcium carbonate increase of over 2% of cement weight raises the permeability of the roller-compacted concrete.

Adding 4% of nano-calcium carbonate to the roller-compacted concrete pattern increases the intensity of the peaks in the XRD test. Given that the average crystallite size is obtained from full *width* at *half height* of the *peaks*, by increasing the peaks' intensity and their width at *half height* of the *peaks*, we get smaller crystallite size. Also, by adding 4% of nano-calcium carbonate, the widths of the peaks are increased, which means smaller crystals and increased crystallite inner tension.

Conclusion

Nano-calcium carbonate, due to its special features, including a high specific surface area, has a good performance in improving the mechanical properties and durability of the roller-compacted concrete, if it is used at a certain and optimal amount. The roller-compacted concrete with the grade of 300 kg / m3 has better functionality than other mixtures, and lasted more in the 30 to 40 second range.

The mix design containing 2% of nano-calcium carbonate replacing cement, has the highest compressive strength at the age of 7 days and shows 4% increase in resistance compared to a control sample at the age of 7 days. The mix design containing 2% nano-calcium carbonate has the highest compressive strength at the age of 28 days and shows 12% increase in resistance compared to a control sample at this age and improved the compressive strength. The mix design containing 2% nano-calcium carbonate has the highest compressive strength at the age of 90 days and shows 15% increase in resistance compared to a control sample at this age. The mix design including 3% of nano-calcium carbonate replacing cement, has the highest tensile strength at the age of 7 days, and shows 25% increase in resistance compared to a control sample at the same age. The mix design containing 2% of nano-calcium carbonate replacing cement, has the highest tensile strength at the age of 28 days and shows 30% increase in resistance compared to a control sample at the same age. The mix design containing 2% of nano-calcium carbonate replacing cement, has the highest tensile strength at the age of 90 days and shows 30% increase in resistance compared to a control sample at the same age.

Keywords: Nano calcium carbonate powder, Nano Engineering, Roller, compacted concrete, Permeability, Resistance

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