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Effect of nano-silica on mechanical properties and internal structure of pozzolanic concrete

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ABSTRACT

In this research work, advancement of nanotechnology is used in order to improve performance characteristics of pozzolonic concrete (concrete having 30% class F fly ash in replacement of cement) with use of nano-sized silica (SiO_2) particles, known as Nano-silica. This study may be considered as an important step towards better understanding the use of nano-silica in concrete as a remedy to overcome drawbacks of the use of pozzolans (drawback like late strength gain of hardened concrete). This research program aims at 1) further understanding the behavior of cementitious materials when amended by nano-silicon various physio-mechanical properties (workability, compressive, tensile, flexural strength etc.) of pozzolanic concrete and 2) exploring the effect of this enhancement on the microstructure of cement matrix using SEM. The experimental program that was conducted included a laboratory investigation of concrete mixtures in which nano-silica was added to the compound cement and Class F fly ash. Three ratios of nano-silica (0%, 3% and 6% by wt. of the cementitious compound) were used in concrete mixtures to examine the extent and types of improvements that could be imparted to concrete. The conducted experimental program assessed these improvements in terms of mechanical properties and internal structure of the mixtures under investigation.

Keywords: *Nano-silica, Pozzolanic concrete, Mechanical properties.*

1. INTRODUCTION

The new technological capabilities made it possible to explore and control new levels of existence which were never known before. Although the nano-sized matter existed as early as the existence of earth, it was not until early 20th century when the nano-scale science started with the study of the molecular and atomic-sized objects. However, the development of methods to control the materials on the nano-scale level was not started until the last few decades. Current global trends are shifting towards a more sustainable construction industry, which has generated new research needs to control and improve concrete performance. The main approach applied to produce sustainable concrete is to reduce consumption of portland cement, while building more durable structures that have a longer service life, yet require minimal maintenance. The reduction of Portland cement use may be achieved either by decreasing its content in concrete mixtures or through replacing cement with recycled materials, thus reducing the carbon footprint of concrete. Furthermore, using other recycled materials (e.g. recycled concrete or aggregates) in mixtures is considered as one of the sustainable solutions for concrete another significantly important aspect of concrete sustainability is extending concrete structures' service time while reducing maintenance cost. This is mainly depending on enhancing concrete serviceability, long-term durability, and resistance to aggressive environmental attacks. This aspect becomes especially critical in case of structure expected to have a long service life in harsh conditions including, but not limited to, highway pavements and bridges, dams and marine structures. In these cases improving the durability of concrete may have a significant impact on the life cycle and maintenance plans for these structures. Concrete pavements and dams demonstrated over the last century that adequately designed and maintained concrete can serve for several decades .

2. GENERAL

In this chapter, the works of various authors on the use of nanomaterials in concrete has been discussed in brief. Nano-silica have been given a special focus for enhancement of various properties of concrete, especially when there is a partial replacement of pozzolanic material (fly ash) in concrete. A great number of researches have been performed to understand the nature of nanomaterials and their effect on the properties of concrete. A number of Research & Development work dealing with the use of nanomaterials like Nano silica, colloidal Nano-Silica (CNS), Al_2O_3, TiO_2, ZrO_2, Fe_2O_3, carbon nanotubes (CNT) in cement-based materials are discussed in the literature. The pozzolanic activity of the material is essential in forming the C-S-H gel and hence the CH crystals are prevented from growing and their number reduces. Thus the early age strength of hardened cement paste is increased. A comparative analysis of this work has been presented in the summary of this chapter which will highlight the significance of each work. Out of the numerous work done in the field only a few relevant works have been highlighted in the next section.

3. STEPS INVOLVED

Various steps can be briefed as follow:

i. Material Testing

(It is done for checking materials quality for suitability of concrete of required strength.)

Following material properties were identified:

a) Size of grains: - for fine aggregates (sand), coarse aggregates (gravels) and cement using sieve analysis.

b) Percentage water absorption: - for fine and coarse aggregates.

c) Colour and texture: - for cement and aggregates.

d) Specific gravity: - for aggregates and cement.

e) Setting time: - for cement fly ash mixes.

ii. Calculation and Casting

Two calculations were done:

a) Mix design calculations for concrete mixes confirming to IS 10262:2009 [48] and IS 456:2000 [49].

b) Calculations for material's quantity for making moulds for various experiments on the principal weight batching.

After calculations 7, 14 and 28 days' batches were cast in different shapes (cubes, cylinders, beams etc.) as per need for various experiments.

iii. Curing

Casted concrete elements were put in curing tank for submerged curing after 24 hours of it being cast. 7,14 and 28 days curing were done for: -

a) Compression strength test: - 7, 14 and 28 days cured batches.

b) Tensile and flexural strength test: - 14 and 28 days cured batches.

c) SEM test: - 7 and 28 days cured batches.

iv. Testing

Tests were done for identity:

a) Fresh concrete properties: - Tests like

• Slump cone/ compaction factor test,

• Pressure method and

• Vicat apparatus test.

were performed on freshly made or plastic concrete/ cement paste.

b) Mechanical properties: -Tests like

• Compressive strength test,

• Tensile strength test and

• Flexural strength test.

were performed on hardened concrete.

c) Microstructural properties: - SEM test, this is a test for visible inspection of the concrete surface at the micro scale.

4. CONCLUSION

The review of a number of literature shows the importance of this field of research. The findings show that a number of nanomaterials like SiO_2, TiO_2, Al_2O_3, colloidal nano-silica, metakaolin, and others can be incorporated to improve the properties of concrete. The results show the improved characteristics of the blended concrete in terms of compressive, tensile and flexural strength. Apart from that the permeability of the specimen can also be decreased by adding a small percentage of the nanomaterial. The SEM analysis shows an improved microstructure with a reduced number of pores. The current study is concerned with the incorporation of Nano SiO_2 in concrete which is made of using class F fly ash as partial replacement of cement (30% replacement).

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