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International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Review Paper on High Performance Concrete using Nano Silica and Copper Slag

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ABTRACT

High Performance Concrete (HPC) is gaining much popularity due to its excellent resistance to aggressive environments and safeguarding the concrete structures from premature deterioration. This is possible by proper selection and proportioning of the concrete constituents and usage of mineral and chemical admixtures. The improvement in the pore structure of HPC is the basis for increased strength and enhanced durability. The main objective of the study is to evaluate the possibility of using nano silica and silica fume as cement replacement materials and copper slag as partial fine aggregate in high performance concrete. The scope of the present study includes the investigation of workability, mechanical and durability properties of high performance concrete incorporating various replacement levels of above materials

Keywords: - - Copper slag, nano silica, CRM, HPC, chemical admixtures, fine aggregate

1. 1 Introduction

Concrete is a mixture of cement, fine aggregate, coarse aggregate and water in predetermined proportion, produced to achieve desired strength at the specified age. The constituents of concrete are derived from various sources, such that, they differ in physical, chemical and reactivity properties. This necessitates the study of properties of the ingredients of concrete and the

characteristics of concrete. With recent advancements in the field of construction, utilization of concrete is increased drastically. Concrete, a manmade material, is the second largest utilized material in the world, next to water. Utilization of such huge mass of concrete results in the depletion of natural resources, by using raw materials for cement production, river sand and coarse aggregate quarrying etc. Also, production of cement involves various operations from which CO2 emissions are very high. About 80% of total CO2 emissions from concrete are due to cement. It is estimated that, out of total CO2 emissions in the world, cement industries contribute about 7%, which needs special attention. It is the right time to find out proper measures to overcome these problems to retain a sustainable environment. With the advent of industrialization, generation of industrial waste increases many folds and industries find difficult in dumping and disposing them.

1. 2 Literature survey & background

Hassan et al. (2000) presented the influence of silica fume and fly ash on the properties of super plasticized high – performance concrete. For producing the concerete mixes, the silica fume and fly ash was replaced at 10% and 30% by weight of cement respectively. The specimens were cured at 20 °C and 65% relative humidity up to the age of 1 year. The mineral admixtures was reported to improve the properties of high performance concrete but at varying rates, based on the binder type.

Björnström et al. (2004) investigated the hydration process of Ca3SiO5 (C3S) cement and the accelerating effects upon addition of colloidal nano silica. C3S pastes were prepared with water to C3S ratio of 0.4 and the dosage of colloidal nano silica used were 1 and 5 percentage of weight of the sol, with respect to the weight of C3S clinker phase. DR-Fourier Transform Infrared (DR-FTIR) and Differential Scanning Calorimetry (DSC) measurements were made on C3S pastes. Dissolution of C3S phase was accelerated by colloidal nano silica addition and rapid formation of calcium –silicate – hydrate binding phase was reported.

Li et al. (2004) studied the mechanical properties and micro structure of the cement mortars containing nano – Fe2O3 and nano SiO2 at constant w/b ratio. The nano particles were added in the proportion of 3, 5 and 10% by weight of cement. The improvement in compressive and flexural strength of the cement mortars with nano – Fe2O3 and nano – SiO2 when compared with plain cement mortar were attributed to the effect of nano particles in enhancing both the cement paste and the interface between paste and aggregates. From the SEM observations, it was concluded that the nano – particles were not only acting as a filler but also as an activator to promote the hydration process in improving the micro structure if the nano particles were uniformly dispersed.

Shih et al. (2006) reported the effect of nano silica on the characterization of Portland cement composite. The liquid form of nano silica particle was incorporated into the Portland cement paste at dosage level of 0, 0.2, 0.4, 0.6 and 0.8 wt%. Compressive strength test on Portland cement composite with 0.6% of nano silica addition by weight of cement reported the maximum strength. The interactions between nano silica particles with Portland cement were analysed using zeta potential measurements in rheological state to determine the mechanism of dispersion and the optimal mix was reported same as that obtained for compressive strength. Micro structural examinations, namely, NMR, BET and MIP reported that the micro structure of Portland cement composite added with nano silica was denser and strongly bonded. At the same time, MIP technique revealed that nano silica addition results in dense micro structure when pore size is greater than 10 nm whereas the micro structure loosens at the regions of pore size less than 10 nm.

Sobolev et al. (2006) examined the mechanical properties of mortars containing nano silica produced by sol – gel method. The paper exposes the influence of nano materials and nano technology for high performance cement composites. The paper describes the methods to produce nano materials and the principles of nano modification, development of nano materials for construction industry, synthesis of nano silica for cement systems, formation of active nano layers on the surface of cement. The efficiency of nano particles was reported to depend on their morphology, genesis, application of superplasticizer, thermal treatment, ultrasonification

etc. Nano silica was found to increase the early compressive strength of Portland cement mortars but the later stages of hardening was affected by other additives.

Belkowitz & Armentrout (2009) reported the investigation of nano silica in the cement hydration process. The experimental investigation consists of determination of heat of hydration by calorimetry, concentration of

calcium hydroxide by X – ray diffraction, crystallographic structures by scanning electron microscopy, compressive strength. Two different nano silica with varying mean particle size was used in the study

Mondal et al. (2010) compared the effects of adding micro silica and nano silica in concrete, and reported a better understanding of the changes in the concrete nano structure. The mechanical properties of cement pastes containing silica fume and nano silica was analysed using nano indentation with scanning probe microscopy imaging obtained from Hysitron Triboindenter instrument. Replacement of cement by 15% of silica fume was reported to increase the volume fraction of the high stiffness calcium silicate hydrate by a small percentage along with decrease in the volume fraction of calcium hydroxide.

Nazari & Riahi (2011 a) investigated the compressive strength and abrasion resistance of concrete specimens containing SiO_2 and Al_2O_3 nano particles that are cured in different curing media. Portland cement was partially replaced up to 2 wt% of nano particles. The specimens were cured under water and saturated lime water up to the age of testing.

Nazari & Riahi (2011 b) studied the effects of SiO_2 nano particles on physical and mechanical properties of high strength compacting concrete. The content of nano silica varied from 0 to 5 wt% of cement. Improvement in strength and resistance to water permeability was reported up to 4% weight of SiO_2 nano particles due to acceleration of hydration and act as nano fillers. Also, at this replacement level, acceleration in the appearance of the first peak in conduction calorimetry test was reported due to the formation of hydrated cement products.

Kontoleontos et al. (2012) studied the influence of colloidal nano silica addition on ultrafine cement in terms of physio mechanical and micro structure properties. Ultrafine cement with a Blaine specific surface area greater than 10.5 cm2/g was prepared in this study and nano silica addition was 2% and 4%. Colloidal nano silica was reported to act as both filler and promoter of pozzolanic reaction. The optimum content of nano silica in ultrafine cement is proposed to be 4% which gave the highest compressive strength. A slight increase in strength at early ages were due to packing effect whereas later age strength enhancement was attributed to the consumption of

$Ca(OH)_2$ by nano silica.

Kang et al., 2020 This study provides fact that densified silica fume can be used for both kinds of castings irrespective of whether it is precast or field casting UHPFRCs. The experimental results clearly show that both the samples densified and unidentified silica fume with UHPFRC. The experimental results indicate that, whether in terms of working capacity, compression strength or bending tensile strength among all specimens, there is no noticeable difference. Even the hydration reaction, which is based on XRD and TG, made it possible to generate or absorb the main hydration substance practically without any discrepancy between the two specimens.

Gorai & Jana (2003) reported the characteristics and possible utilisation of copper slag. For every tonne of copper production, about 2.2 ton of slag is estimated to be generated. Disposal of huge quantities of slag leads to environmental and space problems. From the favourable physico –

mechanical characteristics of copper slag, it was recommended to utilise the slag to make products like cement, fill, ballast, abrasive, aggregate, cutting tools, roofing granules, glass, tiles etc apart from recovering the valuable metals by various extractive metallurgical routes.

Shi et al. (2008) reviewed about the utilisation and engineering characteristics of copper slag in cement and concrete. The common management options for copper slag was reported to be recycling, recovering of metal, production of value added products which does not reduces the disposal of copper slag to a greater extent. The use of copper slag in the production of cement, mortar and concrete as raw materials for clinker, cement replacement, coarse and fine aggregates was observed to provide potential environmental as well as economic benefits

Al–Jabri et al. (2009) studied the effect of copper slag as sand replacement materials on the properties of high performance concrete. The copper slag content ranged from 0% to 100%. Slight increase in concrete density up to 5% was observed with increase in copper slag content due to its high specific gravity. Workability increased rapidly with increase in copper slag percentage due to low water absorption characteristics of copper slag. Upon increasing the content of copper slag to 50% as sand replacement yielded comparable strength as that of control mixture. Beyond 50% copper slag content, reduction in strength properties was noticed.

Wu et al. (2010) investigated the mechanical properties of high strength concrete containing copper slag as fine aggregate. The copper slag was replaced at 0%, 20%, 40%, 60%, 80% and 100% of sand. The workability and dynamic behaviour of concrete was improved due to smooth glassy surface texture, low moisture absorption and excellent compressibility of copper slag respectively. Decrease in quasi – static compressive, flexural and splitting tensile strength was resulted due to the presence of excess water, higher fineness and ferric oxide of copper slag

Brinda & Nagan (2010) studied the potential use of granulated copper slag obtained from M/s. Sterlite Industries India Limited, Tuticorin, Tamilnadu, India as a replacement of sand in concrete mixes. Copper slag was replaced at 0, 5%, 10%, 15%, 20%, 30%, 40% and 50% by weight of sand.

Leaching studies were performed on concrete containing granulated copper slag. A sample having particle size ranging from 5 mm to 50 mm taken from cast specimen was used for the leachant studies.

AlKhatib A, Maslehuddin M, Uthman et al The researcher studied high-performance concrete utilizing industrial waste namely, electric arc furnace slag and cement kiln dust together with nano-silica. Nano-silica with 5% by weight of cement was added to the concrete. It was reported that nano-SiO2 improved the compressive and flexural strength and also improved the early age strength of concrete

Porro et al. (2005) in a comparative study between nanosilica and micro silica reported that nano-silica is more effective than micro-silica in improving mechanical properties and increasing compressive strength when added to the cement paste because the portlandite consumption in the case of nano-silica is higher than that of silica fume. Moreover, they reached a conclusion that the reactivity and the production of C-S-H gel increases with the decrease in the nano-silica particle size and that colloidal nano-silica gives better results than agglomerated silica in increasing compressive strength because in the colloidal solution the nano-silica is purely nano and it is not agglomerated.

H. Li et.al. (2006) studied the abrasion resistance of concrete blended with nano particles of TiO2and SiO2 nano particles along with polypropylene (PP) fibers. It was observed that abrasionresistance can be improved considerably by addition of nano particles and PP fibers. In another study by Green B. (2006) which concentrated on the production of rock matching grout, he discovered that adding nano-particles to the RMG increases its density and modify its viscosity without segregation for fine aggregate. He also proved that without adding nano-silica to the RMG mixture, it would not properly mix, pump or reach the desired mechanical properties.

O et al. (2007) have noted that adding nano- SiO2 to the cement paste raises the heat that evolves during setting and hardening time. That is why they concluded that adding nano-particles to the cement paste should be accompanied with large amount of super plasticizer to delay the early hydration and for heat treating to speed up the pozzolanic reaction. The quantitative analysis that they conducted for the remaining Ca(OH)2 proved that adding nano-silica to the cement paste decreases its percentage in the paste which means more effective pozzolanic reaction, higher strength and smaller pore size distribution.

Madheswaran et al. (2014) reported the use of copper slag as partial replacement of sand in cement concrete and building construction. Cement mortars containing copper slag and sand were tested as masonry mortars and plastering. Copper slag based mortar was reported suitable for plastering but increase in copper slag content increased the wastage due to material rebounding from the plastered surfaces. The use of copper slag was recommended up to 50% by mass of the fine aggregate for plastering of floorings and horizontal surfaces and limited to 25% for vertical surfaces and not suitable for ceiling plaster. Increase in density, improvement in workability and compressive strength of concrete was reported due to the addition of copper slag. The optimum replacement level of copper slag as sand was concluded to be 50% for conventional grades of concrete and 75% for high strength concrete.

Iao et al. (2011) experimentally proved that adding nanoparticles to the asphalt binder enhances its viscosity, failure temperature, complex modulus, and elastic modulus values as well as improves rutting resistance of the binder. They also noticed that a relative high percentage (>1.0% per weight of cement) of nano-particles gives better results in enhancing asphalt binder than low percentage. Sekari and Razzaghi (2011) studies the effect of constant content of Nano ZrO2, Fe2O3, TiO2, and Al2O3 on the properties of concrete. The reults showed that all the nano particles have noticeable influence on improvement on durability properties of concrete but the contribution of nano Al2O3 on improvement of mechanical properties of HPC is more than the other nano particles.

Mithun & Narasimhan (2016) reported the relative performance of alkali activated slag concrete mixtures made with copper slag as fine aggregate in terms of their workability, strength and durability parameters and compared with the properties of normal Ordinary Portland Cement Concrete (OPCC). No significant change in workability was noticed due to addition of

copper slag. There was no marked loss of strength parameters and exhibited lesser total porosity, water absorption and chloride permeability in alkali activated slag concrete containing copper slag.

S. Geetha et al. (2017) investigated on high performance concrete with copper slag for marine environment. Properties of cement containing copper slag, fly ash and silica fumes found more better than normal mic concrete. Copper slag has a wide application in marine construction work as it improves the compressive strength, flexural strength and reduction in sorptivity

S. Geetha, SelvakumarMadhavan 2017. High Performance Concrete with Copper Slag for Marine Environment. 5th International Conference on Material Processing and characterization (ELSEVIER), 3525-3533

Brinda. D et al [4] investigated on various corrosion and durability tests on concrete containing copper slag as partial replacement of sand and cement. In this paper, M50 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0% to 60%, cement 0% to 20% and combination. The results of compressive, split tensile strength test have indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of additions of 15% of cement. Water permeability in concrete reduced up to 40% replacement of copper slag with that of sand.

Arivalagan [2] investigated to explore the possibility of using copper slag as a replacement of sand in concrete mixtures in various percentages ranging from 0%, 20%, 40% 60%, 80% and 100%. It was observed that the flexural strength of concrete at 28 days is higher than design mix (without replacement) for 40% replacement of fine aggregate by Copper slag.

1.3 Objectives of the work

The current study focuses on using waste materials to partially replace traditional concrete components. this paper show M sand replace by copper slag a control mix. Nano silica were used to replace cement by 1 to 3% by weight.

1.4 Conclusion

Due to the increased use of concrete in the modern world, natural resources are being depleted at a faster rate, resulting in environmental issues. In order to reduce both environmental effects and waste management concerns, it is therefore becoming more and more crucial to use stable and solid waste components in concrete. In this study, it was discovered that silica fume and nano silica waste can be used to produce concrete in an efficient manner. The results of the investigation led to the following findings.

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