iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** X **Month of publication:** October 2016

DOI:

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Mechanical Properties of cementitious composite by using ZnO nanoparticles

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Abstract— The split tensile and the setting time of cement with different Concentration of ZnO Nanoparticles (0.5%, 0.1%, 1.5% , 2.0%,2.5% ,3% by weight) has been studied. the mechanical (flexural and split tensile) strength of the specimens measured after 7and 28 days .The results showed that the use of ZnO Nanoparticles up to maximum replacement level of 2% produces concrete with improved split tensile strength. ZnO Nanoparticles improves the split tensile strength but decreases its setting time.

Keywords— cement, ZnO Nanoparticles, setting time, split tensile

I. INTRODUCTION

The use of concrete in constructions and buildings may have begun less than a century ago[1]. However, the increasing the use of concrete from decade to decade has led, much more recently, to extensive and effective research in improvement the properties of concrete, incorporating a wide range of supplementary cementing materials, such as pozzolans and nanoparticles[2]. Nano particles have been attracted increasing attention in recent years and their different types has been used in concrete mixtures in order to improve both the mechanical properties and pore structure of the concrete [3,4]. This may be due to the nanoscale size of particles being able to result in significantly improved properties from predictable grain-size materials of the same chemical composition. consequence, industries can be able to design new and novel products and to re-engineer many existing products that function at unprecedented levels. There are few reports on incorporation of nanoparticles in cement-based concrete[5,6]. More researchers assert that the amount of crystallization in hydrated cement increases as a result of an increase in the amount of nanomaterials research performed over the years has been mainly aimed at achieving high mechanical performance with cement replacement materials at the micro level [7].there are still few works done about incorporating other nanoparticles in concrete. For instance, reported that mortars containing nano-SiO_2 or nanoFe_2O_3 have higher compressive and flexural strength than that of plain cement mortar[8-10].

Nanoparticles can act as heterogeneous nuclei for cement pastes, further accelerating cement hydration, because of their high reactivity, as a nano-reinforcement, and as a nano-filler, making the microstructure denser, and thereby leading to a reduced porosity[11]. This may be due to the fact that nanoscale-size particles are able to significantly improve properties compared with grain-size materials of the same chemical composition[2].

Constructional structures form a very important part while contributing to the GDP of any economy by rendering services ranging from transportation to living to producing useful products to earning livelihood, and at the same time also commanding a very dominant share of the energy produced for utilization, no wonder that it has been estimated by a certain source that construction industry involving nanotechnology will occupy the eighth position out of the usage of nanotechnology materials while being incorporated in constructional structures would not only help in prolonging their lifetime, but would also keep a check on the energy spent by them and at the same time gauging their reactions and reacting to different agents like fire, corrosion, water penetration, fractures, cracks, etc[5].

In this work we study The effect of ZnO nanoparticles on setting time (ST) and measured mechanical (flexural and split tensile) strength of the specimens measured after 7and 28 days of cement.

II. MATERIALS AND METHODS

Samples are prepared by adopting replacement of Portland cement purchased from Atbara cement company by weight with ZnO nanoparticles , The chemical and physical properties of the cement are shown in Table 1 , ZnO nanoparticles used in this study had particle size between 16-20 The chemical and physical properties of ZnO nanoparticles shown in Table 2 , Table 3 . available natural sand with particles smaller than 0.5mm and fineness modulus of 2.25 and specific gravity of 2.58g/cm3 was used as fine aggregate. Crushed basalt stored in the laboratory with maximum size of 15mm and specific gravity of 2.96g/cm³ was used as coarse aggregate Setting time of the specimens was regulated according to the ASTM C191 standard. The ASTM C191 method

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Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

determines the time of setting of hydraulic cement by the means of the Vicat needle . Flexural tests were undertaken in accordance with the The flexural strength of concrete is used as a structural design criterion and as a general indicator of concrete strength. ASTM C 293 (C-293) determines the flexural strength of concrete specimens by the use of a simple beam with center-point loading. Flexural tests were undertaken in accordance with the Flexural tests were undertaken in accordance with the ASTM C293 Standard. To measure the Split tensile test was carried out in accordance to the ASTM C 496-90 standard. samples are prepared for testing of compressive strength of cement for 7 and 28days.

TABLE I
CHEMICAL AND PHYSICAL PROPERTIES OF THE PORTLAND CEMENT(WT%)

Material	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	SiO	Loss on ignition
Cement	5.1	3.44	59.51	5.9	2.9	0.16	21.5	1.12

Specific gravity 1.9 $g.cm^3$

TABLE III
THE CHEMICAL PROPERTIES OF ZNO NANOPARTICLES

Material	ZnO%	Cu	Mn	Ph	Cd
ZnO	99	5ppm	4ppm	7ppm	8ppm

TABLE IIIII
THE PHYSICAL PROPERTIES OF ZNO NANOPARTICLES

Type	Diameter(nm)	Surface/Volume (m^2/g)	Density (g/m^2)
ZnO	18±3	95±9	0.7

III.RESULTS

When a small amount of the nano-particles is uniformly dispersed in the cement paste, the nano-particles act as a nucleus to tightly bond with cement hydrate and further promote cement hydration due to their high activity, which is favourable for the strength of cement mortar[12].

Teihe results from the initial and final setting times of the cement whith ZnO nanoparticles are shown in Table 4 and 5, an increase in the volume fraction of nanoparticles caused a significant decrease in setting time. . Smaller particle size allows a rapid increasn surface area, leading to a significant and fast rise in the number of superficial atoms[3] These surface atoms are highly reactive and unstable, which results in a faster reaction speed. Hence, a cautious approach should be taken for the setting time of the cement paste during the utilization of ZnO nanoparticles [7].It can be seen from Table 6 that ZnO nanoparticles also decrease the Split tensile shown in Table 6 .Therefore, nanoparticles accelerate cement hydration. The compressive strength of the samples increased with addition of ZnO nanoparticles up to 2% and after decreased. This is because of that increasing nanoparticles more than 2% increases agglomeration of the particles and decreases compressive strength of the samples. The flexural strength results of ZnO mixtures are shown in Table 7. theflexural strength of the specimens increases with ZnO nano particles up to 1.5% and then it decreases, although the results of 2.0% replacement is still higher than those of the plain cement concrete.

TABLE IV
EFECT OF ZNO NANOPARTICLES% ON INITIAL SETTING TIME(MINTS)

ZnO NPs %	0	0. 5	1	1.5	2	2.5	3
Initial Setting time(mints)	200	195	180	170	148	125	120

TABLE V
EFECT OF ZNO NANOPARTICLES% ON FINAL SETTING TIME(MINTS)

ZnO NPs %	0	0.5	1	1.5	2	2.5	3
final Setting time(mints)	300	290	255	230	220	200	200

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TABLE VI

EFECT OF ZNO NANOPARTICLES% ON SPLIT TENSILE STRENGTH .

ZnO NPs %	0.0	0.5	1	1.5	2	2.5	3
Split tensile (MPa) 7Days	4.3	4.9	5.6	6.0	5.4	5.0	4.5
Split tensile (MPa) 28 Days	4.7	5.4	6.1	6.3	6.3	5.7	5.0

TABLE VII

EFECT OF ZNO NANOPARTICLES% ON FLEXURAL STRENGTH OF SELF-COMPACTED CONCRETE.

ZnO NPs %	0.0	0.5	1	1.5	2	2.5	3
Split tensile (MPa) 7Days	2.1	2.7	3.1	3.7	3.4	3.1	2.8
Split tensile (MPa) 28 Days	2.3	2.9	3.3	3.5	3.7	3.2	2.1

IV. CONCLUSIONS

The experimental results obtained from the initial and final setting times of the cement mortars in the presence of ZnO nanoparticles an increase in the volume fraction of nanoparticles caused a significant decrease in setting time .ZnO Nanoparticles up to maximum replacement level of 2% produces concrete with improved split tensile strength. .This is probably as a result of the negative impacts of ZnO nanoparticles on C2S hydration.

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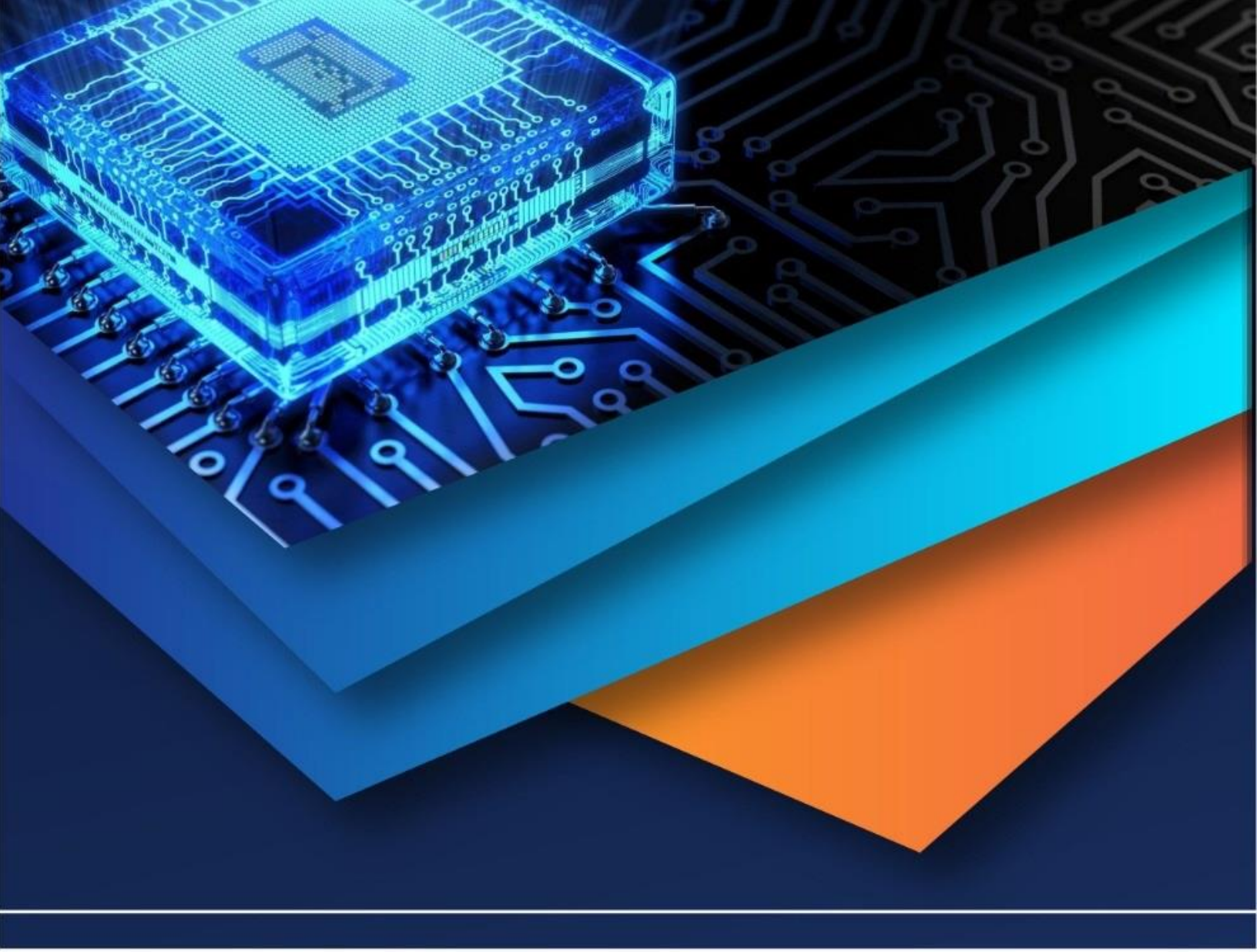

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