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Nanometric Mortars with replacement of rice husk ash and nano-SiO_2

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SUMMARY: The replacement of cement by ashes in mortars has ecological and microstructural advantages. While by replacing cement with nanoparticles (NP) improves the performance of nano-scale properties.Researchers have incorporated nano silica oxide (nSO) and rice husk ash (RHA) into mortar by studies of physical and mechanical properties.However, the study of the synergy of its simultaneous use is scarce mainly related to the resistance to corrosion.

In this work, the performance of the properties of plastic consistency mortars with replacement of ordinary Portland Cement (OPC) by 20% RHA and 1.0% nSO was evaluated, using porosity tests, compressive strength and corrosion resistance by impressed voltage. The simultaneous replacement of RHA+nSO was of greater performance, with a decrease in porosity up to 3.9% and an increase in compression and corrosion resistance of 7.1% and 37.6%, respectively.The simultaneous use of RHA+nSO in mortars of plastic consistency presents advantages in the improvement of physical and mechanical properties, due to the synergistic effect of the combination of ash and nanoparticles.

KEYWORDS: mortar-plastic, mortar-nanometer, accelerated-corrosion, nanoparticles.

I. INTRODUCTION

The durability of reinforced mortars is demerited with the corrosión of the reinforcement, with determining factors such as structure and distributionof the pore, effective porosity and mechanical resistance[R. Kumar, 2003].Researchers have replaced OPC with different types of ashes in order to provide durability to mortars, with satisfactory results.The replacement of OPC with ashes such as: RHA [B. Chatveeraa, 2011; A. A. Ramezanianpour, 2009], fly ash (FA), blast furnace ash, cane bagasse ashes, among others [M. Sahmaran, 2009; M. Bohác, 2009; K. Ganesan, 2007; S. Rukzon, 2009; C. H. K. Lam, 2010; U. I Hernández, 2009],decreces the effects of the corrosión of the reinforcement produced in aggressive environments and improve mechanical, structural, physical, chemical and electrochemical properties [V. Saraswathy, 2007; B. H. Abu Bakar, 2010; Tae-Hyun Ha, 2007].In the particular case of RHA, it is a waste product of power generation in industrial plants that can be used as a replacement for OPC.The replacement of OPC by RHA improves the properties of the cementitious mass of the mortar and at the same time, contributes to the environmental aspect by decreasing the need for cement production, which generates high levels of contamination [P.K. Mehta, 1994].Other replacements of OPC with which there have been increases in the performance of physical, chemical and mechanical properties are the NP [F.Pacheco Torgal, 2011].

NP have also been used as a replacement for OPC in mortars and concrete, with improvements of their properties at the nanometric level, NP such as: nSO [A.Nazari, 2011; A. Naji Givi, 2011; A. Naji Givi, 2010], Iron oxide and Titanium, among others [A. Nazari, 2010].In addition, the simultaneous use of NP and ashes produces a synergistic effect that increases the performance of mortar properties at an early age and increases their durability in aggressive environments [T. Ji, 2005; Y. Qing, 2007; D.F. Lin, 2008; K.L. Lin, 2008].However, the research that deals with the study of the simultaneous use of ashes and NP as cement

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replacement is scarce and focused only on certain types of materials, with few scientific reports that address the issue of durability and corrosion of mortars reinforced with replacements of OPC by nSO and RHA in simultaneous use [T. Ji, 2005; Y. Qing, 2007].The replacement of OPC by RHA and nSO in simultaneous use should favor the microstructure of the cementitious mass and obtain nanometric mortars with a more compact matrix, greater performance in mechanical and corrosion resistance.

The purpose of this work was to study the performance of nanometric mortars of plastic consistency through studies of total porosity, effective porosity, mechanical resistance and corrosion resistance in a reinforced mortar, by replacing OPC with RHA and nSOindividually and simultaneously, with replacement of 20% RHA and 1% nSO of the total cement weight.

II. EXPERIMENTAL PROCEDURE

2.1 Materials

Test tubes were manufactured with fine aggregate, OPC, RHA, nSO, distilled water and superplasticizer (SP).The fine aggregate was siliceous river sand graduated according to ASTM C 33-03, fineness modulus 2.68, mass density 2645 kg/m^3 and 4.1%absorption. The SP was a short-range high-delay water reducing additive without chlorides type F and type I, according to ASTM C 494/C 494M – 99aandC1017 / C1017M - 07. RHA was obtained from industrial waste from Odisha, India, ground in a ball mill for 2 hr. and sieved in a 325 mesh.The physical properties of the cementitious materials are presented in **Table 1**, while the chemical properties, according to chemical analysis of Gravimetry (G) and Stoichiometry (S), are presented in **Table 2.**

Table1.Physical properties of cementitious materials

Property	OPC	RHA	nSO
Volume density (kg/m^3)	3071	2251	-
Surface Area (m^2/g)	20.23	23.82	777.7
Average particle size (Φm)	27.61	29.88	0.015

Table2.Chemical components of the materials

Oxide	OPC	RHA	nSO	Analysis method
SiO_2	20.046	84.375	71.451	G
SO_3	2.589	0.080	-	E
Fe_2O_3	1.976	0.309	-	E
Al_2O_3	0.294	0.235	N.D.*	E

*N.D. Not Detected

2.2 Preparation of mixture and test tubes.

Mortar mixtures were manufactured with a relation Water/Cementitious (A/cm) of 0.55, Sand/Cementitious 2.75, SP necessary to achieve a fluidity of 110 ± 5% according to ASTM C 1437-99 and dosage of cementitiousaccording to **Table 3.** The mixing procedure was similar to ASTM C 305-12 with some variants as proposed by [M.J. Pellegrini, 2013]. The mixtures were poured into P.V.C. molds for 24 hr. until hardened, prior to curing in distilled water.

Table3.Dosage of cementitious in mortar mixtures(%)

Mixing nomenclature	OPC	RHA	nSO
M100-0-0	100.0	0.0	0.0
M80-20-0	80.0	20.0	0.0
M99-0-1	99.0	0.0	1.0
M79-20-1	79.0	20.0	1.0

2.2 Total porosity and compressive strength.

The compressive strength was determined according to ASTM C 109/C 109M-05 with the variant of the use of cubic test tubes of 2.5 cm side.Total porosity of the hardened mortar was performed in a vacuum saturated condition, a method accepted satisfactorily for the calculation of total porosity in cementitious materials [S. Rukzon, 2009; P. Chindaprasirt, 2008].Both tests were conducted at ages 28 and 90 days of curing in distilled water, 100% relative humidity and temperature of 23 ± 2 ° C. The results reported the average of 3 trials.

2.3Accelerated corrosion test with impressed voltaje.

The appearance of the first crack in a cementitious material with reinforcement with application of impressed voltage is a clear indication of the failure due to tension of the material caused by the corrosion products generated on the surface of the reinforcement.So that the Accelerated Corrosion Test with Impressed Voltaje(ACTIV) is useful for a comparative estimate between the resistances to corrosion [P. Chindaprasirt, 2008].The test tubes used were 4.0x4.0x16.0 cm, reinforced with a steel rod of 0.95 cm in diameter, 1.5 cm coating and steel surface exposed to saline medium of 37.3 cm2.

After 90 days of curing, the specimens were subjected to the ACTIV test according to the arrangement shown in **Figure 1**, immersed in 5% aqueous NaCl solution for their next application of constant voltage of 12.0 ± 0.1 V at a temperature of 25 ± 2 oC.The condition of the test tube during the application of voltage was continuously monitored until the appearance of the initial crack and the time of initiation of the first crack was recorded. (TIFC).The reported results were the average of 3 trials.

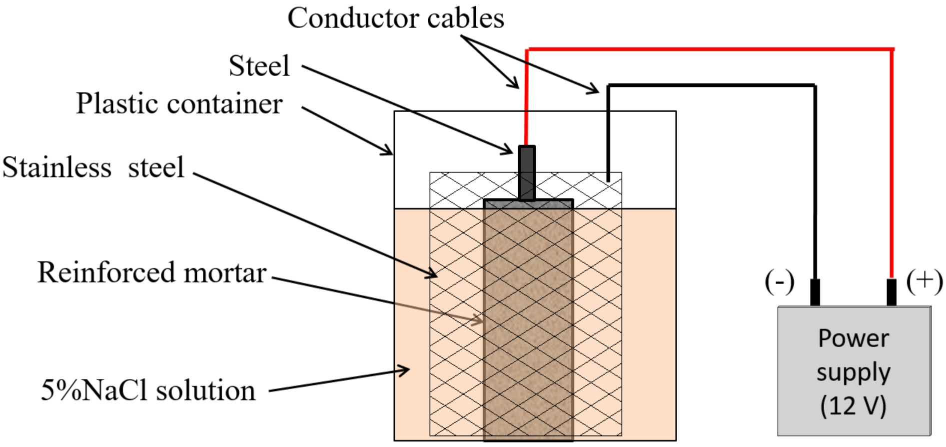

Figure1.Experimental arrangement ACTIV test.

III. RESULTS AND DISCUSSION

3.1 Materials

The replacement of OPC by RHA and nSO increases the performance of mortar properties due to the effect produced by ash and NP on the microstructure of the cementitious matrix [A. A. Ramezanianpour, 2009; A. Nazari, 2011].According to ASTM C618-99, RHA is classified in a natural calcined ash type N by its oxides content, SO3 <4.0% and SiO2 + AlO3 + F2O3> 70%.Both the micro and the macrostructure of the mortars are defined by the physical and chemical properties of the cementitious, as well as by their particle size distribution.

3.2Mixtures and morphology of hardened mortar.

Calcined ashes have a hygroscopic nature and high superficial area, their use causes mixtures that require a greater amount of water or SP for an equivalent desired fluidity [P.K. Metha, 1979; P. Chindaprasirt, 2008].In mixtures conducted in this study, the replacement of OPC by RHA and nSO in simultaneous use increased the amount of SP, with 0.9, 2.2, 1.5 and 2.8% for M100-0-0, M80-20-0, M99-0- 1 and M79-20-1, respectively.The increase in surface area due to replacements of nSO and RHA together with the hygroscopic nature of RHA contributed to the increase in SP.The properties of the mixture in the fresh state and the curing conditions contribute to define the microstructure of the hardened mortar.

The uniform dispersion of nSO has an important role in the improvement of the microstructure of the cementitious matrix [H. Li, 2004].The microstructure of hardened mortars is shown in **Figure 2.**In general, the replacement of OPC by RHA + nSO in simultaneous use produced more compact cement matrix morphologies than the case of absence of replacements or the individual use of nSO and RHA, which is attributed to the generation of hydration products that fill the pore network of the matrix.The microstructure of the cementitious matrix defines, to a large extent, the properties of the porosity, permeability and mechanical strength of the hardened mortar.

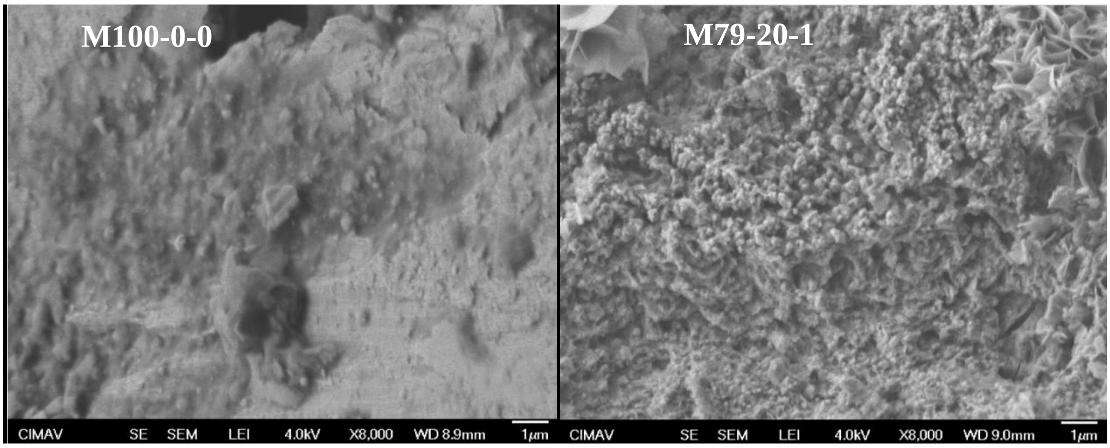

Figure2.SEM mortars hardened at the age of 90 days.

3.3Total porosity and compressive strength.

The replacement of OPC by RHA increases the performance of the total porosity of mortars decreasing to a greater amount of RHA [P. Chindaprasirt, 2008]In manufactured hardened mortars, the total porosities for ages of 30 and 90 days are shown in **Figure 3.**For the use of RHA as individual replacement, the porosity increased 5.1 and 3.9% for 30 and 90 days, respectively, which is attributed to the amount of SP used that has a demerit effect on this property.However, the replacement of nSO, either individually or simultaneously, favored the decrease in porosity, presenting at 30 days the lowest porosity in M99-0-1.While at 90 days of age, the simultaneous replacement of RHA + nSO resulted in greater performance even less than M99-0-1, with lower porosity in M79-20-1 and a decrease of 3.9% compared to M100-0-0.Therefore, the replacement of OPC by nSO increases the performance of porosity in both individual and simultaneous use and manages to counteract the increase in porosity caused by the use of SP in the mixture.Various investigations [B. Chatveeraa, 2011, A. A. Ramezanianpour, 2009, F. Pacheco Torgal, 2011; A. Nazari, 2011] demonstrate the favorable effect of the replacement of OPC by RHA or nSO with respect to physical properties, also reporting benefits in mechanical properties.

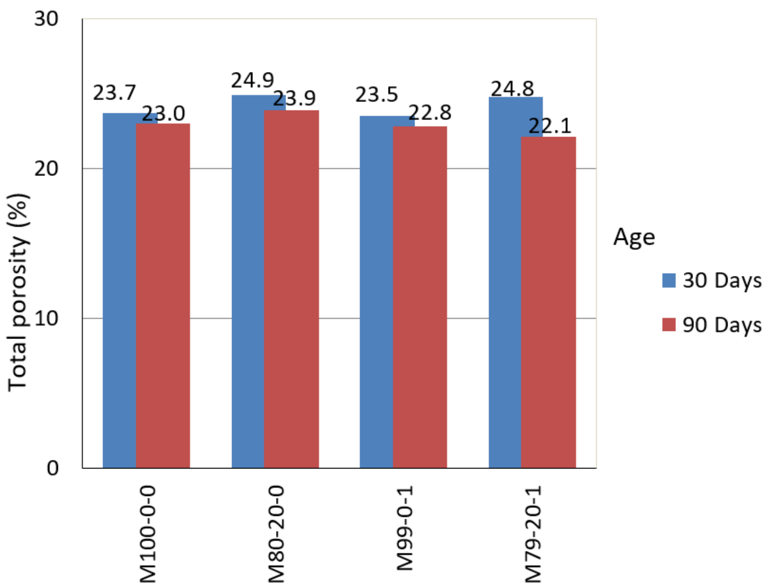

Figure 3.Total porosity of hardened mortars

The compressive strength of hardened mortars increases their performance with OPC replacements by RHA **[32].**For hardened manufactured mortars, the results of simple compressive strength are shown in **Figure 4.**Porosity performance increased with the presence of nSO at the age of 30 and 90 days, with maximum performance in simultaneous use of RHA and nSO for both ages and increases of 7.2 and 7.1% at 30 and 90 days, respectively.Based on the results, the performance increases with the replacement of RHA, surpassed for nSO replacements and with greater resistance to compression with the simultaneous use of RHA + nSO.Just as the mechanical properties in the performance of cementitious materials are important, so is their resistance to corrosion.

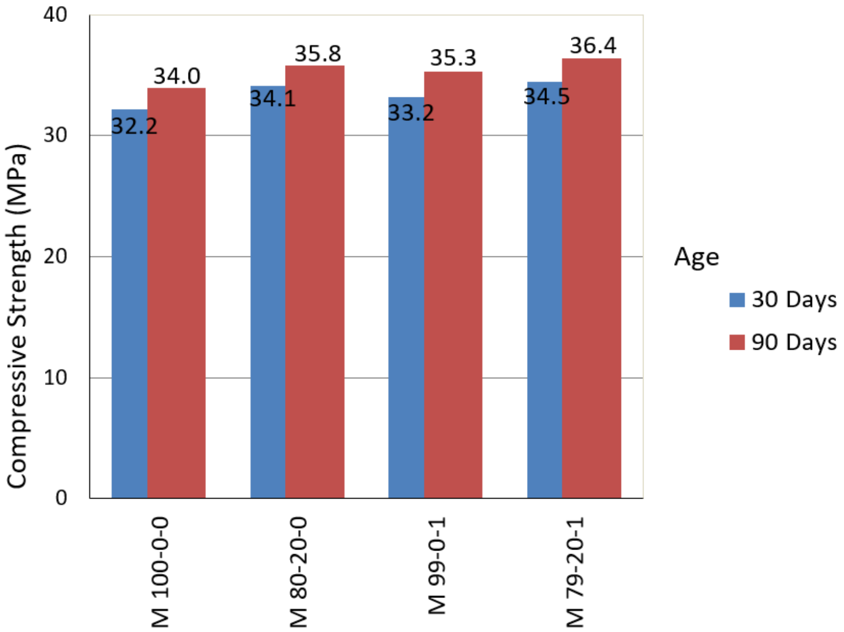

Figure4.Compressive strength of hardened mortars

3.4.Accelerated corrosion test with impressed voltaje.

The replacement of OPC by 20% RHA in plastic consistency mortars increases corrosion resistance up to 83.0% [P.Chindaprasirt, 2008**]**.For manufactured reinforced mortars, the results of the TIFC by ACTIV are shown in **Figure 5** and test tubes after ACTIV in **Figure 6.**

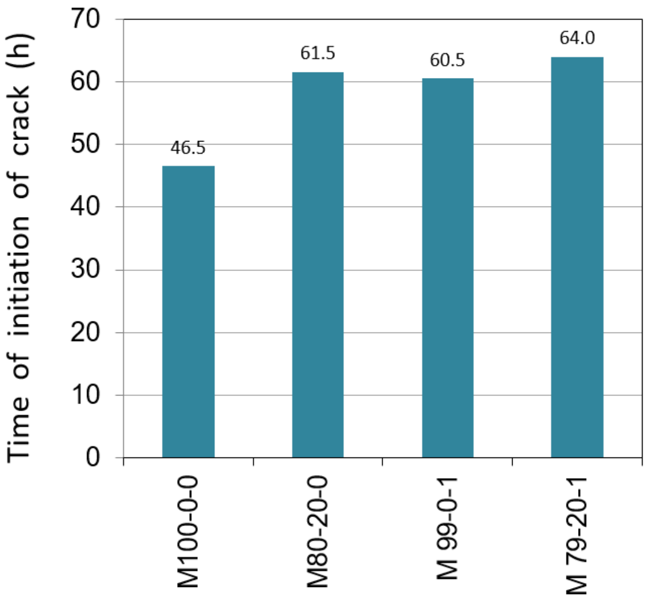

Figure5.TIFC in Accelerated Corrosion Test with Impressed Voltaje.

In all mixture made, by replacing OPC with RHA or nSO individually or simultaneously, TIFC was increased with respect to reference.For individual replacement of OPC by RHA the increase was 32.3%, in individual use of nSO of 30.1% and for simultaneous use of RHA + nSO of 37.6%.The order in the increase in the performance of the ACTIV corresponds to that presented in the compressive strength, which is congruent because the mechanical strength is a determining factor for the presence of the first crack.Based on the results, the replacement of OPC by RHA + nSO in simultaneous use increases the performance of resistance to corrosion to higher levels than the individual use of replacements.

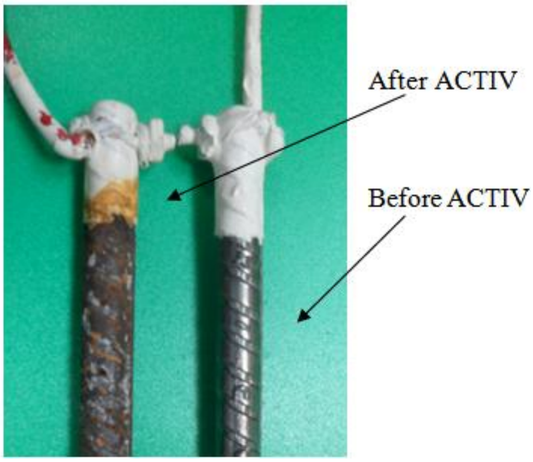

Figure6.Reinforcement Steel after ACTIV.

IV. CONCLUSIONS

The results of the present study demonstrate that: compressive strength, porosity and corrosion resistance of mortar increase its performance with replacements of OPC with RHA and nSO both individually and simultaneously.In addition, the use of SP delays the benefit of the performance in the synergy expected by the simultaneous use of RHA and nSO in mortars for ages under 30 days.

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