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INFLUENCE OF NANO POLYMER ON THE THERMO-PHYSICAL PROPERTIES OF RICE HUSK ASH-CEMENT MORTAR

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ABSTRACT: *Research has shown that Rice Husk Ash (RHA), an agricultural waste, exhibits cementitious properties in the presence of lime. However, in Nigeria, the use of RHA as a construction material has not been fully utilized despite its benefits in terms of sustainability. In this study, RHA was used to partially replace Portland cement at 10% to form a cement-RHA mortar composite at a 1:6 ratio of binder to aggregate. Nano-polymer (Elastobar) was added at 0%, 1.5%, 3.0%, 4.5% and 6.0% of the weight of the binder. Mortar specimens of 100mm by 100mm were prepared and cured for 7, 14, 21 and 28 days respectively. Mortar properties investigated include compressive strength, thermal conductivity, fire resistance, sorptivity and water absorption. The results showed an increase in the density and compressive strength of RHA-cement mortars, with a corresponding decrease in water absorption and sorptivity, following the addition of nano-polymer. Also, thermo-physical properties such as thermal conductivity and fire resistance were improved. The decrease in thermal conductivity indicates better insulating properties of the mortar, while the decrease in water absorption indicates a better waterproofing material. The observed improvements are significant from durability and sustainability perspectives.*

KEYWORDS: Cement, mortar, Nano-polymer, Rice Husk Ash, thermo-physical properties.

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INTRODUCTION

For obvious sustainability justifications, the world is tending towards blended types of cement for concrete and mortar works. Supplementary cementitious materials (SCM) are receiving worldwide attention to curb the greenhouse effects from the emissions of CO_2 from the production of Portland cement. Rice husk ash has been proven from numerous studies (Oyetola & Abdullahi, 2004; Zain et al., 2011; Ferraro & Nanni, 2012; Zerbino et al., 2014; Swaminathen & Ravi, 2016) to exhibit good cementitious properties in the presence of lime and water. Its richness in silica produces a secondary binding agent during hydration. The utilization of rice husk ash in construction works has helped with the challenge of its disposal, hence addressing serious environmental issues associated with this agro-waste.

Rice husk ash is an effective pozzolan (Alireza et al, 2010) improving the mechanical and durability properties of concrete and mortar. It increases concrete resistance to sulphate attack, chemical resistance of mortars, controls destructive expansion due to alkali-silica reaction in concrete and enhances resistance to segregation. The blending of rice husk ash with ordinary Portland cement reduces the porosity and permeability of concrete and mortars by altering the microstructure of the paste (Shatat, 2011; Surajit & Richi, 2016; Fapohunda et al., 2017). This alteration results in a mortar or concrete that is resistant to the agent of degradation. Rashid (2010) observed that with an optimal percentage replacement of 20% cement with RHA, the durability of RHA-cement mortar increased. Investigating the strength behaviour of cement mortar containing RHA, Rashid (2016) recommended a 15–20% range of RHA replacement. Umasabor (2018) reported on the improvement of fire resistance of rice husk ash concrete. A 5% optimal RHA replacement of cement gave better fire resistance than normal concrete. RHA can thus find application in the production of insulating construction materials. Pande (2013) stated that incorporating rice husk ash reduced both bleeding and segregation in concrete while improving the compressive strength of cement mortar. According to Khan et al. (2014), the pozzolanic reaction due to the presence of amorphous silica in RHA produces secondary C-S-H gel (binder) during hydration, which in turn, impacts a higher strength and improved durability to the RHA-Cement matrix. The flowability of cement mortar increased with the addition of RHA, as reported by Kondraivendhan (2013). According to Antiohos et al. (2014), the effectiveness of RHA in cement and concrete is a function of reactive silica and its fineness. The higher the fineness, the more positive is the effect of the RHA inclusion in the matrix.

Wail and Waleed (2018) investigated the effect of nanomaterials on cement mortar characteristics. They observed a significant increase in both compressive and tensile strengths of the mortar at the early stages of hardening, with a maximum increase of 22% in the compressive strength. Corrosion resistance, porosity and strength of blended Portland cement mortar containing Rice Husk Ash and Nano-SiO_2 were studied by Pellegrini et al. (2013). Results revealed improvement in the performance of physical, mechanical and corrosion resistance properties due to the synergy of RHA and N-SO for replacements of up to 20% RHA. Liulei and Dong (2017) studied the properties of cement mortar and ultra-high-strength concrete incorporating graphene oxide nanosheets. It was concluded that the addition of nanosheets improved both the flexural and compressive strengths of mortar and concrete.

The present study focused on the influence of nano-polymer (Eslatobar) on some thermophysical properties of RHA-cement mortar. Test conducted includes compressive strength, thermal conductivity, fire resistance, sorptivity and water absorption.

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MATERIALS AND METHODS

Materials used for the study were commercially available Portland-limestone cement grade 32.5R manufactured by UNICEM-LARFAGE conforming to BS EN 197-1:2011, Rice Husk Ash obtained from Ogoja Rice Mill in Cross River State and a Nano-polymer (Elastobar Type Polymer) manufactured in India. Natural river sand with a specific gravity of 2.71 was used as fine aggregate. A 1:6 binder to aggregate mix ratio was adopted for the study and mortar cube sizes of 100mm by 100mm were prepared and cured following ASTM C109-C109M (2016). A 10% replacement level of cement by RHA was used. Nano-polymer was added to the mixing water in incremental portions from 0–6% by weight of the binder. Okhard Machine Tool's WA-1000B digital display Universal Testing Machine (UTM) with a testing range of 0–1000kN, conforming to BS EN 12390–4:2000, was used for the compression test. The compressive strength of the mortar cubes was determined using Eq. 1:

$$f_c = \frac{P}{A} \qquad (1)$$

where f_c = the compressive strength, P = crushing load, and A = net cross-sectional area of the cube.

The thermal conductivity of the mortar specimens was obtained by subjecting them to heat treatment. The temperatures entering and leaving the cubes were obtained using pyrometer and infrared thermometers respectively. Thermal conductivity was deduced from Eq. 2:

$$\lambda = \frac{P}{LT} \qquad (3)$$

where P = Power in Watt, L = Length in meter, T = Temperature in Kelvin

Power (Watt) = Energy (Joules)/Time (seconds), and 1 Joule = 0.0005265 ^{o}C.

Sorptivity of mortar samples were measured from samples that were oven-dried at 40^{o}C and immersed in water such that the open face of the specimen was fully immersed in the water. The sorptivity was then calculated from Eq. 3:

$$S = \frac{I}{t^{0.5}} \qquad (3)$$

where I = cumulative infiltration, t = time in minutes, and S = sorptivity expressed as percentage.

Fire resistance was estimated by computing the percentage loss in strength of mortar specimens after exposing them to fire for 1 hour.

Table 1 presents the specific gravity of the materials, while Table 2 shows the chemical composition of the cement and RHA used. The technical data of the nano-polymer is shown in Table 3.

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Table 1: Specific Gravity of Materials

Material	Cement	River Fine	Elastobar	RHA
Specific Gravity	3.15	2.75	1.02	2.2

Table 2: Chemical Composition of Cement and RHA

S/N	Sample	Elements and % Composition						
		Z_nO	SiO_2	CaO	Fe_2O_3	K_2O	M_nO	MgO
1	PLC	0.12	23.5	65.2	3.4	0.4	0.18	1.35
2	RHA	0.75	84.55	0.3	0.25	0.69	0.43	0.45

Table 3: Technical Data of Elastobar

Appearance	pH at 25°C	Viscosity at 25°C	Solid Content	Solid Content	Specific Gravity	Flash Point
Milky white free-flowing liquid	6.5 to 8	25–500 cps	50±2%	50±2%	1.02±0.01%	Water-based, non-flammable

RESULTS AND DISCUSSION

Density

Table 4 shows the density behaviour of the cement-RHA mortar at different dosages of the nano-polymer (NP). Density decreased with an increase in the nano-polymer. The low specific gravities of the elastober (1.02) and RHA (2.2) compared to that of cement (3.15) could be responsible for this reduction.

Table 4: Density of Mortar

Control	1.5% NP	3.0% NP	4.5% NP	6.0%NP
1888 (kg/m³)	1866 (kg/m³)	1864 (kg/m³)	1832 (kg/m³)	1823 (kg/m³)

Water Absorption

Water absorption of mortar decreased with an increase in NP as shown in Figure 1. This could be as a result of the seamless cross-linked elastomeric membrane that the nano-polymer forms within the matrix. As a result, this nano-polymer had found extensive applications in waterproofing and crack sealing of mortar.

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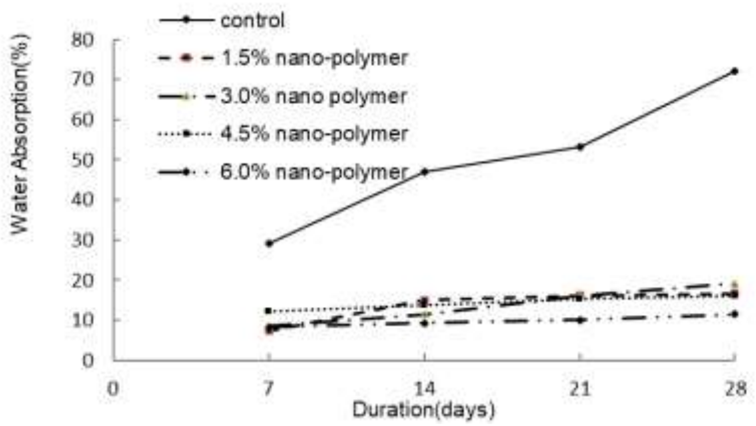

Figure 1: Water Absorption of Mortar

Sorptivity

Sorptivity results are presented in Figure 2. The results showed that samples treated with NP decreased in sorptivity. This depicts elastober as a sealant due to a seamless cross-linked elastomeric membrane formed in the matrix by the NP.

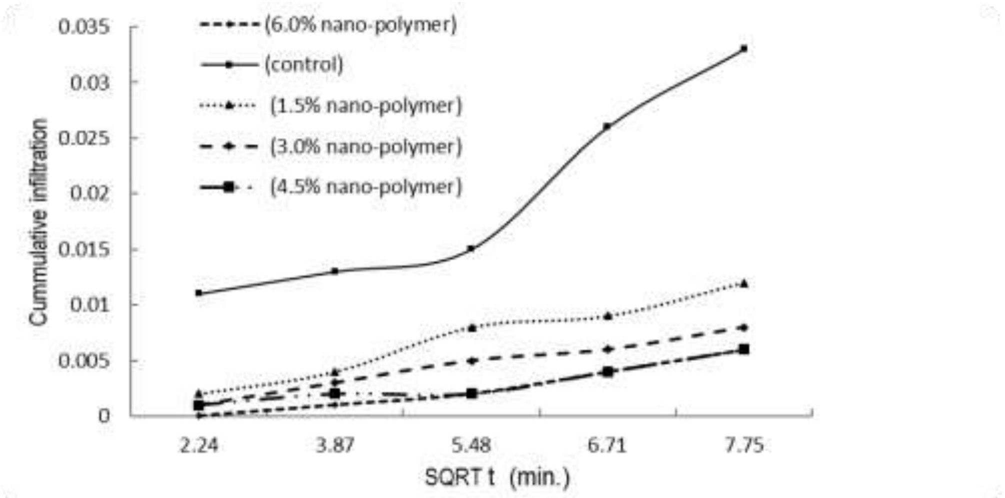

Figure 2: Sorptivity of Mortar

Compressive Strength

The compressive strength of the RHA-cement mortar increased with an increase in the addition of the NP as shown in Figure 3. In addition to the formation of the secondary binding agent as a result of pozzolanic reaction during hydration, the presence of acrylates from the nano-polymer impacts a better bonding to the matrix (by the formation of calcium acrylates) and this could be responsible for the increase in compressive strength.

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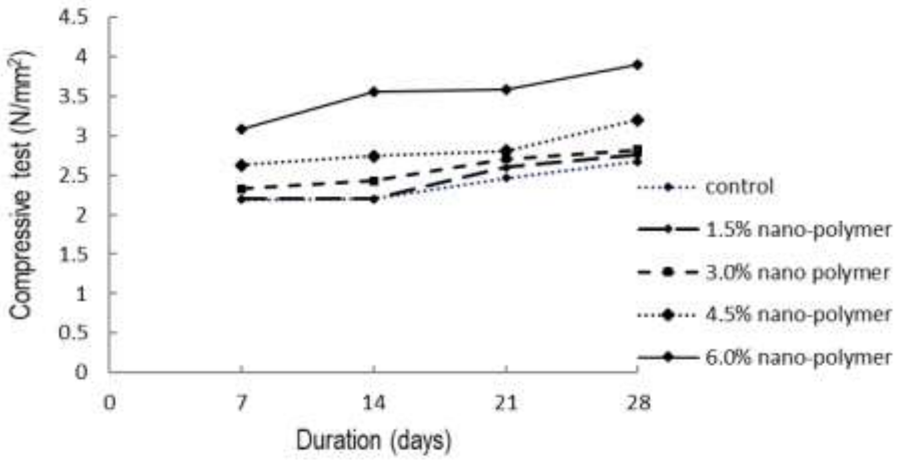

Figure 3: Compressive Strength

Thermal Conductivity

The thermal conductivity results of Figure 4 indicate a decrease in thermal conductivity with the addition of nano-polymer. Thermal conductivity also decreased with the age of mortar. This implies that higher strength gain with curing improves mortar resistance to thermal changes. The result shows that RHA-cement-sand mortar, treated with nano-polymer, has better insulating properties compared to the normal cement-sand mortar. The acrylic composition of elastobar impacts excellent ultraviolet stability to the matrix.

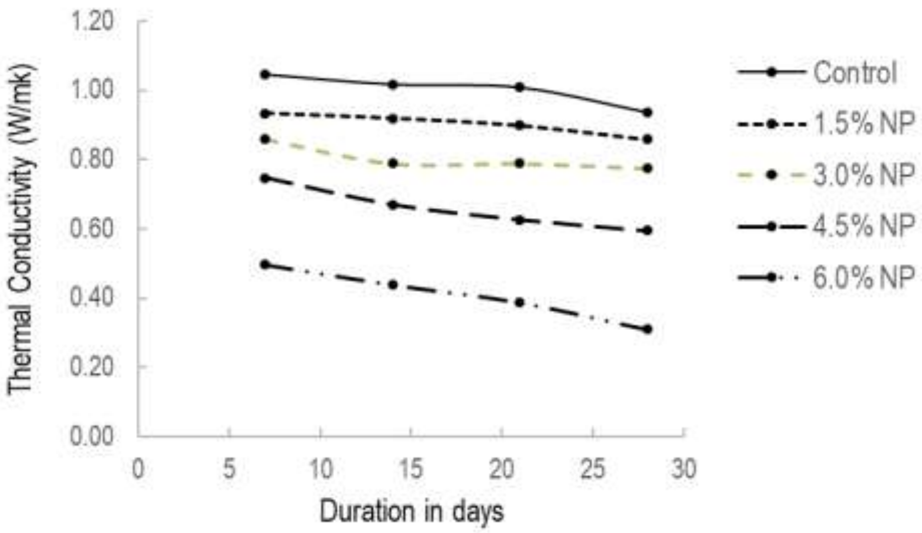

Figure 4: Thermal Conductivity

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Fire Resistance

The influence of nano-polymer on the fire resistance of RHA-cement-sand mortar is shown in figure 5. Fire resistance increased by 3.14% for the sample treated with 6% NP. This improvement could be attributed to enhanced acrylates bonding within the matrix.

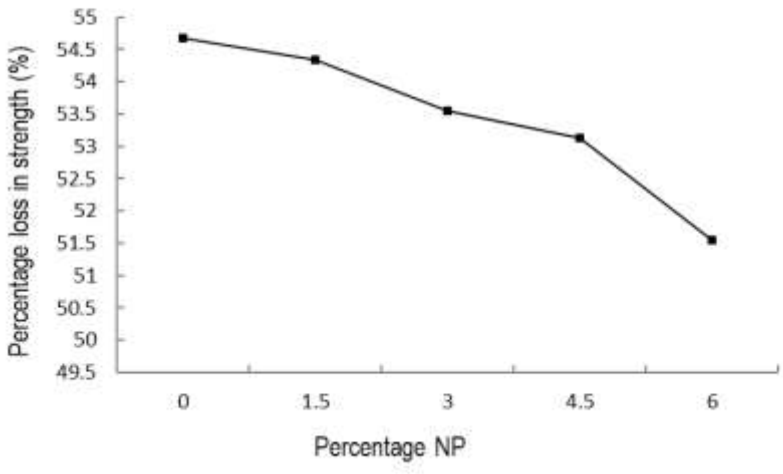

Figure 5: Fire Resistance

CONCLUSION

The study investigated some structural and thermophysical properties of RHA-cement-sand mortar treated with a nano-polymer (elastobar). A 10% replacement of cement with RHA was used while the NP inclusion ranged from 0–6%. Mortar properties considered include density, water absorption, sorptivity, compressive strength, thermal conductivity and fire resistance. While the density, water absorption, sorptivity and thermal conductivity of mortar decreased with the addition of the NP, compressive strength and fire resistance increased. It could be concluded that the application of elastober had shown improvements in the durability and strength properties of rice husks ash cement mortar.

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REFERENCES

Alireza, N. G., Suraya, A. R., Farah, N. A. A, and Mohamad, A. M. S (2010). Contribution of Rice Husk Ash to the Properties of Mortar and Concrete: A Review. *Journal of American Science*; 6(3), pp. 157-165.

Antiohos, S.K, Papadakisb, V. G, and Tsimasc, S. (2014). *Rice husk ash (RHA) effectiveness in cement and concrete as a function of reactive silica and fineness*. Cement and Concrete Research 61(62), pp. 20–27.

ASTM C109/C109M - 16a. *Standard Test Method for Compressive Strength of Hydraulic Cement Mortars.* ASTM International, Pennsylvania, 2016.

BS EN 12390-4:2000. *Testing hardened concrete. Compressive strength specifications for testing machines*. British Standard Institution, London.

BS EN 197-1:2011. Cement - *Composition, specifications and conformity criteria for common cements*. British Standards Institution.

Fapohunda C., Akinbile, B. and Shittu, A. (2017). Structure and properties of mortar and concrete with rice husk ash as partial replacement of ordinary Portland cement – A review. *International Journal of Sustainable Built Environment*. 6(2), pp. 675-692.

Ferraro, R.M and Nanni.A. (2012). Effect of white rice husk ash on strength, porosity, conductivity and corrosion resistance of white concrete. *Construction and Building Materials*. 31, pp. 220-225.

Khana, M. N, Jamil, M, Karimc, M and M.F.M. Zain, M. F. M. (2014). Strength and Durability of Mortar and Concrete Containing Rice Husk Ash: A Review. *World Applied Sciences Journal*. 32 (5), pp. 752-765.

Kondraivendhan, B. (2013). Strength and Flow Behaviour of Rice Husk Ash Blended Cement Paste and Mortar. *Asian Journal of Civil Engineering (Bhrc)*, 14(3), pp.405-416.

Liulei, L. I. and Dong, O. (2017). Properties of Cement Mortar and Ultra-High Strength Concrete Incorporating Graphene Oxide Nanosheets. Nanomaterials 7(187); doi:10.3390/nano7070187. Retrieved from www.mdpi.com/journal/nanomaterials

Oyetola, E.B and M. Abdullahi. (2004). The use of rice husk ash in low-cost sandcrete block production. *Leonardo Electronic Journal of Practices and Technologies*, 8, pp. 58-70.

Pande, A. M and Makarande, S.G. (2013). Effect of Rice Husk Ash on Mortar. *International Journal of Engineering Research and Applications*. 3(1), pp. 1710-1717.

Pellegrini-Cervantes, M.J., Almeraya-Calderon, F., A. Borunda-Terrazas, A., Bautista-Margulis, R.G. , Chacón-Nava, J.G. , G. Fajardo-San-Miguel G., Almaral-Sanchez, J. L., Barrios-Durstewitz, C.P. , Martinez-Villafañe, A.(2013). Corrosion Resistance, Porosity and Strength of Blended Portland Cement Mortar Containing Rice Husk Ash and Nano-SiO_2. *International Journal of Electrochemical Science*, Vol. 8 pp. 10697 – 10710.

Rashid, M.H (2016). Strength Behaviour of Cement Mortar Assimilating Rice Husk Ash. *Int'l Journal of Advances in Agricultural & Environmental Engg*. (IJAAEE), 3(2) pp. 288-292.

Rashid, M.H, Molla, M. K. A and Tarif, U. A. (2010). Durability of Mortar in Presence of Rice Husk Ash. *World Academy of Science, Engineering and Technology* 43, pp. 736-739.

Shatat, M. R. (2016). Hydration Behaviour and mechanical properties of blended cement containing various amounts of rice husk ash in presence of metakaolin. *Arabian Journal of Chemistry*. 9(2), pp.1869-1874.

Surajit, M. and Richi, P, S. (2016). Experimental Investigation on Strength and Water Permeability of Mortar Incorporate with Rice Straw Ash. *Advances in Materials Science*

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DOI URL: https://doi.org/10.52589/IJMCE-VWSKS1EI

and Engineering Volume 2016, Article ID 9696505, 7 pages http://dx.doi.org/10.1155/2016/9696505.

Swaminathen, A.N and Ravi, S.B. (2016). Use of rice husk ash and metakaolin as Pozzolans for concrete: a review. *International Journal of Applied Engineering Research. 11 (1), pp. 656-664.*

Umasabor, R. I. and Okovido, J. O. (2018). Fire resistance Evaluation of Rice Husk Ash Concrete. Heliyon 4(12) e01035. Doi: 10.016/j.heliyon. 2018.e01035.

Wail, N. A. and Waleed, K. A. (2018). Effect of Nanomaterials in Cement Mortar Characteristics. *Journal of Engineering Science and Technology*, 11(9), pp.1321-1332.

Zain, M.F.M., Islam, M.N., Mahmud, F., Jamil, M.A. (2011). Production of rice husk ash for use in concrete as a supplementary cementitious material. *Construction and Building Materials.* 25 (2), pp. 798-805.

Zerbino, R., Giaccio, G., Marfil, S. (2014). Evaluation of alkali-silica reaction in concretes with natural rice husk ash using optical microscopy. *Construction and Building Materials.* 71, pp. 132-140.

Zydex Industries. www.http://magnumassociates.co.in/nano-technologies/water-proofing-solution/ (retrieved on the 19th April, 2019).

Article DOI: 10.52589/IJMCE-VWSKS1EI
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