Evaluation Some Properties of NanoMetakaolin or Rice Husk Ash Cement Mortar and its Resistance to Elevated Temperature

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Abstract

The objective of this research is to find the optimum value of some properties like compressive, flexural strength of blended cement mortar by nanometakaolin (NMK) or rice husk ash (RHA) and to evaluate the effect of high temperature on these properties. The ordinary Portland cement(OPC) of mortar was partially substituted by NMK or RHA of 5,10,15 and 20% by weight of cement. (108) control and blended specimens were casted and tested at ambient temperature (33 ºC) for compressive and flexural strength for 28 and 90 days. Another (270) of the control and blended specimens were casted and cured for 90 days and exposed to elevated temperature of a gradual increase in temperature up to 200 ºC,300 ºC, 400 ºC,600 ºC and 800 ºC for two hours in an electrical furnace and they were under the same previous tests. The test results at ambient temperature indicate that the optimum compressive and flexural strength was with ratio of 15% NMK cement replacement in mortar for 28 and 90 days but for RHA was ratio of 10% for 28 days and 15% of cement weight in mortar for 90 days compared to control specimens. The results of exposing control and blended specimens of (90) days to elevated temperature showed that the optimum strength for control and the best MK replacement ratio were found at 200 ºC, and the best RHA replacement ratio specimens was found at 300 ºC. It is also found that exposing the mortar to more than these temperatures destroyed its strength and it was detrimental to its properties.

Key words: NanoMetakaolin, Rice Husk Ash, Cement mortar Properties

الخلاصة:

يهدف هذا البحث لا يجاد القيمة المثلى لبعض خواص مونة السمنت المخلوطة بالنانوميتاكاؤلين او رماد قشور الرز كمقاومة الانضغاطية ومعاير الكسر(الانثناء) وتقييم تأثير الحرارة العالية على تلك الخواص. استبدل سمنت المونة البورتلاندي الاعتيادي جزئيا بالنانوميتاكاؤلين او رماد قشور الرز بنسبة(5،10،15،20)% من وزن السمنت. صبت(108) نموذج للمونة المرجعية والمخلوطة وفحصت قوتها الانضغاطية ومعاير الكسر بدرجة الحرارة الاعتيادية(33) مْ لعمر(28) و(90) يوم. صبت (270) نموذج اخرى مرجعية ومخلوطة وتم اسقائها لمدة (90) يوما وتعريضها تدريجيا" للحرارة في فرن كهربائي بدرجة(200) مْ،(300) مْ،(400) مْ،(600) مْ و(800) مْ لمدة ساعتين واجراء نفس الفحصين السابقين.أظهرت نتائج الفحص بدرجة الحرارة الاعتيادية ان مقاومة المونة المثلى للانضغاط والانثناء كانت لأفضل نسبة لاستبدال السمنت بالنانوميتاكاؤلين وهي(15)% من وزن السمنت بالمونة بعمر(28) و(90) يوما" والمثلى كانت لأفضل نسبة للاستبدال برماد قشور الرز وهي (10)%من وزن السمنت بالمونة لعمر(28) يوما" و(15)% لعمر(90) يوما" مقارنة بمقاومة النماذج المرجعية. اظهرت نتائج تعريض نماذج المونة المرجعية والمخلوطة للحرارة العالية بعمر(90) يوما" ان المقاومة المثلى للمونة المرجعية ولنماذج أفضل نسبة للاستبدال بالنانوميتاكاؤلين هي بدرجة(200) مْ ولأفضل نسبة للاستبدال برماد قشور الرز بدرجة (300) مْ. لقد وجد ايضا" ان تعريض المونة لدرجات حرارية اعلى اتلف مقاومتها وكان ضارا" بخواصها.

I. Introduction:

Apozzolona is a aluminous / siliceous material which in itself has little or no cementitious value, but which will in finely divided form and in the presence of water, chemically reacts with calcium hydroxide liberated during the hydration of Portland cement to produce stable, insoluble cementitious compound which contributes to its strength and impermeability (Sima,1974).

Kaolin is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain. NMK differs from other Supplementary Cementitious Materials (SCMs) such as fly ash, silica fume, and slag, in that it is not a by-product of an industrial process ; it was manufactured for a specific purposes under controlled condition. NMK was produced by thermal activation alumino-silicate of impure natural kaolin clay by calcining kaolin clay within the temperature range of(700 - 850)ºC for 2hrs to break down the structure of kaolin (Belkowitz and Armentrout,2010).In most cases, mortars and concrete containing material with pozzolanic characteristics have (in normal condition), porosity values equal or superior to that of OPC concrete. Typically Nano means 10^{-9}, so nanometer is one billion of a meter and a unit of length that is generally most appropriate for describing the size of single molecule (Zhang and Malhotra ,1996).

NMK is increasingly being used to produce materials with higher strength, denser microstructure, lower porosity, higher resistance to ions, and improved durability (Paiva *et. al*.,2012,Guneyisi *et. al*.,2013, Nadeem *et. al*.,2013). NMK was a pozzolanic material used in a wide range in partial replacement of cement in concrete which was treated as economical and also due to its pozzolanic action increases strength and durability properties of concrete (Srinivasu *et. al*.,2014).Partial replacement of MK by the (5–20) % of cement weight affects concrete pore size causing variation in micro –structural properties, mechanical properties and corrosion behavior (Siddique and Klaus,2009). Concrete evolution of the porosity depends on the characteristics of pozzolanic materials, such as fineness, mineralogy, loss of ignition, chemical composition and water / binder ratio used (Gjorv,1992).

When NMK is used as partial replacement for OPC, it is capable of reacting with portlandite to form supplementary calcium – silicate – hydrate (C-S-H) similar in composition and structure to those obtained from Portland cement. (Silva and Glasser ,1992). Replacement the cement of mortar at 10% MK and 15% MK by weight shows better viscosity and shear stress and improved the cement paste flow ability (Sabria *et. al*.,2010). Employed specimens with various replacement ratios of metakaolin of (5,10,15 and 20)% of cement weight in mortar (1:1 mix) produces higher compressive strength and greater resistance to efflorescence for compressive strength improves to(51.34)N/mm^2,(53.46)N/mm^2,(55.72)N/mm^2 and (50.02) N/mm^2 respectively compared to control strength of (40.22)N/mm^2 (Aggelis et al. ,2013). RHA is a pozzolanic agricultural waste contains a large amount of silica. When rice husk is burnt, about 20% of weight of the husks is recovered as ash where 75% of weight is silica and its cement replacement in concrete will improve workability, reduce permeability with heat revolution and increase strength at longer ages (Ganesan *et. al*.,2007).

It was observed that the optimum replacement of cement in high strength concrete by RHA was(10 -20)% of its weight. The burning of rice husks under controlled temperature below 700 ºC, time conditions produce rice husk ashes with grinding to obtain high pozzolanic activity containing silica in amorphous form (Ramezanianpour *et. al*., 2009, 2010) and (Agarwal,2006). Addition of rice husk ash to Portland cement does not only improve the early strength of concrete, but also forms a calcium silicate hydrate (CSH) gel around the cement particles which is highly dense and less porous, and may increase the strength of concrete against cracking (Saraswathy and Song, 2007).

The non - crystalline silica and high specific surface area of the RHA are responsible of its high pozzolanic reactivity (Sakr,2006).At 10% of cement replacement by RHA improves concrete compressive strength to 44.8 MPa and tensile strength to 4.19 MPa at 28 days compared to control value of 40.3 MPa and 3.87 MPa respectively for same curing age (Ramezanianpour *et. al*.,2009). Compressive strength of normal mortar cubes(1:4 mix) increases to 16.43 N/mm^2 and

17.44 N/mm^2 for RHA composition 7.5% and 10.0% respectively compared to control strength of 10.39 N/mm^2 but For higher proportion of RHA, 12.50%, 15.00% and 17.50% compressive strength decreases to 12.74 N/mm^2, 10.73 N/mm^2 and 7.71 N/mm^2 respectively for 28 days curing age(Sudisht and Deodhar, 2012).

The effect of elevated temperature of cement mortar was discussed with the inclusion of fly ash in the laboratory to establish a relation between strength and temperature. The compressive strength of cement fly ash mortar initially increases up to 200 ºC temperature and after that it decreases with further increase of temperature (Ahmed *et. al*.,2004). The bond strength of cement fly ash mortar also increases up to 200 ºC temperature and after that it decreases with further increase of elevated temperature(Sazzad *et. al*.,2003).

Heating of mortar specimens with different RHA cement replacement ratios up to 700 ºC for 30 minutes. Specimens of 15% RHA cement replacement increases compressive strength to 48.3 N/mm^2 at 300 ºC, control specimens increases to 44.5 N/mm^2 at 200 ºC compared to control value of 35.8 N/mm^2 at ambient temperature of 32 ºC (Rashid *et. al*.,2011).

II- Objective of Experimental Study:

The main objective of this experimental work is to study the mortar as follows :

a) Find the optimum value of compressive and flexural strength of blended cement mortar by finding the best partial cement replacement ratios of NMK or RHA that affect the producing of these optimum strengths at ambient temperature.

b) Evaluate the effect of many elevated temperature levels on these properties of blended cement mortar and the temperature that produces the optimum strengths.

III- Experimental Program:

Materials :

Local materials were used in this research except nanometakaolin. All the materials are complying to ASTM or to Iraqi standard specification requirements.

Cement :Ordinary Portland Cement(OPC), conforming to Iraqi specification (IQS) no.5/1984 requirements, was supplied from Iraqi Kufa cement factory and its chemical and physical analysis are given in table 1 and 2.

Sand:Locally available fine aggregates of Al –Akhadir sand quarry, in saturated surface dry condition were used, they were clean, hard, strong free of organic impurities and deleterious substances and relatively free of silt and clay. The physical properties of the sample comply with Iraqi specifications (IQS) no. 45/1984 as given in table 3. Fine modulus is 2.38, Maximum Particle Size is 4.75mm and Grading is given in table 4 with fig.1.

Rice Husk Ash:The rice husks were supplied from local private rice hulling factory. The husks are plant fibers contain cellulose, hemicellulose, lignin and silica. The rice husks sample was allowed to dry under sun for four days. Then the rice husks were burnt under well-controlled temperature of an incinerator with regulated blowing air at 650 ºC temperature for 1 hour to avoid unburnt carbon and to produce a rice husks ash with amorphous silica content on the porous structure of the ash with high activity below 700 ºC. The material was sieved and grinded to obtain very fine particles complying to ASTM C204 - 07 specifications with Blain fineness of 28000 cm^2/ gm. The pozzolanic ash activity was tested and found to comply to the chemical and the physical requirements of ASTM C618 -12a Class N Pozzolanic. The activity was complying to requirements of ASTM C311-07 specifications as mentioned in table 1.(Ramezanianpour *et. al*.,1995;Cook and Suwanitaya,1983).

Nanometakaolin: A white fine of nanometakaolin sample which was supplied from Middle East Mining Investments Company, Cairo, Egypt from mineral ground clay of kaolin and calcined in an electric furnace at 750 ºC for a period of 2 hours to give active amorphous NMK. The sample then cooled gradually to room temperature. The material used in this study was Nano- clay of Blaine surface area is 480000 cm^2/ gm. and average dimension (200×100×20)nm as previously mentioned by the exporting company. The chemical and physical analysis of the sample was complying to ASTM C618 -12a specifications as given in table 1.

Water : Distilled potable water.

Cement paste Setting Times:

Vicat needle is used in this test to determine the initial and final setting time of hydraulic cement according to Iraqi Specifications(IQS) no.5/1984 given in table 2 with other cement physical properties. Normal consistency of cement paste was 38 % by Vicat test on accordance to ASTM C187- 11e1 requirements.

Mortar Flow Test:

The mortar mixes were prepared to have a mortar flow of 95 ± 5 % as per ASTM C230-02 specifications.

Table 1: Chemical and Physical Analysis of Cementitious Materials *

Chemical Analysis %	Cem. (OPC) %	IQS No. 5/1984 Limits for Cement %	RHA %	MK %	ASTM C618-12a pozzolanic Class N
SiO2	20.98	-	85.31	56.2	Sum of the three Components ≥70 %
Al2O3	6.15	-	0.06	35.73	
Fe2O3	3.30	-	0.29	1.24	
CaO	61.72	-	0.85	0.68	-
MgO	3.5	< 5.0	0.63	0.23	-
Na2O	0.05	-	0.1	0.15	≤ 1.5 %
K2O	0.08	-	1.6	0.07	-
SO3	2.33	>5< 2.8 for C3A	0.11	0.01	≤ 4%
L.O.I	1.4	< 4.0	4.65	3.86	≤ 6 %
TiO2	-	-	-	0.02	-
P2O5	-	-	-	0.06	-
Free Lime	1.05	-	-	-	-
Insoluble Res.	0.68	< 1.5	-	-	-
L.S.F	0.8	1.02 – 0.66	-	-	-
C3S	34.65	-	-	-	-
C2S	33.8	-	-	-	-
C3A	10.6	-	-	-	-
C4AF	10.10	-	-	-	-
Physical Tests					
Activity Index %	-	-	107	122	≥ 75
Flow Test %	95	-	102	90	≤ 115
Specific Gravity	3.15	-	2.15	2.34	-
Blain Specific Surface (cm2/g)	3100	> 2300	28000	480000	-

* The cementitious materials were tested at Geological Surveying Directorate - Baghdad. NMK sample was an Egyptian production.

Table 2: Physical Tests of Cement Confirming to IQS No.5/1984

Test Type	Result	IQS No. 5/1984 Limits
Setting Time of Paste (min): Initial Final	 105 235	 45 ≥ ≤ 600
Soundness of Cement(Autoclave) %	0.35	≤ 0.8
Fineness of Cement(Blain) : m^2/ kg	310	≥ 230
Compressive Strength : MPa days3 7 days	 19 27.1	 15 23

Table 3: Physical Properties of Sand according to IQS No. 45/1984

Physical Properties	Value	IQS No. 45/1984 Limits
Max. Density m^3/Kg	1605	-
Specific Gravity	2.6	-
Water Absorption %	0.73	-
Sulphate Content %	0.15	≤ 0.75
Clay %	0.60	≤ 1.0

Table 4: Sand gradation complying to IQS No. 45/1984 Specification

Sieve Opening (mm)	Accumulative %passing	IQS No. 45/1984 Limits- zone no.3
10	100	100
4.75	96	90 - 100
2.36	89	85 - 100
1.18	82	5 - 1007
0.6	67	60 - 79
0.3	24	12 - 40
0.15	4	0 - 10

Specimens Preparation and Casting:

The mortar was prepared using cement– sand ratio of 1: 2.75 and water/ cement ratio (w/c) of 0.55.Work procedure of mortar is prepared and placed according to ASTM C-109M-02 standards. The ordinary Portland cement(OPC) is used in preparing all mortar specimens. One of the two sets is (3) of 50mm mortar cube of 3 days age and the other of 7 days age for cement physical properties test and the result was found to be complying to IQS no. 5 /1984 as given in table 2. (108) specimens of control and blended specimens were prepared and cured for 28 and 90 days and tested for compressive and flexural strength at ambient temperature (33ºC) and the results are given in table 6. Another (270) of control and blended specimens were prepared and tested at elevated temperature for the same tests after (90) curing days as given in table 7 and 8. Mortar specimens are mixed after preparing the molds and materials quantities. Electric mixer is used to assure complete mortar ingredients homogeneity. The mortar are molded in (50×50×50) mm cubes for compressive test and prisms of (160×40×40) mm for flexural strength with the required tamping. (3) specimens are casted per each set. The molds are vibrated for 1 minute to remove any air voids and kept in molds at 100% relative humidity for 24 hours. The cubes and prisms are stripped from the molds and inserted in clean water for 28 and 90 days curing as per ASTM C511- 03 requirements. The blended cement mortar is partially substituted by NMK or RHA of 5,10,15 and 20 % by weight of cement in mortar as given in table 5. After the required 28 or 90 curing days the specimens are taken out curing water tank in each case and transferred to drying oven with 105 ºC temperature for 24 hours (Mohamedbhai,1986). The elevated temperature specimens of 90 curing days are subjected to gradual increase in temperature around(5ºC/ min) up to 200 ºC,300 ºC,400 ºC,600 ºC and 800 ºC for two hours in an electrical symmetrical furnace for the NMK and RHA compressive and flexural specimens. Specimens are cooled in ambient temperature for 24 hours to be ready for testing. The tests result as given in tables 6 ,7and 8.

Table 5: dry mix ratios of blended cement mortar groups(Mass%)

Mix Designation	OPC %	or RHA NMK %
A0 (Control)	100	0
A5	95	5
A10	90	10
A15	85	15
A20	80	20

IV.Testing and Results:

Compressive Strength:

All mortar compressive strength specimens of 50 mm cubes were tested at 28 &90 days curing age for RHA,NMK at ambient conditions and for 90 days age of fire exposing specimens according to ASTM C-109M - 02 specifications. The loading rate on the cubes was 0.72 mm / min. The average strength result of three Specimens was reported in tables 6,7 and 8.

Flexural Strength:

Mortar prisms of (160×40×40) mm specimens for flexural strength were tested in two curing stages, temperature state as in compressive strength specimens according to ASTM C348 - 02. The loading at mid third of prism span as simple beam and the strength was calculated as follows:

$F = PL / B D^2$ where : F is flexural strength in N / mm^2

P = max. value of loading at failure(N) B,D : prism average width and height (mm)

L = The space between prism supports (mm)

The average flexural strength of the three Specimens was reported in tables 6,7 and 8. The result in these tables are the average of three Specimens of each test set.

Fire effect on Specimens Colour:

After the subjection of mortar specimens to around 600 ºC temperature, the change in color was noticeable. Inner section of cement mortar was near to be bluish. When the heating temperature was increased to 800 ºC, the inner color was changed to bluish dark grey. No clear color transitional zone and the mortar had maintained its outside color with more darkness.

Table 6 : NMK , RHA Blended Mortar Properties for 28 and 90 curing days at ambient temperature

Mix No.	NMK Replacement				RHA Replacement			
	Compressive Strength MPa		Flexural Strength MPa		Compressive Strength MPa		Flexural Strength MPa	
	28 D	D90	28 D	90 D	28 D	90 D	28 D	D 90
A0	34.63	36.66	5.81	6.15	34.63	36.66	5.81	6.15
A5	39.20	42.25	6.58	7.09	34.96	37.72	5.86	6.33
A10	44.93	49.67	7.54	8.34	35.28	38.67	5.92	6.49
A15	47.05	53.52	7.89	8.98	33.41	39.81	5.60	6.68
A20	41.27	51.24	6.93	8.60	28.29	37.32	4.75	6.26

Table 7 : NMK Blended Mortar Properties for 90 curing days under Elevated temperature

Test	Mix No.	Temperature Level					
		33 ºC	200 ºC	300 ºC	400 ºC	600 ºC	800 ºC
Compressive Str. MPa	A0	36.66	40.09	37.90	31.19	15.91	2.61
	A5	42.25	45.16	41.62	36.54	19.08	4.85
	A10	49.67	51.18	45.60	39.01	23.94	7.50
	A15	53.52	56.03	51.13	45.20	28.56	11.50
	A20	51.24	53.1	46.92	41.08	25.60	8.81
Flexural Str. MPa	A0	6.15	6.01	5.29	4.05	2.06	0.26
	A5	7.09	6.77	5.82	4.93	2.48	0.50
	A10	8.34	7.67	6.45	5.40	3.11	0.75
	A15	8.98	8.40	7.15	6.10	3.71	1.15
	A20	8.60	7.96	6.70	5.63	3.32	0.88

Table 8 : RHA Blended Mortar Properties for 90 curing days under Elevated temperature

Test	Mix No.	Temperature Level					
		33 ºC	200 ºC	300 ºC	400 ºC	600 ºC	800 ºC
Compressive Str. MPa	A0	36.66	40.09	37.90	31.19	15.91	2.61
	A5	37.72	38.87	40.33	32.81	16.89	3.54
	A10	38.67	40.79	43.46	37.36	21.94	4.89
	A15	39.81	42.61	46.82	39.63	24.31	6.72
	A20	37.92	39.27	41.52	34.40	18.75	3.91
Flexural Str. MPa	A0	6.15	6.01	5.29	4.05	2.06	0.26
	A5	6.33	5.83	5.64	4.26	1.94	0.33
	A10	6.49	6.11	6.08	4.85	2.52	0.46
	A15	6.68	6.39	6.55	5.15	2.79	0.63
	A20	6.37	5.89	5.81	4.47	2.15	0.37

V. Result and Discussion:

Strength at ambient temperature :

Compressive Strength:

Fig.2 illustrates the compressive strength of control (100% OPC) and blended mortars for different replacement ratios of NMK and RHA for 28 and 90 curing days. It is clear that, the control compressive strength increases by 5.86% for 90 days higher than its strength of 28 days. The optimum increase of mortar compressive strength with NMK replacement is found at 15% ratio of NMK in mortar. The compressive strength of mortar with 15% ratio of NMK increases by 35.86 % at 28 days and by 45.99% at 90 days higher than their control mortar at the same age respectively. The compressive strength of mortar with 20% ratio of NMK increases by 19.17% at 28 days and 39.77% at 90 days higher than their control mortar as given in table 6. The compressive strength of RHA mortar increases with the increase of RHA ratio up to optimum increase with 10% replacement ratio of RHA at 28 days by 1.87% and the optimum increases with 15% ratio of RHA in mortar at 90 days by 8.59% higher than their control mortar at the same age. The compressive strength of mortar with 20% ratio of RHA decreases by 18.30 % at 28 days and increases by 1.8% at 90 days respectively compared to control mortar strength at the same age. The lowest mortar compressive strength for control and blended mortar is found with 20% ratio of RHA mortar for 28 days for its decrease by 18.3% lower than control mortar strength at the same age as given in table 6.

Flexural Strength:

Fig.3 illustrates the flexural strength behavior of blended mortar with NMK and RHA which is similar to compressive strength. The flexural strength of control mortar increases by 5.85 % at 90 days higher than its strength in 28 days. The optimum increase of mortar flexural strength with 15% replacement ratio of NMK is 35.80% for 28 curing days and 46.01 % at 90 days higher than their control mortar of the same age. The flexural strength of mortar with 20% ratio of NMK increases by 19.27 % at 28 and 39.83 % at 90 days higher than their control mortar as given in table 6. The flexural strength of RHA mortar increases up to optimum increase with 10% replacement ratio of RHA by 1.89% at 28 curing days and the optimum increase with 15% ratio of RHA by 8.61 % at 90 days age higher than control strength at the same age. Flexural strength of mortar with 20 % replacement ratio of RHA decreases by 18.24% for 28 curing days and increases by 1.78 % at 90 days respectively compared to their control mortars. The lowest flexural mortar strength for control and blended mortar is found also with 20% ratio of RHA mortars for 28 days for its decrease by 18.24% lower than control mortar strength at same age as given in table 6. This increase in compressive or flexural strength of control mortar at 90 days more than its counterpart at 28 days due to more cement grains hydration and its reaction to gain more strength with more period. The addition of metakaolin to cement mortar enhances compressive strength through the filler effect in the interfacial transition zone between the cement paste and aggregate particles. In addition, CH gels are quickly removed during the hydration of cement with metakaolin and actually accelerate cementitious hydration and develop a more compact, denser pore structure. The formation of secondary calcium-silicate-hydrate (C-S-H)gel(due to metakaolin pozzolanic reaction), although of less density than the primary C-S-H gel, is effective in filling and segmenting large capillary pores into small, herby decreasing the total permeability of cement. Hydration is formed on the surface of the specimens microstructure of these samples reduce the mobility of chloride and other ions, resulting in higher compressive strength and a reduction in crack stretching. More metakaolin addition produces a lot of unreacted precursor powder due to lack of water in mix (agglomeration) which will act to decrease compressive strength.(Nadeem *et. al*.,2013).Improvements in mechanical and durability properties of concretes or mortars contain RHA by the chemical and physical effects of RHA which is mainly due to the pozzolanic reactions between the amorphous silica of RHA and calcium hydroxide(C-H) produced by the cement hydration to form calcium – silicate- hydrates(C-H-S). The physical effect can also be considered as filler effect of the spaces between the cement grains. Moreover, small particles of addition generate a large number of nucleation sites for the precipitation of hydration products. This will accelerate the reactions and form smaller C-H crystals. Therefore, all these mechanisms make the microstructure of the paste more homogeneous and denser produces more increase in compressive and flexural strength. The increase in concentration of RHA in the mix will produce destabilized hydrated silicates and aluminates thereby causing the weakening of the cement structure which explains the reduction of the compressive strength with more RHA addition (Chindaprasirt *et. al*. 2007).

Strength at elevated temperatures:

Compressive Strength:

Fig.4 and 6 illustrate the residual compressive strength of control and blended cement mortars with different replacement ratios of NMK and RHA of 90 days age exposed to elevated temperature. The compressive strength of control and the blended mortars increase as the heating temperature increases up to 200 ºC for control, NMK mortars and up to 300 ºC for RHA mortars then it is followed by a gradual decrease as the temperature increases up to 800 ºC. The compressive strength of control and with 15% replacement ratio of NMK mortars gives the optimum compressive strength increase at 200 ºC by 9.35% and 52.83% respectively higher than the control mortar strength at ambient temperature. The residual compressive strength with 20% ratio of NMK increase at 200 ºC by 44.84% higher than control mortar strength at ambient temperature. The residual compressive strength of control, with 15% and 20% ratio of NMK mortars decreases at 800 ºC to 7.12 %, 31.36% and 24.03% of control strength at ambient temperature respectively. The compressive strength of blended mortar with 15% ratio of RHA gives the optimum increase at 300 ºC by 27.71 % higher than control mortar strength at ambient temperature. The residual compressive strength of 15% replacement ratio of RHA and 20% ratio of RHA decreases at 800 ºC to 18.33 % and 10.66% of the control strength at ambient temperature. It is found that the control, with 5% ratio of NMK and with 5% ratio of RHA mortars, had the lowest compressive strength at 800 ºC for their decrease to7.11% ,13.22% and 9.65% of control strength respectively at ambient temperature as given in tables 7 and 8.

Flexural Strength:

Fig.5 and 7 illustrate the flexural strength of control and blended mortar with NMK and RHA at elevated temperature. Flexural strength of control and the optimum flexural strength with 15% ratio of NMK mortars at 200 ºC decreases to 97.72 % of control strength and increases by 36.58% higher than control strength respectively at ambient temperature. The residual flexural strength of control, with 15% ratio of NMK and with 20% of NMK mortars decreases at 800 ºC to 4.22%, 18.7% and 14.3 % of control mortar strength at ambient temperature respectively. The optimum flexural strength of 15% ratio of RHA mortar increases at 300 ºC by 6.5 % higher than control strength of 90 days at ambient temperature. The flexural strength of RHA mortar after 300 ºC gradually decreases as the temperature increases up to 800 ºC also to have 15% ratio of RHA mortar 10.24 % of control mortar at ambient temperature. It is found that the control, with 5% ratio of NMK and with 5% ratio of RHA mortars, had the lowest flexural strength at 800 ºC for they decrease to 4.22%, 8.13% and 5.36% of control flexural strength at ambient temperature as given in tables 7 and 8. It is obvious that the cement mortar exhibits more resistance to high temperature as the cement replacement ratio by NMK and

RHA increase up to 15% in mortar for increasing bond between mix particles. The generated bond in control and the blended cement specimens shows an increase in compressive strength at 200 ºC for control, NMK specimens and at 300 ºC for RHA specimens may be due to the hydration of unhydrated NMK or RHA particles which were activated as a result of heating temperature rise. This increase may be also due to further hydration of unhydrated cement grains as a result of steam effect under the condition of the internal autoclaving formed in the cement paste (Nimityongskul *et. al.*, 1995).

Effective thermal expansion in NMK mortar specimens is commencing at heating level more than 200 ºC and in RHA mortar specimens more than 300 ºC. The mortar specimens thermal expansion at elevated temperature is strongly affected by the expansion of fine aggregates because fine aggregates generally occupy more than(70%) of the volume of mortar. A differential thermal expansion exists between the fine aggregates and cement paste in mortar body. So increasing disintegration in mortar specimens with increasing temperature level usually predominates over cement paste cohesion forces with fine aggregates and results in strength loss at elevated temperature(Oyetola and Abdullahi ,2004).

VI. Conclusions :

In the present study, the following conclusions can be drawn out:

1-The compressive and flexural Strength of mortar at ambient temperature or residual strength at elevated temperature depends on the cement type, curing age, pozzolanic material percentage (amorphous silica percentage), pozzolanic material activity and the level of temperature at heating the mortar.

2-The addition of NMK or RHA as partial cement replacement materials is quite satisfactory and shows higher compressive and flexural strength than control mortar at ambient or at elevated temperature up to 300 ºC for NMK or RHA mortar.

3-At ambient temperature the performance of mortar incorporating 15% ratio of NMK cement replacement shows the optimum compressive, flexural strength at 28, 90 days and for RHA mortar, the optimum strength for mortar contains 10% ratio of RHA cement replacement at 28 days and ratio of 15% of RHA at 90 days.

4-At elevated temperature the performance of 90 days age mortars, the control and the best replacement ratio of 15% NMK mortars shows the optimum compressive and flexural strength at 200 ºC but for the best replacement ratio of 15% RHA mortar at 300 ºC temperature. Obviously the more heating of mortar higher than these temperature levels is very detrimental and it destroys the blended mortar properties.

5-The flexural strength is more sensitive to the elevated temperature than compressive strength for it is affected more by fire.

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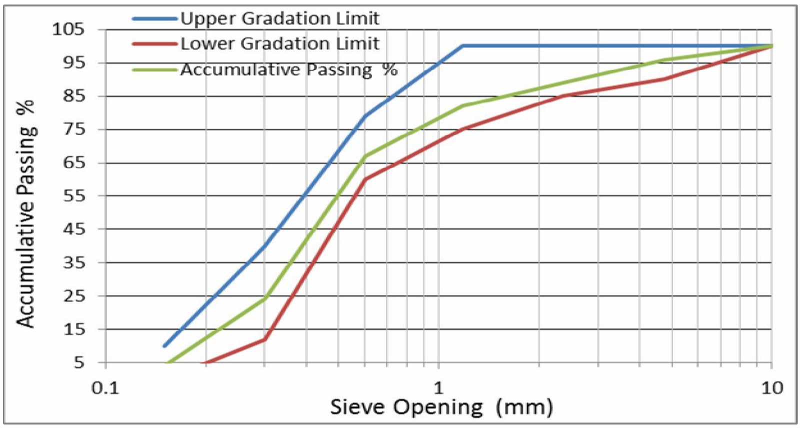

Figure 1.Fine Aggregate gradation according to (IQS) no. 45/1984 limits

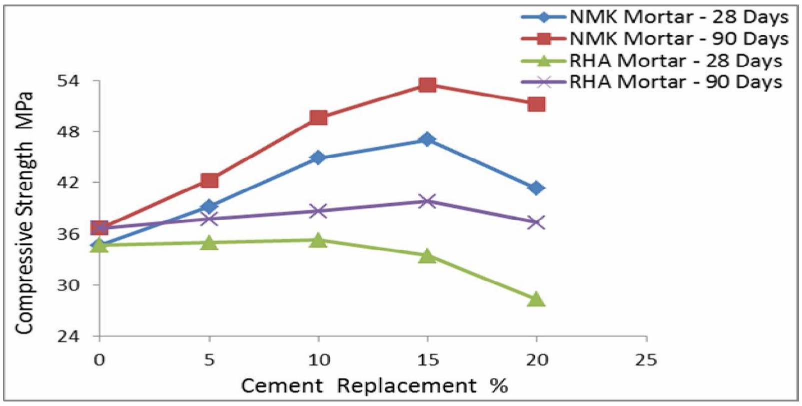

Figure 2. Blended Cement Mortar Compressive Strength at ambient Temperature

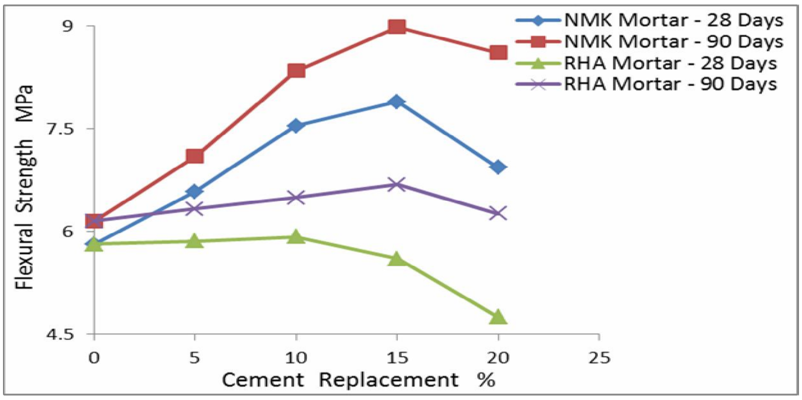

Figure3. Blended Cement Mortar Flexural Strength at ambient Temperature

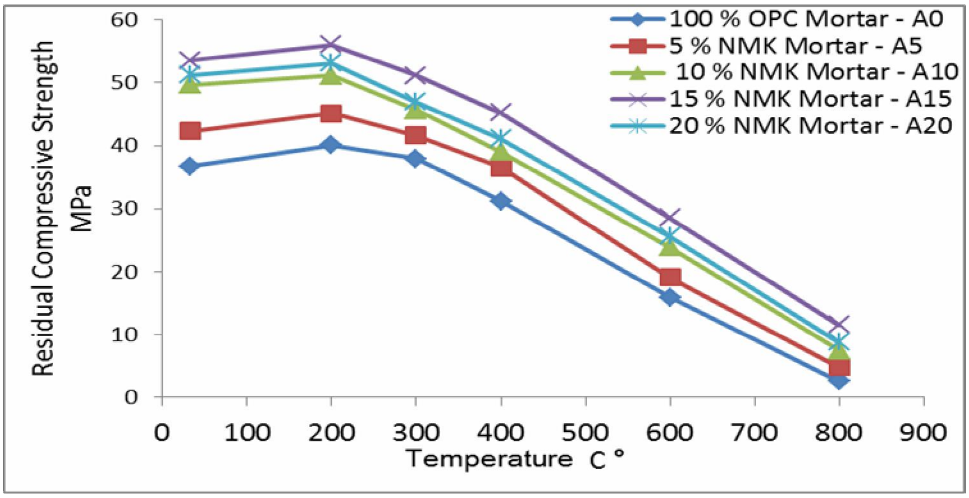

Figure 4. Residual NMK Blended Cement Mortar Compressive Strength at Elevated Temperature

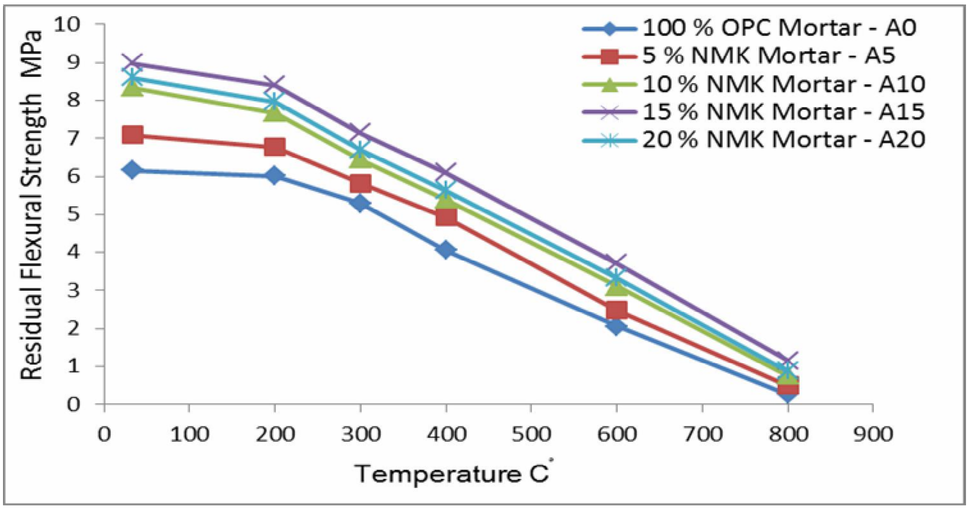

Figure 5. Residual NMK Blended Cement Mortar Flexural Strength at Elevated Temperature

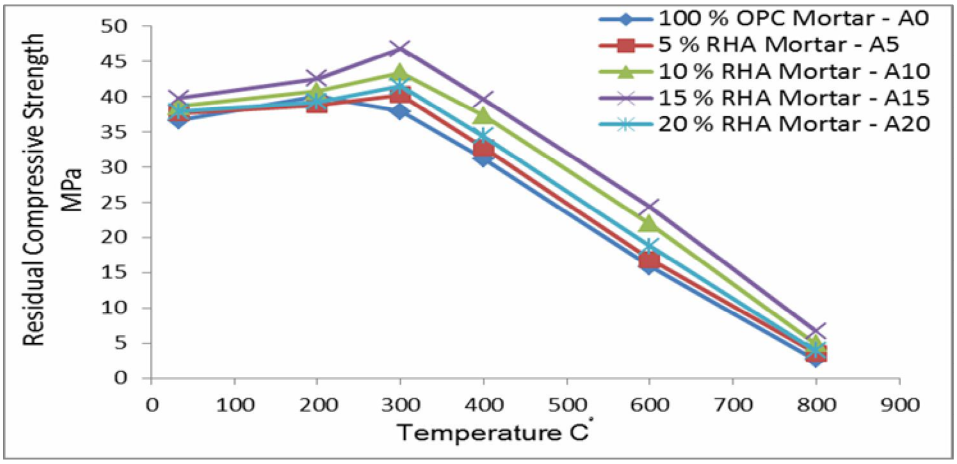

Figure 6.Residual RHA Blended Cement Mortar Compressive Strength at Elevated Temperature

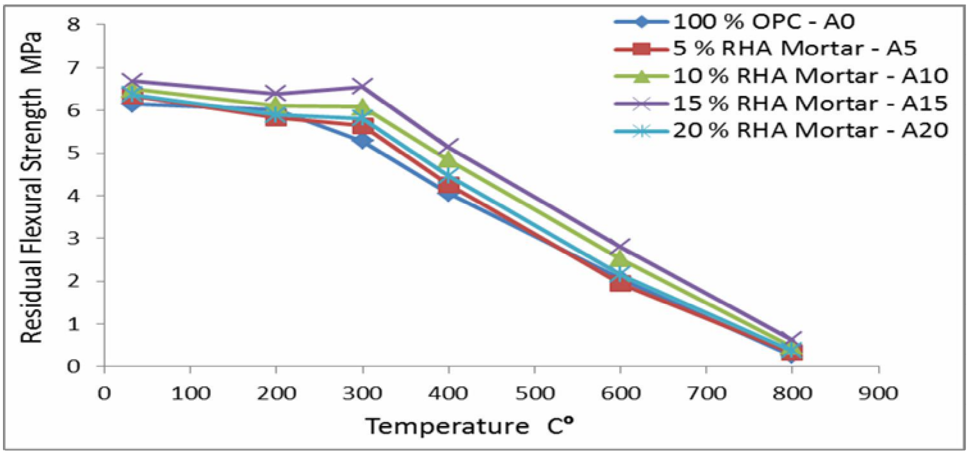

Figure 7. Residual RHA Blended Cement Mortar Flexural Strength at Elevated Temperature

Fig.8 : Rice Husk Ash before grinding

Fig.9: Bag of NMK Sample

Fig.10: Some of Mortar Specimens Fig.11: Electric Furnace of Mortar Burning