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THE EFFECT OF NANO METAKAOLIN MATERIAL ON SOME PROPERTIES OF CONCRETE

Shakir A. Al-Mishhadani[1] , Amer M.Ibrahem[2], Zeinab H.Naji[3]
[1]University of Technology , [2,3]Engineering Collage Diyala University
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ABSTRACT:- This investigation aimed to study the effect of nano metakaolin (NMK) on some properties (compressive strength ,splitting tensile strength & water absorption) of concrete. The nano metakaolin (NMK) was prepared by thermal activation of kaolin clay for 2 hours at 750 Ċ. The cement used in this investigation consists of ordinary Portland cement (OPC). The OPC was partially substituted by NMK of (3, 5 & 10%) by weight of cement.

The C45 concrete was prepared , using water/cement ratio (W/c) of (0.53) .The Water absorption was tested at 28 days while the tests (compressive strength ,splitting tensile strength) were tested at ages of (7, 28, 60,& 90) days . The compressive strength and splitting tensile strength of concrete with NMK were higher than that of reference concrete with the same W/c ratio.The improvement in the compressive strength when using NMK was (42.2, 55.8 , 63.1%) at age 28 days for (3%, 5%, &10%) replacement of NMK respectively whereas the improvement in the splitting tensile strength was (0% , 36% & 46.8 %) at age of 28 days when using (3%, 5%, &10%) NMK respectively. The improvement in the water absorption was (16.6%, 21.79%, &25.6) when using (3, 5, &10%)NMK.

Keywords:- concrete ,nano metakaolin , water absorption , compressive strength, splitting tensile strength

INTRODUCTION

Supplementary cementitious materials (SCMs) are finely ground solid materials that are used to replace part of the cement in a concrete mixture. These materials react chemically with hydrating cement to form a modified paste microstructure. In addition to their positive environmental impact, SCMs may improve concrete workability, mechanical properties, and durability. SCMs may possess pozzolanic or latent hydraulic reactivity or a combination of these. The term pozzolan refers to a silecious material, which, in finely divided form and in

the presence of water, will react chemically with calcium hydroxide to form cementitious compounds.[1] Kaolin is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain.Nowadays ,in concrete design, concrete researchers and developers are taking advantage of secondary cementitious materials to give concrete greater strengths.

One of the newest technologies to break into the concrete design is the use of pozzolanic nano-particles in the concrete matrix. By using pozzolanic nano-particles, the development of the strength bearing crystals of cement paste can be increased or controlled. [2] Typically nano means 10^{-9}. So, a nanometer is one billionth of a meter and is the unit of length that is generally most appropriate for describing the size of single molecule. Nanometer objects are too small to be seen with naked eye. Anyhow the rough definition of Nanoscience could be anything which has at least one dimension less than 100 nanometer.[3]

EXPERMENTAL WORK

A.Materials

A.1. Cement

The ordinary Portland cement (OPC) manufactured in Iraq with trade mark of (Al-mass) . The oxide composition of ordinary Portland cement is shown in Table (1)

A.2 . Fine Aggregate

Normal sand has been used from (Al-soddor source). The specific gravity, bulk density ,absorption, and the percentage of sulfate content of the fine aggregate are listed in Table (2).The grading of fine aggregate was as show in Table (3).It was conformed to Iraq specification No.(45)-1984 [4] and gradation lies in zone (3) .

A.3. Coarse Aggregate

A crashed coarse aggregate brought from (Al-soddor source),was used throughout this work and its max size was (10 mm) ,the grading of crashed coarse aggregate was as shown in Table (4) .It was conformed to the Iraq specification No.(45)-1984 [4] .The specific gravity , bulk density ,absorption, and the percentage of sulfat content of the crashed coarse aggregate are listed in Table (5).

A.4. High Range Water Reducing Superplasticiser

SP 703 'S type A according to ASTM C494-2004 [5] was used as a high range water reducing admixture throughout this work .Table (6) ,illustrates it's properties according to the supplying company .It was recommended by supplier to use (0.75-2) L of SP 703 'S for each 100 kg of cementitious material

A.5. Nano Metakaolin(NMK)

Nano metakaolin was brought from (Senaa desert-Egypt) with the help of Middle East Mining Investments Company MEMCO. According to previous investigation [6] NMK was calcinations for reactivation clay . The calcinations temperature and the time of calcinations at that temperature adopted in this study were 750 Ċ and 2 hr. respectively. The materials used in this study were nano-clay of Blaine surface area ≈ 480000 cm2/g and of average dimensions of 200*100*20 nm. Table (7) gives the grading of NMK ,and Table (8) gives the chemical composition of NMK . Figure (1) shows the X-Ray dealing of NMK .

B.CONCRETE PREPERTION

Only one grade of concrete C45 is used in this investigation .This type was prepared using W/c ratio of 0.53 .The concrete was prepared using ordinary Portland cement with a partial replaced by NMK . the ingredients were homogenized on mixer to assure complete homogeneity and then adding water. The molds used in this study were cubes at (100 mm) size and cylinders (150 * 300 mm). The concrete casted in to layers and vibrated for one minute for each layer. The samples were kept wet in molds, and then cured in water until testing age . Table(9) gives the details of all mixes used in this study.

C.TESTING

C .1 .COMPRESSIVE STRENGTH TEST

The compressive strength test was carried out using cubes (100mm) according to BS 1881:part 116-2004 [7]. The cubes tested by using (ELE) machine ,with capacity (2000 kN) at loading rate of (3 MPa/second) ,the average of three cubes were recorded . This test was conducted at (7,28,60,& 90) days of age .

C.2.SPLITTING TENSILE STRENGTH TEST

The splitting tensile strength test was carried out according to ASTM C496-2004 [8] ,using ELE machine at rate load (2.1MPa/second). A cylindrical specimens of dimensions

(150*300 mm) were used for this test .The average of three cylinders was recorded .This test is conducted at (7,28.60,& 90)days. Equation (3-1) has been used for calculating splitting tensile strength .

$Fsp=2P/\pi DL$ …….(3-1)

Where:

Fsp= splitting tensile strength(MPa)

P= maximum applied load(N)

D= diameter of the specimen(mm)

L= length of the specimen(mm)

C.3. TOTAL WATER ABSORPTION TEST

The absorption test was carried out according to ASTM C642-2004 [9] .A 100 mm cubic specimen used throughout this test .Equation (3-2) used for calculating absorption.

Absorption% =((Ba-Aa)/Aa)*100…....(3-2)

Where:

Aa=oven dry weight (gm)

Ba=saturated surface dry weight (gm)

This test was conducted at 28 day

RESULTS AND DISCUTION

1.Compressive Strength

In Fig. (2), it can be seen that ,pozzolanic materials (NMK) when used as cement replacement materials in concrete. The increase percentage are (67.3 ,42.2 ,26.3 & 11.29%) for ages (7 ,28 ,60 & 90) days respectively when using 3% NMK. While when using 5% NMK this increase are (75.5 ,55.8 , 26.1,& 23.0 %) for ages (7 ,28 ,60 & 90) days respectively . Finally the increase are (86.6 ,63.1 ,35.5 ,&23.0 %) when using 10% NMK for ages (7 ,28 ,60 & 90) days respectively . That improves in the compressive strength of concrete due to the more consumption of $Ca(OH)_2$, better pore refinement, micro filling action, early gain of strength, higher pozzolanic reaction. It also helps in reducing the consumption of cement. This leads to the saving of natural resources and reduction in the emission of green house gases like CO_2.

2.Splitting Tensile Strength

Figs.(3) shows the tensile strength results of all mixes containing different NMK ratios. It is observed that the tensile strength of NMK concrete increases as the NMK ratio increases . There is no increase for all ages when using 3% NMK. While when using 5% NMK this increase are (10.3 ,25 , 10.2 & 4.6 %) for ages (7 ,28 ,60 & 90) days respectively.

Finally the increase are (17.2 ,34.3 ,20.5 ,&16.2%) when using 10% NMK for ages (7 ,28 ,60 & 90) days respectively . The most effective way of improving the interfacial transition zone (ITZ) is by the addition of chemical and mineral admixtures[10]. Basically, NMK enhances the tensile strength of hardened cement concrete by two mechanisms. The first mechanism is the packing effect of NMK as filler into interstitial spaces inside the skeleton of hardened microstructure of cement concrete and thus increasing its density as well as the strength. The second mechanism is the pozzolanic effect. The thermal treatment of nano-kaolin produces anhydrous alumino-silicate (Al_2SiO_5) which is mainly amorphous material and behaves as a highly reactive artificial pozzolan. The reaction of alumino-silicate elements in NMK with the lime elements of calcium oxide and hydroxide in cement leads to the addition of bond strength and solid volume

3. Total Water Absorption

Fig(4) shows that improvement of water absorption in concrete when using (3 %, 5%, &10%) NMK as replacement material ,and the increase percentage are (16.6, 21.79 ,&25.6%) when using (3, 5, & 10%) NMK respectively.

CONCLUSIONS

Based on the experimental studies presented in this paper, the following conclusions can be drawn:

- The compressive and tensile strength of concrete with NMK is higher than that of the reference concrete with the same w/b ratio.
- The enhancement of compressive strength was (42.2, 55.8, & 63.1%) at 28 days for (3, 5, &10%) replacement of NMK respectively
- The enhancement of splitting tensile strength was (0, 36, &46.8%) at 28 days when using (3, 5, &10%) NMK respectively.
- The improvement in the water absorption was (16.6%, 21.79%, &25.6) when using (3, 5, &10%)NMK

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Table (1): Chemical oxide analysis, for type I cement.

Oxide	% by weight	Limit of Iraq specification No.(5) _ 1984
CaO	61.52	__
SiO2	21.8	__
Al2O3	6.5	—
Fe2O3	2.2	__
MgO	1.403	<5
SO3	2.5	< 2.8
Na2O	0.28	__
K2O	0.51	__
Insoluble Residue I.R	0.544	<1.5
Loss on ignition L.O.I	2.4	<4.0
Main Compounds		
C3S	42.527	__
C2S	30.505	__
C3A	13.507	__
C4AF	6.688	__

Table (2): Some properties of fine aggregate used throughout this Work.

Physical properties	Test results	Limits of Iraqi specification No. 45/1984
Specific gravity	2.65	-
Sulfate content	0.11%	≤0.5%
Absorption	2.2%	-
Density	1650 m3	-

*The test is carried out at SIEI of Minster of Manufacture and Mining

Table (3): Grading of fine aggregate used in this work.

Sieve size (mm)	% Passing Sand	Limits of Iraqi specification No. 45/1984
9.5	100	100
4.75	92.0	90-100
2.36	82.8	85-100
1.18	76.1	75-100
0.6	63.4	60-79
0.3	35.9	12-40
0.15	9.8	0-10
Clay Material%	4.6%	5%
Organic Material%	0.69%	3%

*The test is carried out at Consulting Engineering Bureau-College of Engineering –University of Baghdad

Table (4): The grading of coarse aggregate.

Sieve size (mm)	% passing	Limit of Iraq specification No.(45) _ 1984
12.5	100	100
10	86	85-100
4.75	8	0-25
2.36	0	0-5

* The test is carried out at College of Engineering –University of Diayala

Table (5): Some properties of coarse aggregate used throughout this Work.

Physical properties	Test results	Limits of Iraqi specification No. 45/1984
Specific gravity	2.68	-
Sulfate content	0.05%	≤0.1%
Absorption	0.6%	-
Bulk Density (kg/m3)	1565	-

Table (6): Properties of chemicals admixture.

Appearance	Dark brown /black liquid
Specific gravity	1.235@25±2Ċ
Chloride content	Nil
Flash point	N/A

*According to Manufacturer.

Table (7): Grading of NMK fraction %.

Sieve size (μm)	Passing %
<10μm	100
<4μ	93
<2μm	88

Table (8): Chemical properties of NMK.

Chemical content	%
SiO2	45.5
Al2O3	37
Fe2O3	0.2
TiO2	1.5
CaO	0.01
MgO	0.02
Na2O	0.03
K2O	0.07
L.O.I	12.5

*chemical & grading tests are made by Middle East Mining Investments company MEMCO

Table (9): Constituents Of Concrete.

Designation	Cementitious material content (kg/m3)			Aggregate (kg/m3)		Water (kg/m3)	High Range Water Reducing Admixture (HRWRA) (L/100kg cement)	w/c ratio to give slump 80±10%
	Cement	MK	NMK	Sand	Coarse			
C45	418	-	-	735	1017	221.5	-	0.53
C45+10%MK	379.2	41.8	-	735	1017	221.5	3.13	0.53
C45+3%NMK	405.4	-	12.54	735	1017	221.5	-	0.53
C45+5%NMK	397.1	-	20.9	735	1017	221.5	3.45	0.53
C45+10%NMK	379.2	-	41.8	735	1017	221.5	3.45	0.53

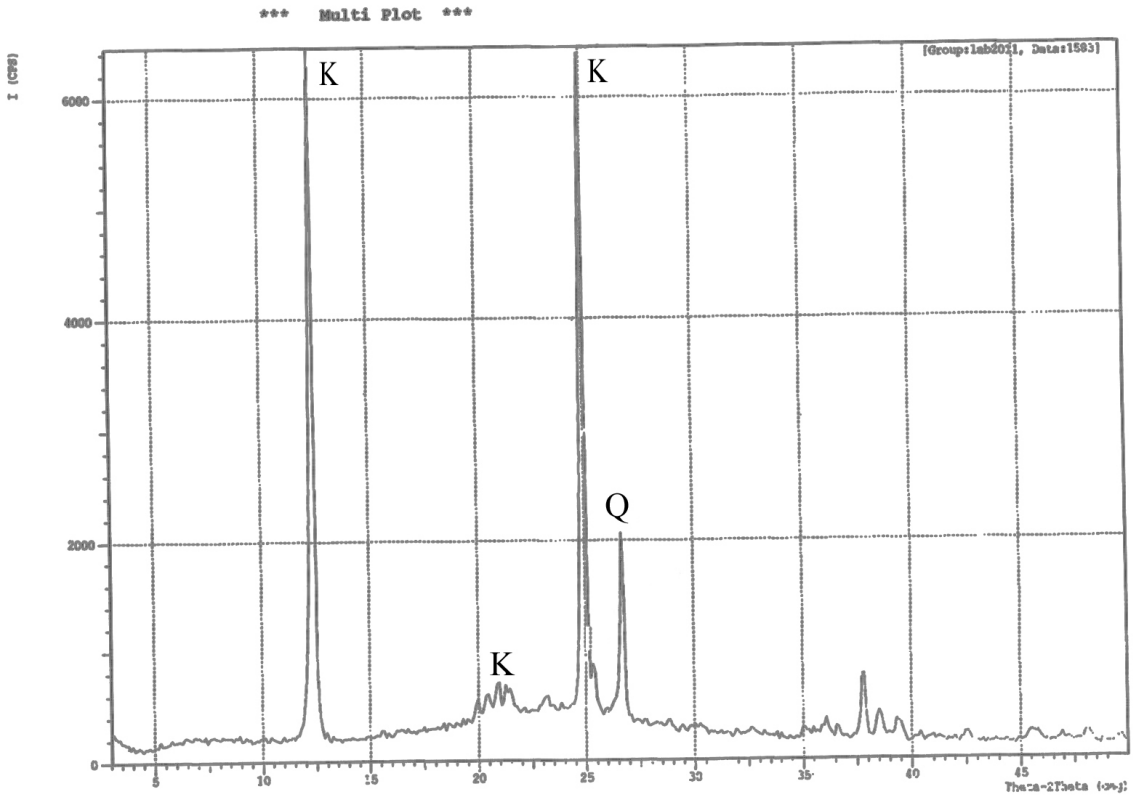

Fig (1): X-Ray Diffraction Analysis of Activation NMK.

*The test is carried out at S.C of Geological Survey and Mining.

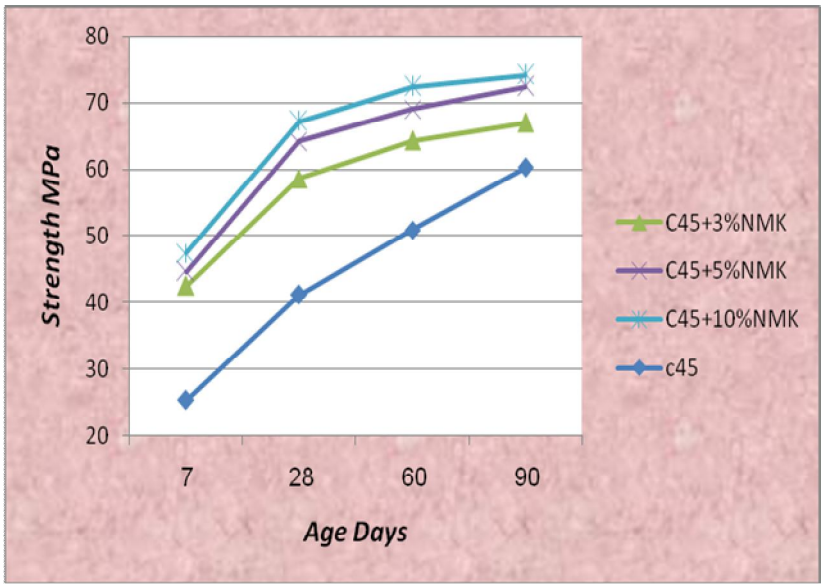

Fig. (2): Compressive strength development for C45 mixes.

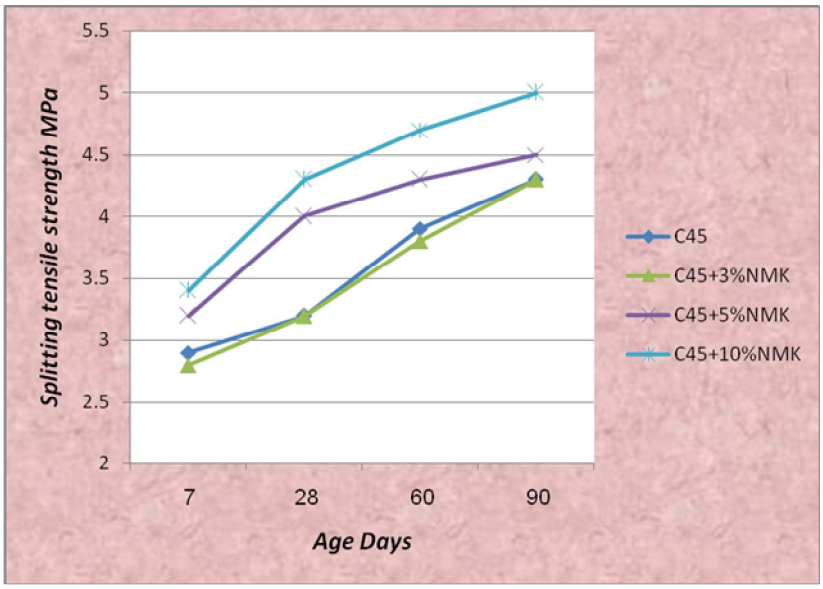

Fig.(3): Splitting tensile strength (ft) development for C45 mixes.

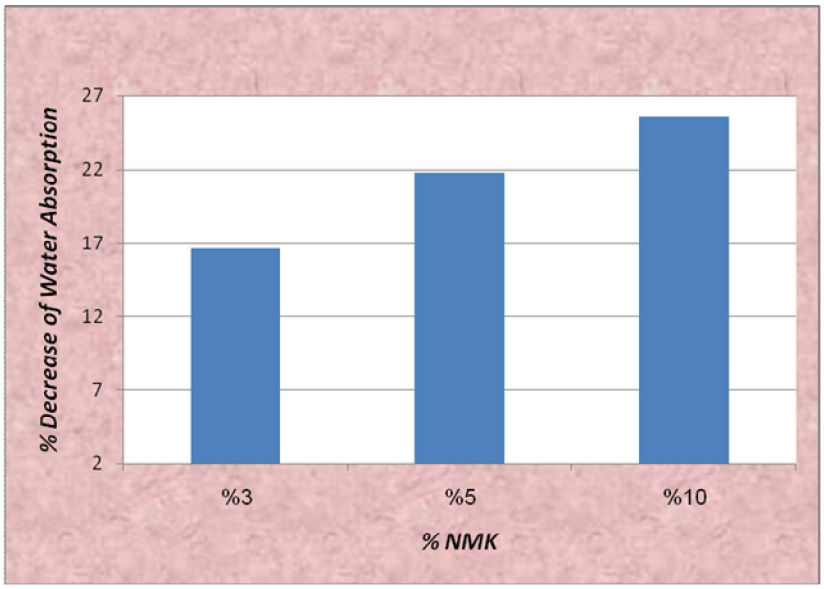

Fig. (4-19): The effect of pozzolanic material on the water absorption for concrete at 28 days age.

تأثير المواد البوزولانية النانوية على بعض خواص الخرسانية

د. شاكر المشهداني	د.عامر محمد إبراهيم	زينب هاتف ناجي
أستاذ	أستاذ	مدرس مساعد
الجامعة التكنولوجية	كلية الهندسة_جامعة ديالى	كلية الهندسة_جامعة ديالى

الخلاصة

هذا البحث يهدف الى دراسة تأثير مادة النانو ميتاكائولين على بعض خواص الخرسانة (مقاومة الانضغاط، مقاومة الشد الانفلاقي، وامتصاص الماء) تم تهيئة مادة النانو ميتاكائولين بواسطة التفعيل الحراري لاطيان الكاؤولين لمدة ساعتين و عند درجة حرارة ٧٥٠ درجة مئوية .الاسمنت المستخدم بهذه الدراسة هو اسمنت بورتلاندي اعتيادي .تم استبدال الاسمنت جزئيا بمادة ثانوية هي الميتاكاؤولين بنسب (٣%،٥%،و١٠%) من وزن الاسمنت .الخرسانة المستخدمة بهذا البحث كانت ذات مقاومة انضغاط C45 ونسبة W/C المستخدمة =0.53 .تم فحص امتصاص الماء عند عمر ٢٨ يوم اما بقية الفحوصات فيتم فحصها بالاعمار (٦٠,٢٨,٧،و٩٠) يوم .اظهرت النتائج زيادة في لمقاومة الانضغاط للخرسانة الحاوية النانو ميتاكاؤولين مقارنة مع الخلطة المرجعية عند نفس نسبة الاسمنت بمقدار (٤٢.٢، ٥٥.٨،و ٦٣.١%) عند استخدام مادة النانو الميتاكاؤولين بنسب استبدال (٣%،٥%و١٠ %) على التوالي بينما كانت نسبة التحسين لمقاومة الشد الانفلاقي هي (٣٦،٠%، و٤٦.٨%) عند استخدام نسب استبدال لمادة النانو الميتاكاؤولين (٣%،٥%، و١٠%) على التوالي .نسبة التحسين الحاصل في فحص امتصاص الماء (١٦.٦%،٢١.٧٩%، و٢٥.٦%) عند استخدام (٣%، ٥%، و١٠%) نانو ميتاكاؤولين على التوالي.

كلمات الدالة: الخرسانة، الميتاكاؤولين متناهي الصغر ، امتصاص الماء، مقاومة الانضغاط، مقامة الشد الانفلاقي.