Study of Adding Cement to Hardened Powdered Novolac Resin Matrix for Manufacturing Novel Concrete in the Presence of Heat and Pressure

Amer M. Ibrahim[1], Tahseen H. Mubarak[2], Al katawy A. Adwan[3] and Wissam A. Hussian[4]

[1]Department of Building and Construction Engineering-College of Engineering- University of Diyala- Diyala- Iraq

[2,4]Department of Physics- College of Science- University of Diyala- Iraq

[3]Department of Materials Engineering- College of Engineering-University of Diyala- Iraq

[2]dean@sciences.uodiyala.edu.iq

[4]wesam77117@yahoo.com

Received: 22 December 2016 **Accepted: 28 February 2017**

Abstract

In this study, a new concrete has been manufactured by mixing powdered hardened novolac resin with cement in equal proportions and in the presence of heat (150-200) ^{0}C and pressure (100 kN) as catalysts. The results of laboratory tests showed that the new concrete have a compressive strength of (92 MPa) and a density of (1761.1 kg/m^3) while the compressive strength of the normal concrete at the age (28) days (25 MPa) and the density was (2368 kg/m^3). It can be seen from the images taken by the scanning electron microscopy that there is a correlation between concrete components (hardened powdered novolac resin with cement) in the presence of heat and pressure as catalysts (Bakelite concrete).

Key words: New concrete, Hardened powdered novolac resin, Cement, Heat, Pressure

DIYALA JOURNAL FOR PURE SCIENCES

Study of Adding Cement to Hardened Powdered Novolac Resin Matrix for Manufacturing Novel Concrete in the Presence of Heat and Pressure

Amer M. Ibrahim, Tahseen H. Mubarak, Al katawy A. Adwan and Wissam A. Hussian

دراسة إضافة السمنت الى مصفوفة مسحوق راتنج النوفولاك المصلد لصناعة خرسانة مبتكرة بوجود عاملي الحرارة والضغط

عامر محمد إبراهيم[1] ، تحسين حسين مبارك [2] ، علي عدوان حمود[3] و وسام عبد الكريم حسين [4]

[1]جامعة ديالى – كلية الهندسة – قسم البناء و الانشاءات الهندسية
[2,4] جامعة ديالى- كلية العلوم– قسم الفيزياء
[3]جامعة ديالى- كلية الهندسة– قسم هندسة المواد

الخلاصة

تم في هذا البحث صناعة خرسانة متكونة من (سمنت ومطحون راتنج النوفولاك المصلد بنسب متساوية مع وجود حرارة تتراوح من (150- 200) درجة مئوية وضغط (100 كيلو نيوتن) كعوامل مساعدة. أظهرت النتائج المختبرية ان قوة الانضغاط للخرسانة الجديدة قد بلغت (92 ميكا باسكال) اما الكثافة فقد بلغت (1761.1 كيلوغرام\م^3) ، بالمقارنة مع الخرسانة الاعتيادية عند عمر (28) يوم والتي كانت قوتها الانضغاطية (25 ميكا باسكال) وذات كثافة بلغت (2368 كغم\م^3) . ومن خلال صور المجهر الالكتروني الماسح (SEM) نلاحظ ترابط بين راتنج النوفولاك المصلد مع السمنت مما يعطي قوة انضغاط ممتازة.

الكلمات المفتاحية : مسحوق راتنج النوفولاك المصلد، سمنت ، حرارة وضغط كعوامل مساعدة

Introduction

Composite materials are quite common today and are used in nearly every segment of civilian and military industries. The idea of reinforcement is not new. Over the centuries natural fibers, such as grass or animal hair, have been used to improve the strength and to lessen shrinking of pottery prior to firing and increase the strength in mud houses. This idea in the present form has been exploited with the development of glass, carbon and later of aramid fibers [1].

The major advantages of composite materials are low density, high specific strength and stiffness, good corrosion resistance improved fatigue properties, and low cost. Because of these properties, they have successfully replaced many conventional metals, polymeric composite materials, for example, can solve some of the problems resulting from the deficiencies of conventional steel-reinforced-concrete materials, and other polymeric materials in load-bearing structures in aircraft, automobiles, ships, pipelines, storage tanks, etc [2,3,4]. Phenol formaldehyde (PF) resins are a large group of oligomers and polymers, which consists of various structures as resulting products from the reaction of phenol and formaldehyde. When the phenolic resins first introduction in the 1900s, they were primarily used in molding parts, insulating vanishes, industrial sheeting and coating. Later, phenolic resin were utilized as wood adhesives wood and fiber bonding to make composite. Despite the innovation of new type of thermosetting resins and other high-performance polymeric materials, phenolic resin still retains its important application in these areas and further to high-technological development especially in electronics and aerospace. This is due to the highly stable nature of phenolic resins with ultimate mechanical strength acquired during the curing process. Besides, they are inherently resisted against heat, flame and chemicals, which brings the application of PF resins to aerospace and transportation industry as thermo-structural materials [5]. Phenolic resins are synthesized from the petroleum-based phenol or substituted phenol with formaldehyde under either alkaline or acidic condition, which are known as resol and novolac PF resins, respectively [6]. The novolac resins are produced under acidic condition with formaldehyde to phenol ratio of less than one. The first step in the novolac resin synthesis is conversion of formaldehyde (methylene glycol) in to hydrated carbonium ion under the effect of acid catalyst. The hydrated carbonyl compound then attacks the phenol molecule on its para- and or ortho- position to from the corresponding para- or ortho- benzylic ions with hydroxymethyl groups through dehydration reaction [7].

Since hydroxymethly group on the benzylic ions are unstable in acidic condition, these hydrated benzylic ions further react with additional phenol and add to the free para- and ortho- sites on the phenol molecule by creating a methylene bridge between two phenolic aromatic rings [7].

Since reaction can happen at any of the three positions on each phenolic aromatic ring, the resulting novolac polymer acquires a complex structure with different polymer sizes and a molecular weight of up to (5000 g/mol). The reaction terminates as all the formaldehyde are consumed leaving with approximately (10%) of excess phenol, which can be remove along with water during the further distillation of the resin [8].The objective of the present study was to manufacture a novel concrete by mixing powdered hardened novolac resin with cement in equal portions in the presence of heat (150- 200) ^{0}C and pressure (100 kN) as catalysts.

Materials and Methods

The ordinary Portland cement (type1) manufactured in Iraq by Al-Mass cement refractory was used throughout this study. It has been stored in sealed plastic bags to inhibit susceptibility to weather conditions and the test result showed that the manufacture of cement follows the criteria of Iraq specification No. (5)-1984 [9]. The crushed hardened novolac resin aggregate was used as a powder and the required quantity of hardened novolac resin manufactured from novolac resin with hexamethylenetetramine (put 120gm from hexamethylenetetramine per kilogram from novolac resin).

1- Heat with pressure

The mold making (cubic) dimensions (100*100*100) mm^3 with link hitter on the mold and linked the copper wire in order to get a temperature ranging from (150 – 200) ^{0}C take in to consider put selephon thermal on the mold to keep heat mold and use pressure of (100 kN) as the shown in Fig(1).

Fig. (1). Mold image in the presence of heat and pressure catalysts.

2- Compressive strength

The compressive strength test was onducted on a concrete cubes according to the **BS 1881:part 116-1989** [10] by using (2000kN) capacity. Digital Electrical testing machine. The loading rate used in the test was (0.3 MPa/sec) as shown in Fig (2). The test was conducted after (2 and 28) days and the average of three tests was considered.

Fig. (2) Compressive strength measurement device.

Results and Discussion

The compressive strength test was conducted for (100*100*100) mm^3 cubes to measure the compressive strength for each mix after (2 and 28) days. The strength values, which were obtained as the average of three cubes for each test, are shown in Table (1).

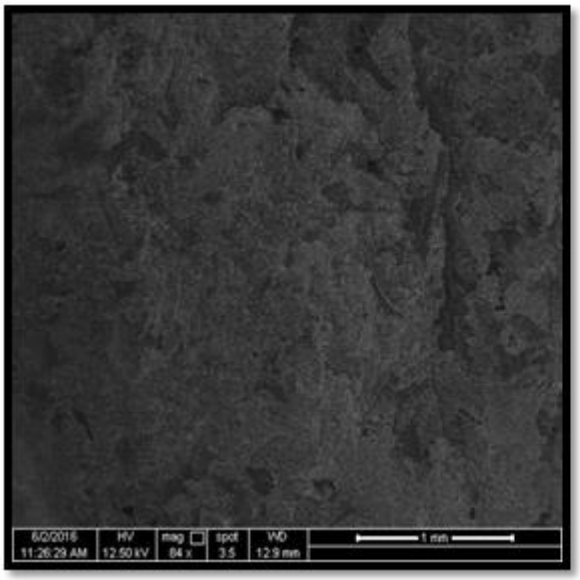
Table (1) The compressive strength and densities of the new and normal concretes at the age of (2 and 28) days.

Set No	Mixture details	Compressive strength at 2_____days (MPa)	Compressive strength at 28_____days(MPa)	Density (kg/m^3)
1	New concrete (hardened powdered novolac resin, cement and heat with pressure as catalysts)	92	---	1761.1
2	normal concrete	---	25	2368

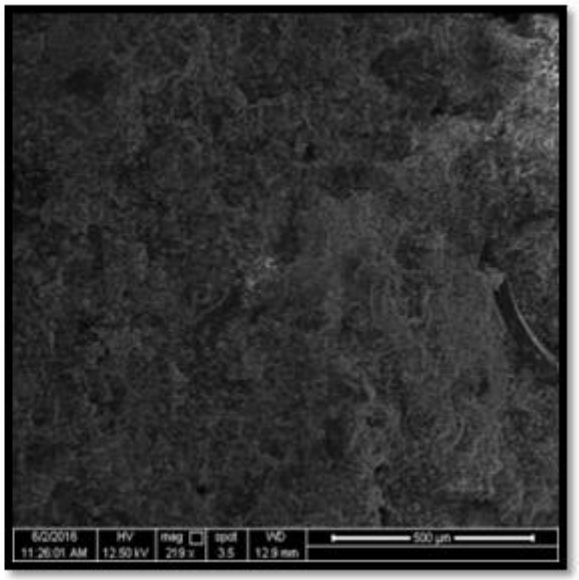
The compressive strength value of the new concrete which has been manufactured by mixing the hardened powdered novolac resin, cement and heat with pressure as catalysts was (92 MPa) while the density was(1761.1 kg/m^3) which give an indication that the cement is filling the gaps that occur during physical interaction of crushed hardened powdered novolac resin and this gives excellent compressive strength.Analysis by scanning electron microscope (SEM) after mixing the cement with hardened powder novolac resin to produce the new concrete [Bakelite concrete] at a temperature ranging between (150-200) ^0C showed that physical reaction occurs during physical interaction and the iterance of cement in the gaps that get in the hardened powdered novolac resin because the very small atoms of cement, making it easier for the atoms to overlap in the cement to bridge the gaps that get in the hardened during interaction which can be considered as a substitute for sawdust (feller), but after the addition of cement the new concrete gets compressive strength of (92MPa) and addition to that stay within the lightweight concrete specifications as shown in Figure (3).

Study of Adding Cement to Hardened Powdered Novolac Resin Matrix for Manufacturing Novel Concrete in the Presence of Heat and Pressure

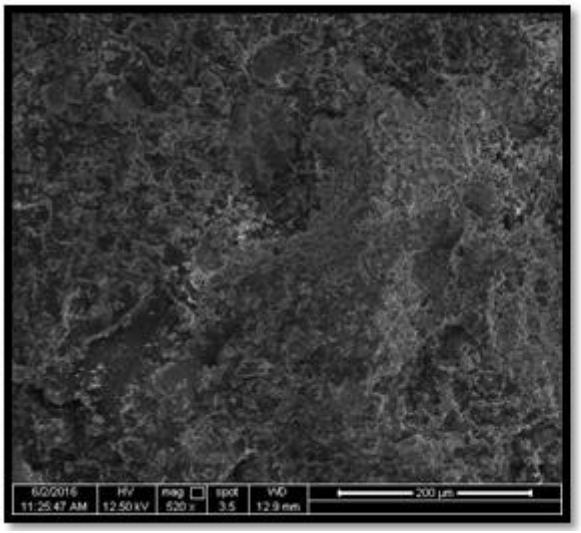
Amer M. Ibrahim, Tahseen H. Mubarak, Al katawy A. Adwan and Wissam A. Hussian



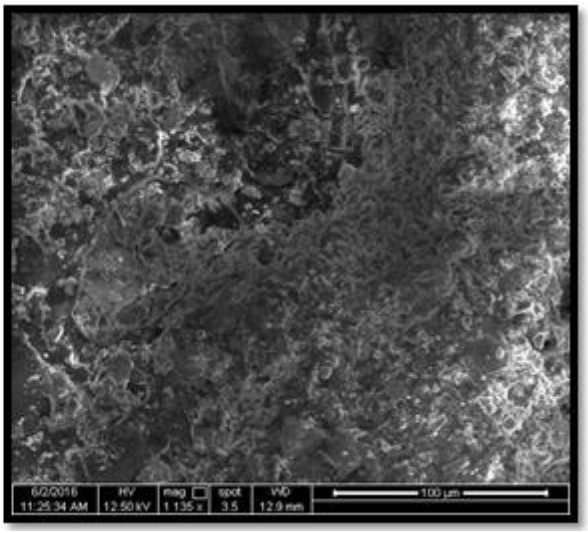
a.(1mm X magnification)



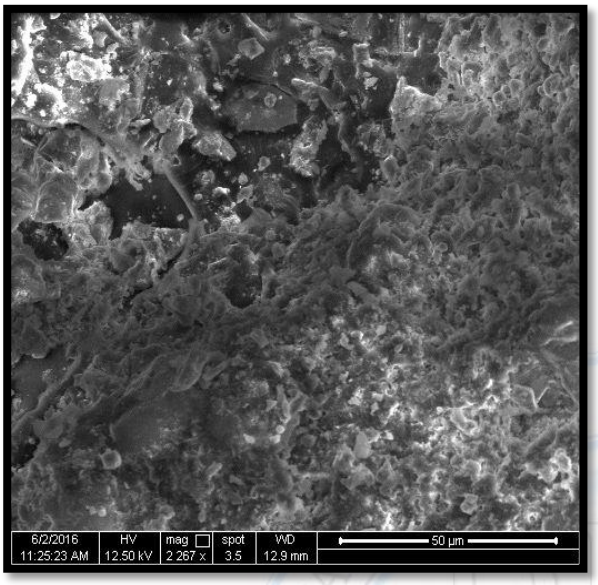
b. (500 µm X magnification)



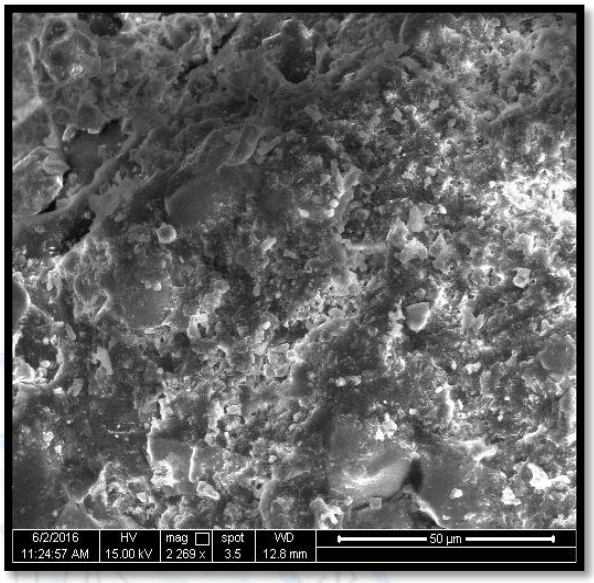
c.(200 µm X magnification)



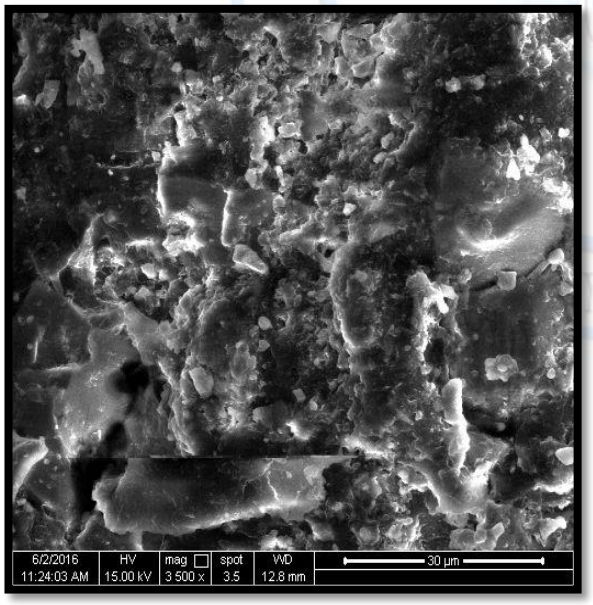
d.(100 µm X magnification)



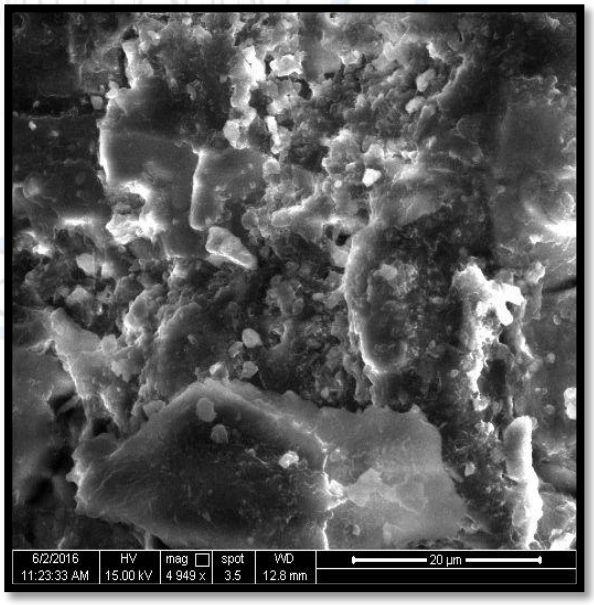
e.(50 µm X magnification)



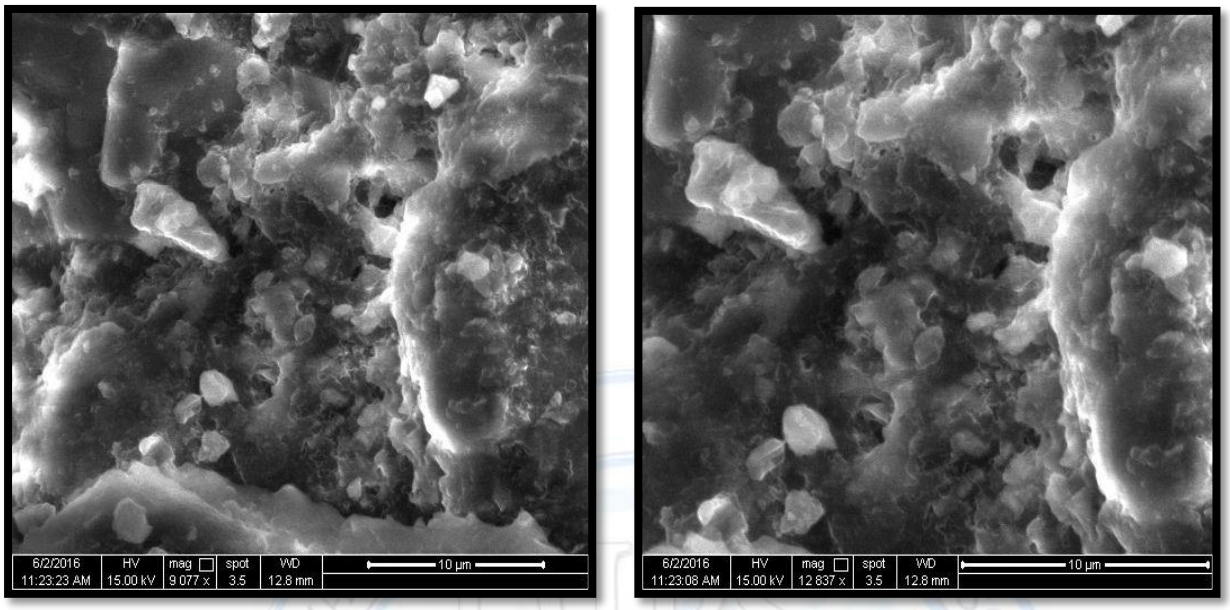
f.(50 µm X magnification)



g.(30 µm X magnification)



h.(30 µm X magnification)



i.(10 µm X magnification) j.(10 µm X magnification)

Fig.(3) SEM images of the new concrete which has been manufactured from hardened crushed novolac resin and cement in the presence heat and pressure as catalysts. [Bakelite concrete].

Conclusions

1- The compressive strength is higher than normal concrete.

2- Low density compared to normal concrete.

3- Through SEM images note correlation existence between crushed novolac resin hardened and cement this leading to an increase in the compressive strength.

References

1. Asbty A. and D.Jones, ”Engineering Material, An Introduction to Microstructure Processing and Design”, Pergaman Press, England, 1986
2. د. ذنون محمد عزيز بيريادي، "كيمياء اللواصق والأصباغ والأطلية البوليميرية"، مطبعة دار الحكمة، كلية العلوم جامعة بغداد، 1990.
3. Gaylord W.”Reinforced Plastics Theory and Practice”, Cahners Publishing Co.Inc.USA. 1974
4. Hull D. ”An Introduction to composites materials”, Cambrige University Press, U.K. 1981
5. Raquez J., Deleglise M. and Lacrampe M. “Thermosetting (bio) materials derived from renewable resources: A critical reviews,” progress in polymer sicience, vol. 35, no.4, gan, pp.487- 509, 2010
6. Conner A. “ wood: Adhesives,” Encyclopedia of materials: Science and Technology. Amsterdam; New York : Elsevier Science, Ltd, pp. 9538-9599, 2001
7. Kopf P. “Phenolic Resins”, Encyclopedia of materials: Science and technology. Vol.7, pp. 322-367, July 2002
8. Phenolic Novolac And Resol Resins, Plenco [online]. Avalible: http://www.plenco.com/phenolic-novolac-resol-resins.htm [Accessed:17 Oct.
9. المواصفة القياسية العراقية رقم (5) " الاسمنت البورتلاندي" ، الجهاز المركزي للتقيس والسيطرة النوعية لسنة 1984.
10. B.S.1881, Part 116, “Method for Determination of Compressive Strength of Concrete Cubes”. British Standard Institution, PP.3. 1989