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Effect of Biopolymer Alginate on some properties of concrete

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ABSTRACT

Alginate from Large brown seaweeds act as natural polymer has been investigated as polymer and has been added to concrete in different percentages (0% , 0.5% , 1% and 1.5%) by the cement weight and the study show the effect of using alginate biopolymer admixtures on some of the fresh properties of the concrete (slump & the density fresh) also in the hardened state (Compressive strength , Splitting tensile strength and Flexural strength) at 28 days. The mix proportion was (1:2.26:2.26) (cement: sand: gravel) respectively and at constant w/c equal to 0.47. The results indicate that the use of alginate as a percent of the cement weight possess a positive effect on fresh properties of concrete at 28 days. In other words, increasing the percentages of alginate addition has enhanced the slump and fresh density of concrete at 28 days, so the 1.5% alginate addition as percent of the cement weight showed the higher percentage of increasing where it was 2.5% for fresh density and 41%for slump of concrete at 28days compared with the reference mix without any addition, also the hardened properties (compression ,splitting tensile and flexural strength) at 28 days showed an increasing when using alginate at a percentage from the cement weight, so the highest increase was at 0.5% and 1.5% of alginate addition where it was about 40%.

Keywords: concrete, alginate, strength, biopolymer.

تأثير البايوبوليمر الجينات على بعض خواص الخرسانة

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الخلاصة

الالجينات من أعشاب بحرية بنية كبيرة تم دراستها كبوليمر طبيعي وأضيفت إلى الخرسانة بنسب مئوية مختلفة (0,0.5,1,1.5 من وزن الأسمنت وأظهرت الدراسة تأثير استخدام البوليمر الحيوي الالجينات كمواد مضافة على بعض خواص الخرسانة الطرية (الهطول والكثافة الطرية) وعلى خواص الخرسانة المتصلبة (مقاومة الانضغاط، مقاومة الشد ومقاومة الانثناء) في 28 يومًا.

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كانت نسبة الخلط (1: 2.26: 2.26) (الأسمنت: الرمل: الحصى) على التوالي بنسبة ماءِ \ سمنت ثابتة مساوية الى 0.47. اظهرت النتائج إلى أن استخدام الالجينات كنسبة مئوية من وزن الأسمنت له تأثير إيجابي على بعض الخواص الخرسانة الطرية. بمعنى آخر ، فإن زيادة النسب المئوية لإضافات الالجينات قد حسنت الهطول والكثافة الطرية للخرسانة في 28 يومًا ،حيث ان اضافة الالجينات بنسبة 1.5٪ كنسبة مئوية من وزن الأسمنت أظهرت اعلى نسبة زيادة حيث كانت 2.5٪ للكثافة الطرية و 41٪ للهطول في 28 يومًا مقارنة بالخلطة المرجعية دون أي إضافة ، كذلك أظهرت الخواص المتصلبة للخرسانة (الانضغاط وقوة الشد والانثناء) في 28 يومًا زيادة عند استخدام الالجينات كنسبة مئوية من وزن الأسمنت ، حيث انه اعلى نسبة للزيادة كانت حوالي 40 ٪ عند 0.5 ٪ و 1.5 ٪ من إضافة الالجينات.
الكلمات الرئيسية: الخرسانة,الالجينات,المقاومة,بايوبوليمر.

1. INTRODUCTION

Biopolymer has been defined as polymer that developed from living being. Polymers became an essential part in our daily life. They have tremendous advantages have been used in every field. Furthermore these polymer products form about 150 million ton of non-bio degradable waste every year such waste leads to varies problems of pollution, soil erosion and others environmental problems . To overcome this, biopolymers have been found to replace the synthetic polymers as they are degradable by microbes after its purpose, thereby making the environment clean and safe. The construction industry has become a major field of use for biopolymers. Application of Biopolymers at constructions are broad prevalent and various . several situations, Biopolymers present diverse benefits in enactment and price above artificial polymers, whereas in else regions Biopolymers perhaps is the exclusive product existing that can offer specific properties for building materials. Biopolymers too stand the image of being environmentally further satisfactory than artificial polymers made in a chemical factory. **(Plank And Verbeek 2012)**

Alginate as a type of biopolymer has been investigated in this paper. It is supplied as a powder that is packed as either in bulk, tins or in pre weighed individual containers, dough kind of alginate is as well as existing. Dough form is usable in two viscosities, tray and syringe viscosities. The dough-kind material has a smaller gelation time than the powder-type material **(Murata, et al., 2004)**. The best surface quality can be obtained with the dough-kind material It has been recommended to distribute the powder by fluffing it by spreading out and tumbling the can, dipping the scoop, tapping the scoop gently with the spatula, and levelling the powder in the scoop with a spatula (**Madhavan And Abirami, 2015**)

2. Materials and methods

2.1 Materials

2.1.1 Cement: Ordinary Portland cement O.P.C (I) was used. The chemical and physical properties of the cement are given in the **Table 1.** And **2.** Respectively. Results of the test showed that the cement stratify to the Iraqi standard IQS 5/1984-Type I **(COSQC)** requirements.

Table 1. Properties of Portland cement used (Chemical Composition) *

Oxide	Percentage by weight	IQS 5 /1984– Type I **(COSQC)** Limits
SiO_2	21.2	——
CaO	61.2	——
Fe_2O_3	3.12	——
Al_2O_3	5.05	——
So_3	2.07	<2.8
MgO	2.06	<5
L.S.F	0.88	0.66-1.02
Loss on ignition L.O.I	3.21	<4
Insoluble residue I.R	1.32	<1.5

The main compounds		
C_3s	58.52	—
C_3A	8	—
C_4AF	9.4	—
C_2s	19	—

*all the tests were conducted at the (Central Organization for Standardization and Quality Control).

2.1.2 Aggregate:

- Fine Aggregate: Fine aggregate in this work was local natural sand it was according to the Iraqi specification requirements No.45/1984 **(COSQC)** zone2.Its physical properties and grading are given in the Table **2.** & **Table 3.** Respectively.

Table 2. Physical properties of fine aggregate*

Property	Fine aggregate
Specific gravity	2.67
Fineness modulus	3.12
Water absorption (%)	1.58
Sulfate content (%)	0.1
Bulk density (kg/m^3)	1605

* The tests were conducted at Industry and Minerals Ministry - Alkarama General Company

Table 3. Fine aggregate grading *

Sieve size (mm)	Percent of passing	IQS No.45 /1984 Limits zone2**(COSQC)**
9.5	100	100
4.75	97	100-90
2.36	88	95-60
1.18	59	70-30
600 µm	24	34-15
300 µm	13	20-5
150 µm	6	10-0

* This test was conducting at Industry and Minerals Ministry - Alkarama General Company

- Coarse Aggregate: Crushed gravel of 12.5 mm maximum size was used as coarse aggregate in this work, and it was tally to the Iraqi specification No.1945/1984**(COSQC)**. Physical properties & coarse aggregate grading were given in the **Table 4.** & **Table 5.** Respectively.

Table 4. Physical Properties of Coarse Aggregate*

Property	Coarse aggregate
Specific gravity	2.36
Bulk density (kg/m^3)	1685
Absorption of water (%)	0.62
Content of sulfate (%)	0.082

*The tests were conducted in the laboratory of concrete at civil engineering/ University of Technology.

Table 5. Coarse aggregate grading *

Size of sieve (mm)	Percent of passing	IQS No.45 /1984 Limits (5-20 mm)**(COSQC)**
20	100	100
14	100	90-100
10	60	50-85
5	5	0-10
2.36	0	0

*These tests were carried out in the laboratory of concrete at civil engineering/ University of Technology.

2.1.3Alginate: Normal setting alginate from Zhermack tropicalgin .Alginate is an irreversible hydrocolloid impression and an elastic material, has been the main of the most dental applications for many years. The common use of irreversible hydrocolloid faraway exceeds that of any impression material, the physical properties and the chemical composition shown in the **Table 6. And 7**. below*. Supplied as powder and added as percentage of cement weight (0.5%, 1% and 1.5%) mix with cement before added to mixer.

Table 6. Physical properties of alginate used.

Property	Test result
Density (kg/m^3)	1413
Setting	normal
color	orange

Table 7. Chemical composition of alginate*

Symbol	Element	Concentration ppm
Na	Sodium	<2100
Mg	Magnesium	<350
Al	Aluminum	<84
Si	Silicon	17600
P	Phosophorus	64
S	Sulfur	905.9
Cl	Chlorine	<2

* These tests were conducting at Industry and Minerals Ministry -Materials research directorate

2.1.4 Water: The pH value for the used water which was tap water ranged between (8-8.5). Was used for the mixing and curing of concrete mixes.

2.2 Experimental work

2.2.1 Mix proportions: For all mixes, Mix proportion was (1: 2.26:2.26) (371:839:839) (kg/m^3) (cement: sand: gravel) and w/c equal to .47, depending on American Concrete Institute method for mix design of concrete, **Table 8**. Below shows the details of mixes.

Table 8. Detail of mix designation.

Mix designation	% of alginate (by weight of cement)	Weight of alginate (kg)
Ref.	0.0	0.0
1	0.5	1.75
2	1	3.5
3	1.5	5.25

2.2.2 Preparation of concrete: According to **(ASTM C192),** materials used for this work prepared and weighed on a laboratory balance. Concrete specimens prepared were four types. Reference mix cast as the first set of concrete specimens and the other three were with (0.5%, 1% and 1.5%) adding of alginate by cement weight respectively.

2.2.3 Experimental Tests

- Slump test: The test of the slump was performed, as specified in the **(ASTM C143)**. Using constant w/c for all mixes equal to 0.47 and the mix proportion was 1:2.26:2.26.

- Test of the Fresh Density: Fresh density test was performed according to **(ASTM C 138M-01)**.

- Test of the Compression Strength: The concrete compressive strength was conducted, according to the **(BS 1881 Part 181)**. Average of compressive strength of the three specimens was calculated for each concrete mix. Using (100*100) mm three cubes for each test

- Splitting tensile strength test: Splitting tensile strength test was conducted, as stated by the **(ASTM C496 - 04)**. Using (100* 200) mm two cylinders for each test.

- Test of Flexural strength: Flexural strength test was performed, depending on the **(ASTM C 78 - 04)**, Using (100*100*400) mm prisms, the two point of applying load were in the side that was perpendicular to the cast face.

2.2.4 Results and discussions:

- Slump: The use of an alginate biopolymer as a percent of the cement weight in concrete can increase the slump of concrete at 28 days about(12.5%, 25%and 41%)for (0.5%. 1%and 1.5%) of alginate addition as a percent of the cement weight respectively compared to the reference mix without any addition, This is might be to the presence of the lingo sulfonates in the chemical composition of the bio polymer admixtures that present in the HRWR which achieve increasing the workability at the same water content. the results of slump test are shown in the **Table 9** and **Fig. 1** below.

Table 9. Results of slump .

Mix Designation	Slump (mm)
Rf	80
0.5% alginate	90
1% alginate	100
1.5% alginate	113

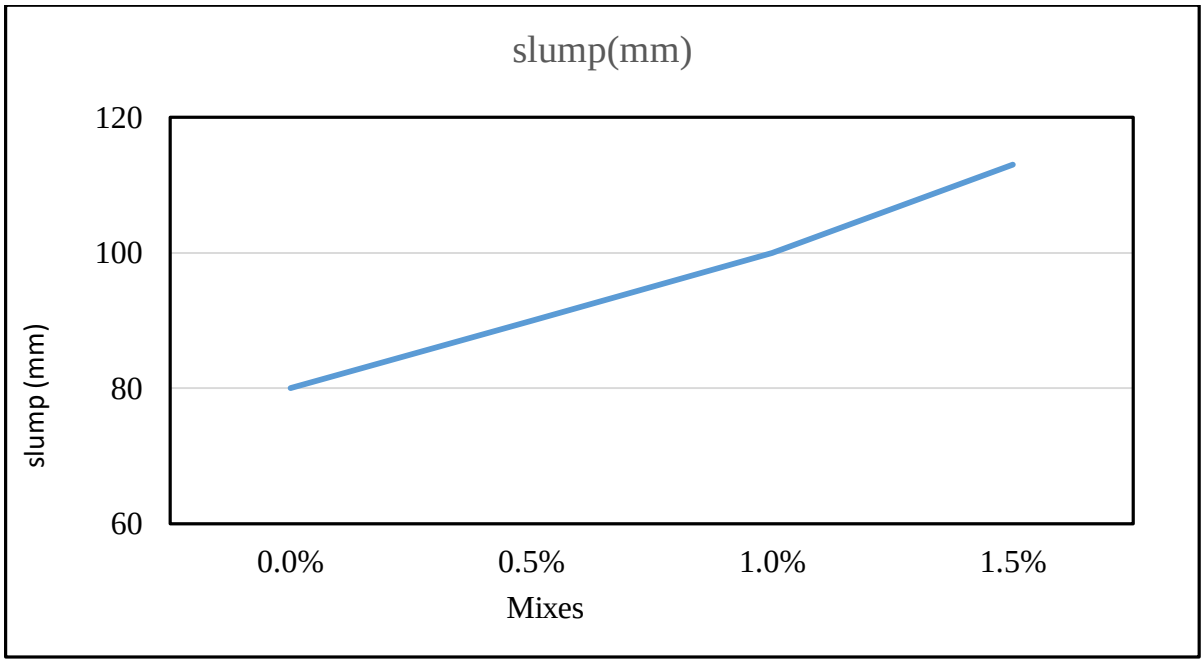

Figure 1. Slump of concrete at 28 days.

- Fresh density: It can observed from the **Table 10.** and **Fig. 2** that, the higher value for the fresh density of concrete was 2440 kg/m^3 at 1% of the alginate addition while the other percentages of additions gave same value for fresh density without large different from the reference mix, this can be explain by there is no a large different in density of the alginate and the density of cement used.

Table 10. Results of Fresh Density

Mix	Fresh Density (Kg/m^3)
Rf	2400
0.5%alginate	2415
1%alginate	2440
1.5%alginate	2390

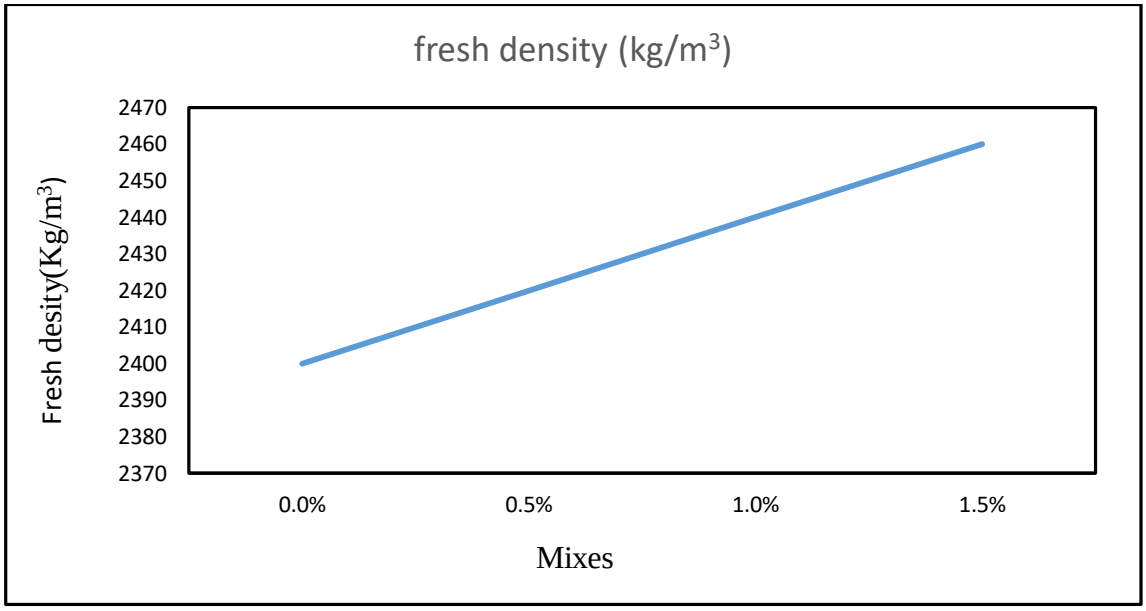

Figure 2. Fresh density of concrete at 28days.

- Compressive strength: **Table 11**. And **Fig. 3** showed a compressive strength results of the test. It has been shown that the addition of alginate biopolymer as a percent of the cement weight has made some improvement in compressive strength, especially at the 1% of the addition (11% increasing), other percentages showed a decrease about 12% approximately. Generally, the inclusion of the alginate biopolymer as a percent of the cement weight caused the compressive strength to decrease, it may be attributed to the reduction in adhesive strength between the surface of aggregate particles and the cement paste containing the alginate addition, the smooth surface of the alginate biopolymer may cause a weak bonding strength between the aggregate and the cement paste.

Table 11. The Compressive strength result.

Mix	Compressive strength (MPa)
Rf	37
0.5%alginate	30.6
1%alginate	37.4
1.5%alginate	30

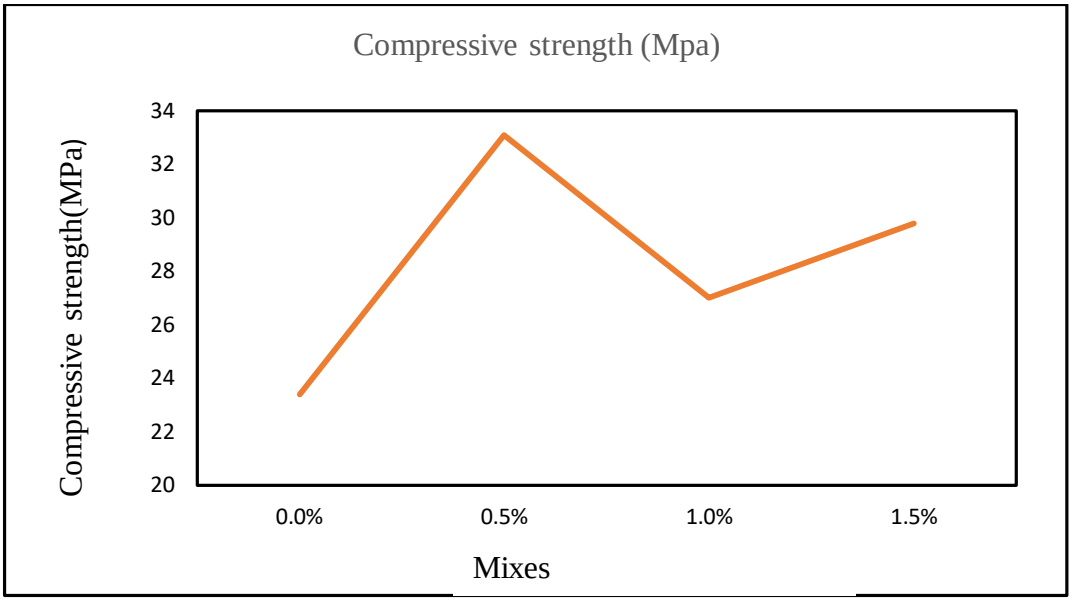

Figure 3. The compressive strength of concrete at (28 days).

- Splitting tensile strength: **Table 12** and **Fig.4** showed the results of splitting tensile strength. It has been shown that the using of alginate biopolymer as a percent of the cement weight caused the splitting tensile strength to decrease, especially at the 0.5% and 1.5% of the addition while at the 1% of the alginate addition the splitting tensile strength increase about 5.3%. This may be explained by the effect of these materials (starch and alginate) on compressive strength, The compressive and tensile strengths are closely related **(Mehta 2017)**

Table 12. Results of Splitting Tensile Strength.

Mix	Splitting tensile strength(MPa)
Rf	3.8
0.5%alginate	3.2
1%alginate	4
1.5%alginate	3

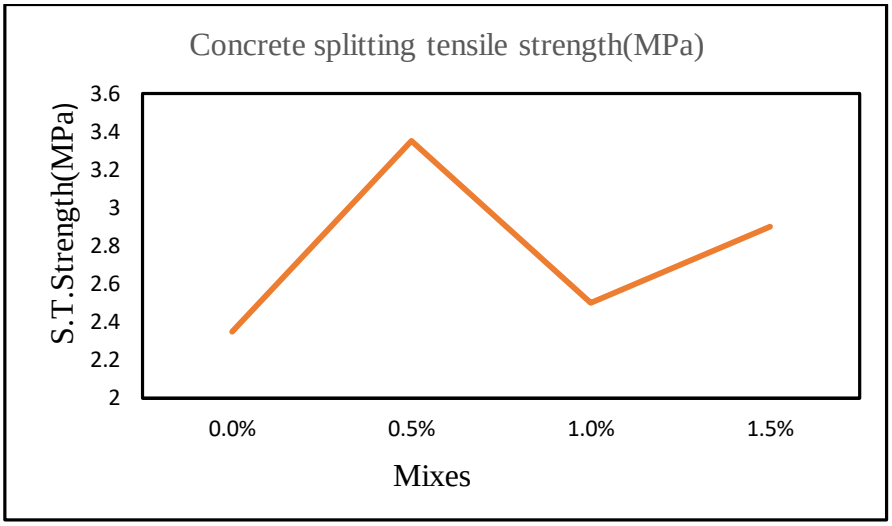

Figure 4. Splitting Tensile Strength of concrete at 28 days.

- Flexural strength: According to the results of flexural strength test in the **Table 13.** and **Fig. 5** below, The alginate addition, as a percent of the cement weight cause the flexural strength to decrease compared with reference mix. Except the 1% of alginate addition, it has been shown an increasing in the flexural strength of concrete about 3.4%. The reduction in flexural strength is attributed to the reduction in adhesive strength between the surface of aggregate particles and the cement paste containing the alginate addition. The smooth surface of the alginate biopolymer may cause a weak bonding strength between the aggregate and the cement paste.

Table 13. Concrete flexural strength results.

Mix	Flexural strength(MPa)
Rf	5.8
0.5%alginate	5
1%alginate	6
1.5%alginate	4.6

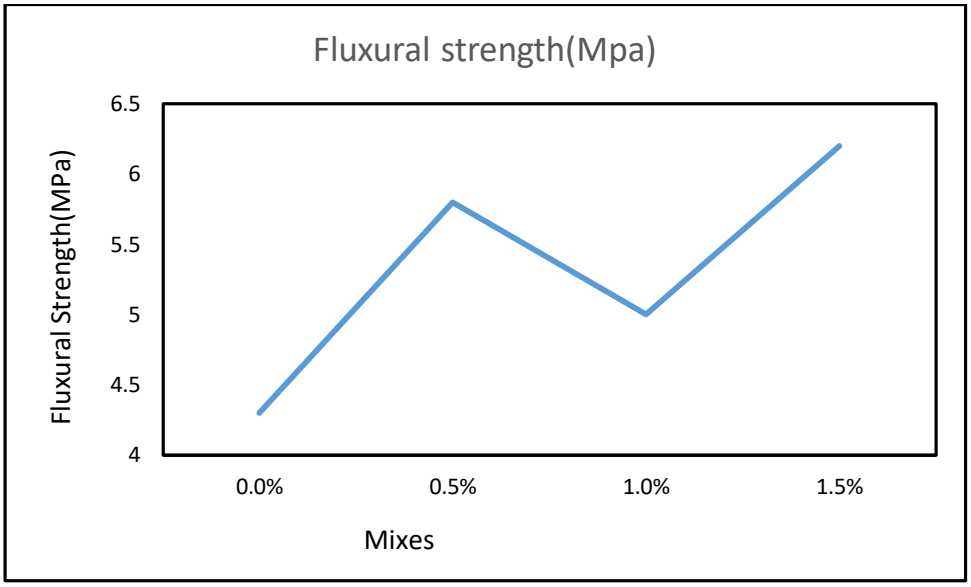

Figure 5. Flexural Strength of concrete at 28 days.

CONCLUSIONS

The addition of the alginate as a percent of the cement weight has some effect of

1. Increasing the slump and improve the workability of concrete.
2. A little increasing in fresh density of concrete.
3. Increasing in the compressive, splitting tensile and flexural strength of concrete at 1% of the alginate addition.

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