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Properties and Behavior of Starch Biopolymer Concrete

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K E Y W O R D S

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A B S T R A C T

Starch act as natural polymer has been got from Wheat, Tapioca, and Corn. Corn starch has been investigated as biopolymer and has been added to concrete in different percentages (0%, 0.5%, 1%, and 1.5%) by cement weight and the study shows the effect of using starch on some properties of concrete in the fresh state (slum and fresh density) and at hardened state (compressive strength, splitting tensile strength and flexural strength) at 28 days. The mix proportion was(1:2.3:2.3) (cement: sand: gravel) respectively and at constant w/c equal to 0.47.The results indicate that the optimum percentage of starch addition was 0.5%, so it showed an increase by 50%in compressive strength and splitting tensile strength; while, the increases in flexural strength were 26%. Slump showed a 25% increase and fresh density showed a 2.5% increase at 0.5% addition of starch.

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1. INTRODUCTION

Biopolymers are new materials in this world. Nowadays the planet facade an altered defy ecological load that is staying away from artificial or Petro-chemically derivative products, while frugal issues are dragging back from often more costly "green" options. That conflict is what petroleum research into materials and products whose properties achieve environmental and economic necessities [1]. The natural biopolymers from plants and natural sources have been used in with the construction materials during the historic and prehistoric period world over and many of these structures are even today uncommon in good shape confirming the durability of these structures which used natural biopolymers. These natural biopolymers are organic materials available from selected plants, seeds, fruit extracts which are chemically carbohydrates, proteins, oils and fats and their derived and hydrolyzed products, plant latexes, gums starches, and natural carboxylic acids/esters and their salts and even blood (animal), milk and eggs, which had properties like to the present day synthetic admixtures in terms of reducing the water content of the binding materials,

which accelerates the hardening processes of the binders providing water retentivity, renderability and compaction desirable to produce a durable compacted hardened structure as desired to bind the stones and aggregates used in these historic and prehistoric structures. These natural biopolymeric additions enhance the properties of construction material formulations (i.e. mortars, plasters mixes used) in fresh (green) & in hardened state and also improve the resistance of the structures to the deterioration processes in nature thereby enhancing the durability of the structures, these biopolymeric additions also exhibited biocidal and insecticidal properties leading to resistance of the constructed structure to bio-corrosion as well as termite resistance [2]. The most popular biopolymer in the world is starch and has a similar deed of starch and starch derivatives in their dispersing ability with petrochemical polymers. The main advantage of starch is that it is from natural resources and renewable material that has varieties of industrial applications because it is low-cost materials and environmentally amicable. [3]. In many cases, biopolymers submission different advantages at the performance and/or cost over artificial polymers, whereas in other zones biopolymers may be the lone product available that can offer certain attributes for building materials. Biopolymers also endure the image of being ecologically more suitable than artificial polymers formed in a chemical plant [4]

2. MATERIALS AND METHODS

I. Materials

1) Cement: The chemical and physical properties of type I Portland cement used are given in Table 1and 2 respectively.

Table 1: Portland cement used (chemical composition)

Oxide	% by weight	IQS 5 /1984– Type I Limits
SiO2	21.2	——
CaO	61.2	——
SO_3	2.07	<2.8
MgO	2.06	<5
Fe_2O_3	3.12	——
Al_2O_3	5.05	——
Insoluble residue (I.R)	1.32	<1.5
L.S.F	0.88	0.66-1.02
Loss on ignition (L.O.I)	3.21	<4
	Main compounds	
C_3A	8.0	—
C_4AF	9.4	—
C_2S	19.0	——
C_3S	58.5	——

Table 2: Test physical properties of cement

The Physical properties	Results of test	IQS 5 / 1984-Type I Limits
Soundness (Autoclave) %	0.05	≤ 0.8
Compressive strength (MPa)		
3days		
7days	20.0	≥ 15
	29.5	≥ 23
Setting time (hrs.: min.)		
Initial	2.05	≥ 45 min.
Final	4.00	≤ 10 hrs.
Specific surface area (Blaine method) (m^2/kg)	367	≥230

2) Aggregate: Crushed coarse aggregate used in concrete based on the Iraqi Standard IQS 45/1984 [6]. The water absorption, particle size distribution and fineness modulus of aggregate are specified. Table 3below shows the physical properties of the aggregate. Tables 4 and 5 show the grading of coarse and fine aggregate respectively.

Table 3: The physical properties of aggregate

Property	Fine Aggr	Coarse Aggr
Fineness modulus	3.13	
Specific gravity	2.67	2.36
Bulk density (kg/m3)	16,5	1685
(%)Absorption	1,6	0.62
The Content of Sulfate (%)	0.1	0.082

Table 4: The grading of coarse aggregate

Size of Sieve(mm)	%Passing	Limits of IQS No.45 /1984 [6]
20	100	100
14	100	90-100
10	81.5	50-85
5	6	0-10
2.36	0	0

Table 5: Test grading of fine aggregate

Size of Sieve (mm)	%Passing	IQS No.45 /1984 zone (2) [6]
9.5	100	100
4.75	97	90-100
2.36	88	75-90
1.18	59	55-90
600 µm	24	35-55
300 µm	13	8-30
150 µm	6	0-10

3) Starch: Corn starch was used as a percentage of cement weight. Its composition is shown in the table below*

Table 6: Chemical composition of starch

Symbol	Element	Concentration (ppm)
Na	Sodium	<640
Mg	Magnesium	<100
Al	Aluminum	<18
Si	Silicon	55.5
P	Phosphor	45.3

* The tests were carried out in Ministry of Industry and Minerals/Materials research directorate

4) Water: Water used for mixing and curing of concrete was Tap water and has a pH value between 8-8.5.

II. Experimental work

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=0.47, depending on American Concrete Institute method for mix design of concrete, Table 7 below shows the details of mixes

Table 7: Details of mix designation

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

2) Concrete Preparation. Materials utilized for the work were prepared following ASTM C192 [7] and weighed on a laboratory balance. Four types of concrete specimens were prepared. Reference mix cast as the first set of concrete specimens and the other three were with (0.5%, 1% & 1.5%) adding of starch by cement weight respectively.

III. Experimental tests

1) Slump test, the test of the slump was performed, as specified in the ASTM C143_ [8]. Using constant w/c for all mixes equal to 0.47 and the mix proportion was 1:2.3:2.3.
2) Test of the Fresh Density; The test of the Fresh Density was performed, according to ASTM C 138M-01_ [9].
3) Test of the Compression Strength; The test of the Concrete compressive strength was performed, depending on BS 1881 Part 181_ [10]. The average compressive strength of three specimens was calculated for each concrete mix.
4) Test of the Splitting tensile strength; The test splitting tensile strength was conducting, according to the ASTM C496-04_ [11]. Using two cylinders for each test with d = 100 mm and h = 200 mm.
5) Test of Flexural strength; Flexural strength test was performed, according to the ASTM C 78-04_ [12]. The load was applied on the side that was perpendicular to the face of the cast.

3. RESULTS AND DISCUSSIONS

I. Slump

The use of starch biopolymer as a percent of cement weight in concrete can increase the slump of concrete about (25, 40, and 43) % for (0.5, 1and 1.5) % addition of starch respectively compared to the reference mix and improve the workability of concrete, the reason for this is the nature of the material starch gelatin

II. Fresh density

The results of fresh density for concrete show that, 2.5% increase in fresh density of concrete for 0.5% and 1 % addition of starch by cement weight while about o.4% increase in fresh density of concrete for 1.5% of starch addition compared to the reference mix, the reason for this, is the nature of the material starch gelatin.

III. Compression strength

From the results of compression strength test, it has been shown that the 0.5% and 1% of starch addition by cement weight can give about 50% and 40% increase in compression strength of concrete

respectively, while the 1.5% of starch addition gave a 28% increase in compression strength of concrete and the reason for this, is the nature of the material starch gelatin.

IV. Splitting tensile strength

The results of splitting tensile strength showed that there was a clear increase in splitting tensile strength ،where the 0.5% of starch addition gave a 50% increase in splitting tensile strength of concrete while the others (1% and 1.5%) of starch addition showed a 38% and 25% increase in splitting tensile strength of concrete respectively and the reason for this, is the nature of the material starch gelatin.

V. Flexural strength

The results of flexural strength of concrete showed that the higher percentage of increase in flexural strength was at 0.5% of starch addition were it was 26%, while the 1% and 1.5% of starch addition showed about 7% and 5% increase in flexural strength of concrete compared to the reference mix 0%. And the reason for this is the nature of the material starch gelatin.

Table 8: Results of fresh properties at 28 days

Mix Designation	Slump (mm.)	Fresh density kg/m3
Ref.	80	2400
1	100	2460
2	113	2460
3	115	2410

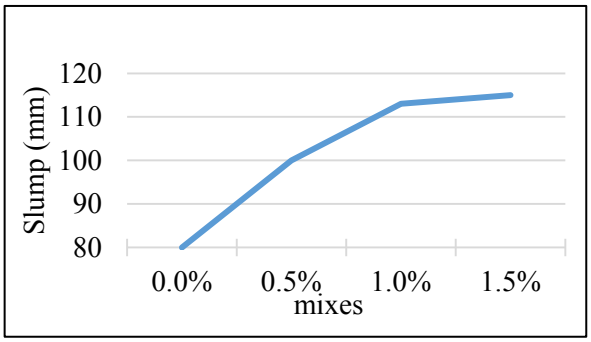

Figure 1: Slump of concrete at 28 days

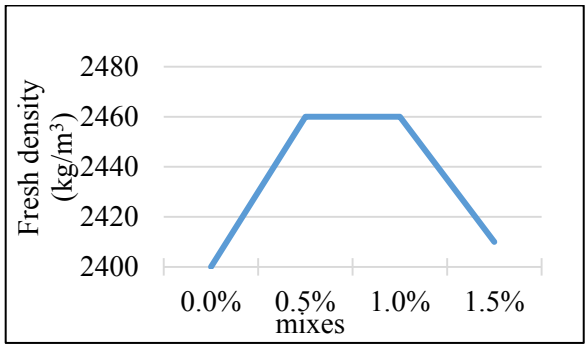

Figure 2: Fresh density of concrete at 28 days

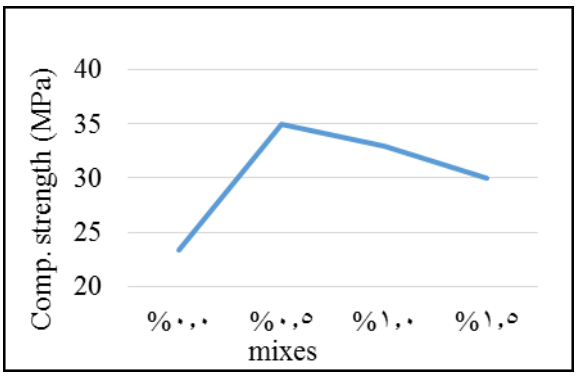

Figure3: Compressive strength of concrete

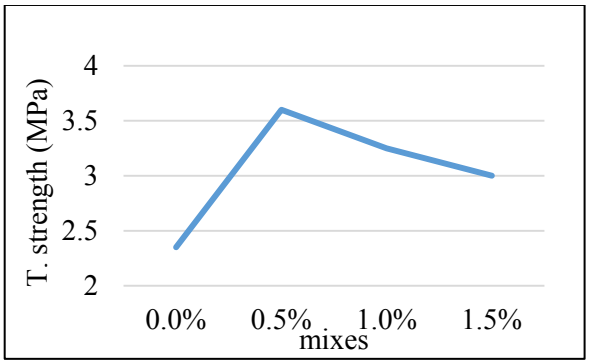

Figure4: Splitting tensile strength of concrete

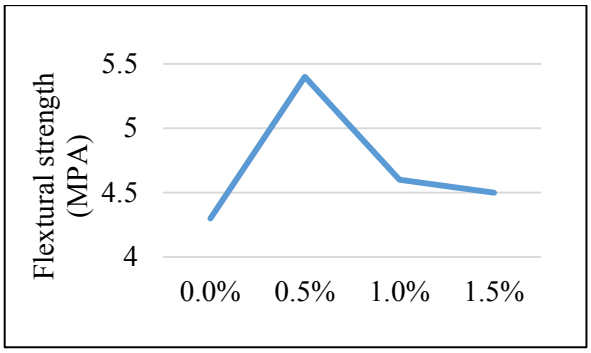

Figure5: Flexural strength of concrete

Table 9: Results of hardened properties at 28 days

Mix designation	Compression strength MPa	Splitting Tensile Strength MPa	Flexural strength MPa
Ref.	23.4	2.4	4.3
1	35	3.6	5.4
2	33	3.3	4.6
3	30	3.0	4.5

4. CONCLUSIONS

From studying the effect of using starch as a biopolymer admixture on some properties of concrete by adding as a percentage of cement weight, it can be observed that starch addition to concrete has some positive effect.

1. The addition of the starch as a percent of cement weight in concrete improves workability and increase the slump of the concrete
2. The addition of 0.5% and 1% of starch cause to increase the fresh density of concrete while the density decrease for 1.5% addition of starch but higher than the reference mix 0%.
3. Other hardened properties of concrete (compression, tensile and flexural strength) also show an acceptable increase by adding the starch.
4. It has been shown that the optimum percentage of starch addition was 0.5% by weight of cement, it showed a 50% increase in compression and splitting tensile strength and also shows 26%increase in flexural strength. It has been shown a clear improvement in workability in addition to increasing the slump & fresh density with an increasing percentage of starch.

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