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Research Article

Effect of Adding Cellulose as Fiber and Crystal on Some Mechanical Properties of Concrete

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Abstract

The present work investigates experimentally the improvement of some mechanical properties of concrete by adding cellulose in the form of fiber or crystal. Each of them can be added through three percentages to fresh concrete. The cellulose may work as superplasticizer which acts to lower the rate of water absorption and influence positively the strength and the elasticity. The percentage of the additive was 2, 5 and 7.5 %. It was found that the best percentage was found as 5% after 28 days of moist- cured. The test specimens was of standard cubic, the percentage of the improvement for the concrete when it was evaluated according to the standard concrete was 14 % for cellulose fiber and 6.5% cellulose crystal, and due to the improvement in the elasticity for fiber additive, it may work properly under the loading condition comparing to concrete standard specimen, while crystal improve the workability.

Keywords: *Cellulose, fiber, crystal, compressive strength, slump*

1. Introduction

Concrete used typically as a construction material in most applications due its good mechanical properties such as formability, toughness and strength. Many different applications make use of concrete as foundations, structural buildings, pathway, ports, land field, viaduct, subways , embankments. It has a broad range of applications that vary from small structures such as fountain and carving to big scale complicated manufacturing productions, so the concrete is used as a major ingredient in the recent construction application (Jonas and Peter 2011).

However, it has weak tensile strength, low ductility, and low energy absorption. An essential due to weak tensile actions of concrete is its low toughness and the presence of imperfections. Consequently to improve the concrete rigidity and to control the size and amount of imperfections in concrete would guide to develop concrete characteristics. A useful method to upgrade the toughness of concrete is by adding a limited fraction (usually 0.5–1% by volume) of short fibers to the concrete blend during mixing. The properties of concretes ingredients, percentage of mix, method of compaction and other controls through placing and curing will influence durability, strength and other characteristic of concrete. Several kind of fibers have been used as an additives to concrete reinforcement and most of them are widely presented for marketable applications. These additives comprise steel, glass, natural cellulose, carbon, nylon, and polypropylene, among others which are adding with pozzolanic material to develop concrete (Patel, *et al,* 2013).

Polymeric fibers may be used as additives, which lead to many different results as the steel fibers. Cellulose fibers though do not suffer corrosion problems as steel fibers nor do they suffer from alkaline attacks unlike glass fibers. In order to achieve a light weight concrete and low cost one, the cellulose fibers can be measured as an another option to polymeric. Concurrence to this information incorporating cellulose fibers into self-consolidating concrete in suitable proportions the fibers can decrease plastic shrinkage, bridge cracks and delay their spread in the concrete. They can be considered as a rheological additive as well as a light weight filler to increase the mechanical resistance. The authors conclude that a super plasticizers is reduced due to integration of cellulose micro fibers in the concrete, beside the reduction in concrete density (Mhamed, Wardeh, 2010).

(R. MacVicar, *et al,* 1999*)* have been studied the aging of marketable cellulose fibers production, which used as a reinforcement in cement. The depository porosity was reduced as well as to water absorption in the aged products of cellulose fiber-reinforced composite cement products. The matrix became denser and the interface between the fibers and the concrete was developed and make the compressive strength increased by 46% when evaluated with the un aged

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concrete after a five years' time. A similar results were achieved for the aged concrete when influenced by climate environments and speed up aging. (Zhengwu, *et al,* 2009) showed that when cellulose fibers were added to self-compacting concrete then they resulting gradually to develop an improvement in impact resistance due to increase fiber density, but it have a small influence or zero effect to the compressive strength. They clearly show that the properties of the fibers have a division of the properties of the concrete, where fiber concentration, fiber geometry, fiber orientation and fiber distribution play a part in the overall behavior of the concrete. The surface of the concrete is also said to positively be modified by improving the abrasion resistance. The efficiency of cellulose fiber in arresting cracks in cementations composites was studied. A ring-type specimen was developed for the restrained shrinkage cracking test. Concretes reinforced with 6 different types of cellulose fibers with a fiber content of 0.5% by volume were tested. Cellulose fiber reinforcement showed an ability to reduce the crack width significantly. For comparison concrete reinforced with 0.5% cellulose fibers showed equally excellent performance as 0.5% polypropylene fibers. The long-term mechanical performance of cellulose and polypropylene fiber reinforced concrete was also evaluated. The details of the study and the findings are presented. The influence of cellulose fiber reinforcement on other properties of concrete was also studied (Sargaphuti, *et, al,* 1993). (U. Tomas and Ganiron, 2013) outline an experimental study which evaluate the effects of polymer fiber on properties of concrete . Polymer fiber may play as a super plasticizer admixture which may result to concrete to reduce the water absorption rate , high-range water reducer, produce high strength and outstanding in elasticity. they found that these application is recommended for earthquake resistance of structure or constructions. (Chen, *et al*, 2013) studied the flexural strength of concrete under the specification ASTM C78 standard test, where The technique of failure in the concrete for flexural strength of were carried out on concrete reinforced by cellulose fiber , three important stages of failure process , cement cracking, fiber – cement de-bonding and fiber breakage /pullout.

The present work is aimed to study the influence of best percentage of cellulose additives as a fiber or crystal on some mechanical properties as compressive strength and slump of concrete.

2. Experimental work

The materials used for preparing the test specimens even with or without the cellulose additives were selected to meet concrete requirement as following:

1-Aggregates: The aggregates used in this work were coarse and fine aggregates due to sieve analysis for both categories, fig. 1 (a & b) show the percentage of passing percentages where the relative density of the aggregate is 2.66.

2- Cement: The used cement was ordinary Portland cement produced by (Tas luoga company in Iraq).

3- Cellulose : the cellulose fiber will absorb moister up to 85% of their weight in moister and they keep small amount of moister around the fiber, where this characteristic produce an excellent bonding between cellulose fiber or crystal and the cement paste. the properties of cellulose was listed at table (1) due to manufacturer information data.

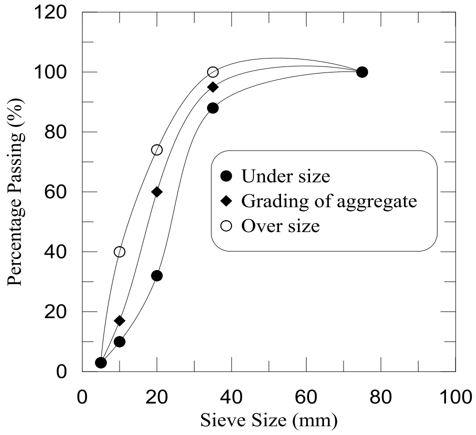

Fig. 1 Sieve analysis for aggregate

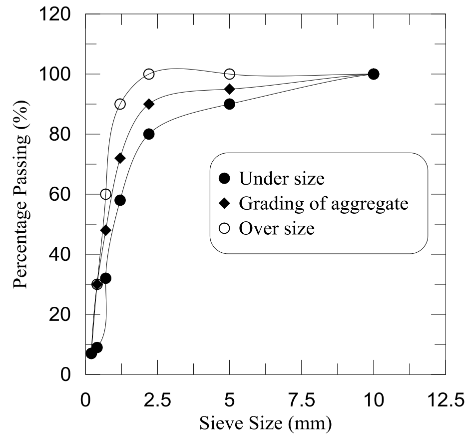

Fig. 2 Sieve analysis for fine aggregate

The chemical composition for the cellulose for the fiber and crystal shown at fig. (3) and fig. (4) respectively, where the analysis carried out at Ibn Sina company at Baghdad.

The concrete produced by mixing cement with aggregate (fine and coarse) as (1:1.5:3) by conventional concrete mixing equipment for pure concrete without any additives through the following process (Sieving, Weighting, Mixing, Preparing molds, Forming, Vibrating, Setting, Curing). The mold was cubic with dimension (150x150x150) mm according to ASTM C109 and after placing the mix into cubic the specimen were tamped layer by layer and imposed to the vibrator for a certain time . The specimens 1 day after casting have been cured in water until testing, where was carried out at 7, 10, 14, 21, 28, 35 days age.

The images of the cellulose (fiber and crystal) shown in fig 3 and 4 respectively.

Table 1 Fiber specifications and data

Average fiber length	2.1 mm
Diameter	0.016 mm
Max. moister	85% by weight of fiber
Fiber count	At 0.9 kg/cm^3 1.44 billion
Density	1.1 gm/cm^3 (water =1.0)
Surface area	25000 (cm^2/gm)
Fiber tensile strength	620-900 MPa
Fiber spacing in concrete	480 μm avg. (at 0.9 kg/m^3)
Plastic crack resistance	85.1% less than ordinary conc. (at 0.9 kg/m^3)
Compressive strength increase	7-16% (at 0.9 kg/m^3, 28 days)

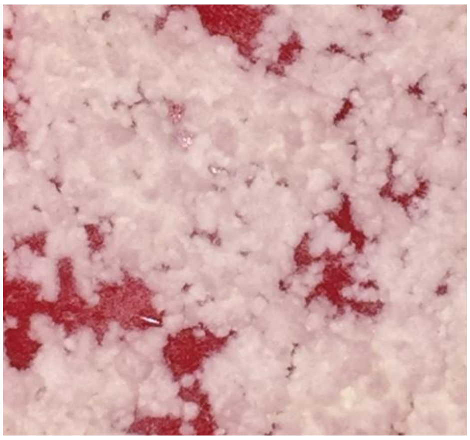

Fig. 3 Cellulose fiber image

Fig. 4 Cellulose crystal image

2.1 Experimental procedure

The cellulose added to the concrete through mixing process gradually for the following percentage (2.5, 5 and 7.5 %) for both fiber and crystal cellulose while they produce six mold for each percentage and cured in water until testing was carried out at 7, 10, 14, 21, 28, 35 days age. The cubic were cured by immersed them in tap water until the age of 35 days. The chemical analysis for the tap water shown in table (1).

Table 2 Chemical analysis of tap water used for curing concrete

Compound	Concentration in ppm	Compound	Concentration in ppm
SO4^{-2}	81	HCO3^{-2}	122
Cl-1	80	HCO3-2	0
Ca+2	128	Na+1	50
Mg+2	44		

The water-reduction characteristic of the polymer fiber as being added to cement. It is found that the mix become more viscous when the crystal percentage increased, the number of cubic that have been tested shown in table (1).

Table 3 Number of cubic and tested sets

No. of cubic	Composition
6	Fresh (without cellulose)
6	With 2.5% fiber cellulose
6	With 5% fiber cellulose
6	With 7% fiber cellulose
6	With 2.5% crystal cellulose
6	With 5% crystal cellulose
6	With t% crystal cellulose

Fig. 5 Mixing machine and cubic

2.2 Types of test

The following tests were carried out due to evaluate the result concrete:

Compression test: The test carried out on a cubic specimen in a hydraulic compressive tester at the Engineering Technical College Baghdad. Fig (6) shows the cubic in the testing machine.

Slump test: The test carried out on standard slump cone and through standard steps at the engineering technical college Baghdad. Fig (7) show the slump test steps, where the test were carried for fresh concrete and those with cellulose as fiber or crystal.

Fig. 6 Cubic in compression testing machine

Fig. 7 Standard slump test

3. Results and Discussion

The Portland cement which used in the present work were chemically analyzed at Ibn Sina company at Baghdad and the results shown in table (4).

For the compressive strength test under the applied load, it shown that the specimens start to fail through cracks which developed when the load reach the ultimate strength especially for those with the fiber additives while for those with crystal cellulose the failure happen suddenly. Fig (8) shows the experimental results achieved from the tested of cubic concrete that contains cellulose fiber at different curing time. The main case noticed is the de-bonding of the fiber through the concrete, where these force influence the extra strength for the compressive test.

Table 4 Composition of Portland cement

Item	Composition	Oxides % of Portland Cement
Iron Oxides	Fe_2O_3	5
Sulfate	SO_3	2.5
Silica	SiO_2	26.277
Alumina	Al_2O_3	4.5
Magnesia	MgO	2.02
Insoluble	-	0.36
CaO	-	remain
Organic	-	-

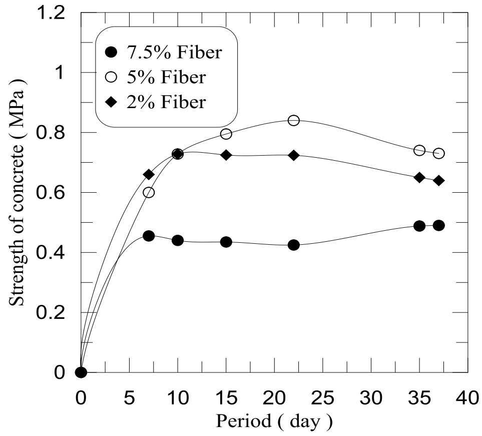

Fig. 8 Relation between strength and time at different percentage of cellulose fiber

When the cellulose added as a crystal to the mixing machine, it is found that the concrete became more viscous which mean increase of the workability but it show clearly decrease in compressive strength, for 5% crystal it was found that this percentage have a higher strength in 14 days curing but after 35 days they have a close amount of strength, as shown in fig (9).

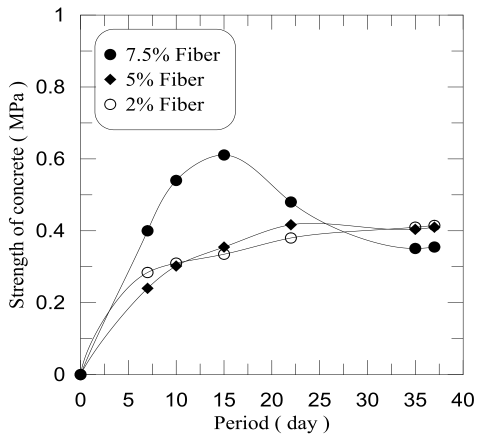

Fig. 9 Relation between strength and time at different percentage of cellulose crystal

The slump test results for fresh concrete as well as to the concrete with different percentage of cellulose as fiber or crystal shown at fig (10) , it can be refer to the slump as an indicator of the workability of concrete, where one disadvantage of fiber is to reduce the workability. When the percentage of cellulose fiber increased in the concrete the slump reduces, while when cellulose crystal added to the concrete the concrete becomes more viscose and then the slump increases and take an extra time to solidification.

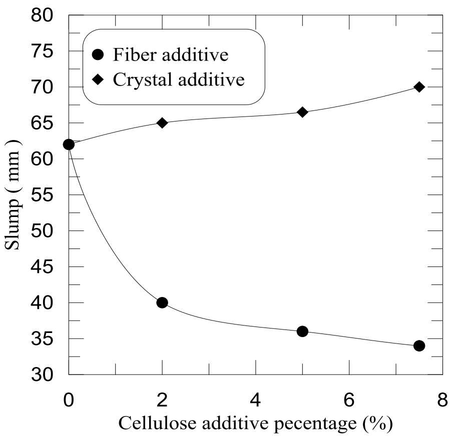

Fig. 10 The Slump of fresh concrete after adding the cellulose as fiber or crystal

Conclusions

From the above results and achievements it can conclude the following:

1- Adding cellulose fiber to concrete increases the compressive strength of the concrete.
  - The maximum compressive strength was about 0.85 MPa. when adding 5% cellulose fiber at curing period was 25 days
  - While it was about 0.6 MPa. when adding 5% cellulose crystal at 15 days curing period.

2- Fiber reduces the slump for concrete while the crystal increases the slump.

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