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Experimental Investigation of Shrinkage of Nano Hair Reinforced Concrete

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Abstract: Basically most of cement based mixtures are likely shrinking. Use of fibers is not a new idea in this case. Previously, there were some evidences that horse hair, straw and cotton fibers were used in mud and mortars in ancient times. Then, utilizing these fibers in concrete mixture may increase concrete workability and decrease shrinkage cracks. Due to nano cross-section of hair and its proper tensile strength this project investigates its application to reduce the shrinkage of concrete mixtures. For this purpose, human hair fibers were used in 0.4 and 0.8 and 1.2 weight percent and the length of the fibers in each case varied between 15 and 60 millimeter and the samples were made of dimensions of 40×40×160 millimeters. Results are shown as considerable amount of hair may reduce in the shrinkage in the hair reinforced concrete.

Key words: Concrete Shrinkage · NHRC · Reinforced Concrete · Human Hair

INTRODUCTION

Concrete as one of the most widely used building material; it is composed of three main elements: cement, sand and fillers in which they are bonded together by cement and formed concrete that is in fact a man-made stone. Its compressive strength is acceptable and tensile strength is very low (about ten percent of compressive strength). This weakness has plumbing problems, including concrete shrinkage and cracking (which is caused by shrinkage). Shrinkage of concrete depends on too many factors including: the ingredients, temperature and relative humidity of concrete, concrete age, size and structure. In fresh concrete due to shrinkage concrete dimension has changed and created cracks and these cracks in concrete increase permeability, loss of concrete surface, reinforcement corrosion and reduced mechanical properties. To compensate such weak tensile strength of concrete and construction materials like concrete, reinforced with fibers was invented. Man waste hair and straw as natural fibers are used. With reinforcing fibers within the concrete its tensile strength extremely increases. This composite has suitable integrity, continuity and provide appropriate use of concrete as a flexible material to produce high levels of curvature resistant surfaces. Concrete fiber also has high energy absorption and under impact loads is not easily torn apart. The use of fibers, widely, started in developed industrial countries in early 1960s and during these fifth decades the quality of fibers and the way of making fiber concrete has improved and its use also increased. Historical evidence of this technology is the use of thatch in the building.

After the concrete was cured and dried, due to hydration and moisture reduction, also tensile stresses reduction in the concrete surface happens, causing shallow cracks in concrete [1]. If one does not pay attention to these cracks that extend by shrinkage they create channels for passing of external destructive elements and reduce concrete durability in long term. According to the review of technical literature, there were generally four main types of shrinkage listed in the sources. Shrinkage of hardened concrete caused by loss of water in concrete is known as shrinkage caused by drying. Frit shrinkage, refers to loss of moisture in fresh concrete before or shortly after the formation of concrete. Shrinkage resulted in from the carbonate, because of the chemical reaction of cement hydration products with carbon dioxide in the air is created and is limited to the concrete surface with low permeability [2]. Spontaneous shrinkage occurred in concrete during hydration due to chemical reactions and loses of water. This type of shrinkage with increase in concrete strength becomes more interesting. This type of shrinkage is the same as shrinkage by drying [3].

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A very effective method in controlling cracking due to clay shrinkage is reinforcing concretes with fibers. Metal fibers and polypropylene which are randomly distributed, create junction forces within cracks width and that would prevent more crack formation [4]. Non-metallic fibers such as polypropylene, glass and polyethylene fibers may lead to reduction of cracks width that are as a result of shrinkage which is caused in drying concrete at high ages [5]. According to Madandost *et al*. [6] with relative distribution of nylon fibers may resist better than polypropylene; while nylon fibers can take to prevention of cracks caused by shrinkage. Pasoleh *et al*. [7] declared that PVA fibers alone may reduce shrinkage; also can significantly reduce the mentioned cracks. Shrinkage control mechanism by fiber based on the gradual liberalization of the water which is trapped within the fibers. Thus reduction of the amount of pore water in the process of hydration and moisture loss that may increase the pore water pressure which is partly compensated. This problem causes tensile stresses between adjacent components and finally shrinkage of cement frit.

An increase in volume of non-metallic fibers, although the crack profile significantly improve, concrete loses its high strength and such expansion in concrete may cause serious problem [8]. This problem usual increase in volume of air trapped in the concrete that cause reduction in concrete strength and life of the exploitable material. The aim of present work is to control the shrinkage parameter by introducing the hair fibers into the mortar. Therefore, sample mixtures of the mortar with 0, 0.8, 1.2 by weight percents of hair fibers with lengths of 15 and 60 mm were prepared for future analysis.

MATERIALS AND METHODS

Materials: In most of construction projects, ordinary Portland cement with standard specifications stated in Table 1 and fine granulated sand according to ASTM c33 standard with softness factor of 2.76 water absorption of 2.8 percent and specific weight 2.71 percent and maximum size sand aggregate of 2.36 mm were used. Water used in this project for making and curing concrete and growing samples is drinkable water and it is in accordance with ASTM c119-89 [9]. Also two different lengths of hair fibers 15 and 60 mm were used. The characteristic of hair is discussed in following section and the reason of its usage as an amplifier in mortar is expressed.

Table 1: Chemical composition of cement

	Type 2	
Chemical composition	ISRI 389 Iranian standard	Experiment results
SiO_2	>20	21.90
Al_2O_3	<6	4.86
Fe_2O_3	<6	3.30
CaO	-	63.32
MgO	<5	1.15
SO_3	<3	2.10
Compressive strength (kg/cm^2)		
3 day	>100	185
7 day	>175	295
28 day	>315	379

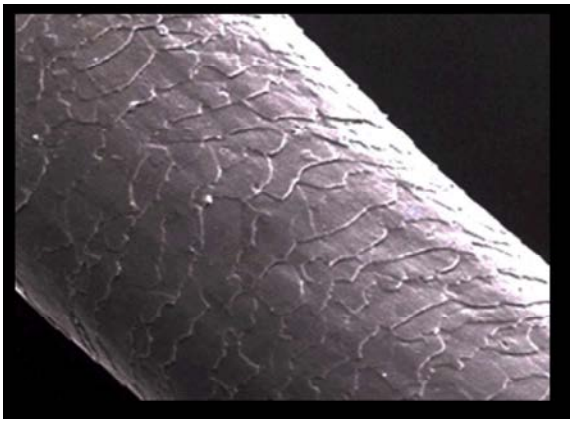

Fig. 1: Details of external surface hair

Hair: The main element of hair composition is keratin. Keratins are proteins with long chains of amino acids that form the cytoskeleton of all cells of outer shell. Number of investigations clearly stated that sulfur is the main reason of strength of hair cords in front of disintegration in the face of environmental stress and these sulfur compounds are linked with amino acids at very high levels in hair cords. Sulfur in Amino acid molecules is adjacent to keratin protein till form disulfide chemical chains (chains are very strong and resistant to breakage). These chains are very resistant to acids disulfide performance, but in alkaline solutions they can decomposed. In fact alkaline environment looses the hair cords [10]. The potential impact of reduced strength in the cement mortar is still a noteworthy but we have to mention that the purpose of this article is to investigate the impact of hair cord in control of shrinkage and cracks which are caused in normal concrete. Before the alkaline environment loose the hair cords, these cords may respond on purpose to their functions to prevent shrinkage.

Figure 1 shows the details image of the external surface of a human hair that has been studied with electron microscope. The outer layer of hair which is

Table 2: Features of mixture samples

Size of hair fibers	-	------- 15mm -------			------- 60mm -----		
Sample name	NF	S1	S2	S3	T1	T2	T3
Percentage of fibers	0	0.4	0.8	1.2	0.4	0.8	1.2

called cuticle is much like tree trunks and has bumps like what is shown in this figure [11, 12]. Hairs diameters are 50 to 100 micrometer [13] and bumps on it are in nano size. These bumps help to lock cement mortar with hair cords. Size and number of these bumps is variable depending on hair type.

Characteristics of Mortar Mixture: This research includes 5 mortar mixing samples with 0.4, 0.8, 1.2% from hair fibers in two different lengths of 15 and 60 mm. In all samples the ratio of water to cement is 0.55 and amount of granular stone is stable and equals 1835 kg/m^3 and cement grade is 3150 kg/m^3. The ratio of mixed samples are summarized Table 2.

Tests were carried via standard ASTM C596 [14] by different length of hair; 160 mm length and 40 mm width and depth (since the aim of these experiments were to compare degree of condensation, dimension of samples had no significant effect on final result). Based on standard, condensation caused by drying in mortar has linear relation with condensation caused by drying in concrete made from that cement. In fact the same environmental conditions exist. Therefore, in this research sand-cement mortars are used.

For comparing degree of condensation, weight percents of 0.4, 0.8 and 1.2 hair fibers in two medium lengths 15 and 60 mm for each weight percent were used. The selection of these lengths is based on available hair length and the size and dimension of fibers. Test includes five control concretes and three sample concretes for each mixture with different weight percent and hair length. Generally, it was considered and made twenty four samples for implementation of the test. Figure 2 shows the sample hair used in preparation of concrete samples with hair fibers.

For preparation of samples, we used pure cement and sand with identified weight in a dish and mix it by hand about 2 or 3 minutes. Then we add required amount of water in 2 steps and mixture obtained compound in required amount. In this step, control concrete was modeled. In the next step, waste hair base on percentage was added. The mixture was vibrated for uniform sample. Based on ASTM C596, after molding, it was covered molds by nylon for reserving against wet changes. After 24 hours processing in wet situations, the samples were exited from steel frames. The prepared samples are shown in Figures 3 and 4.

Fig. 2: Photos of sized fibers used in this project

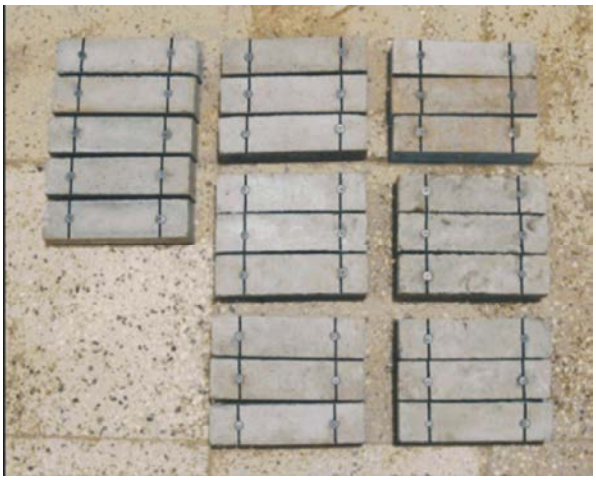

Fig. 3: The position of the ball planes on samples

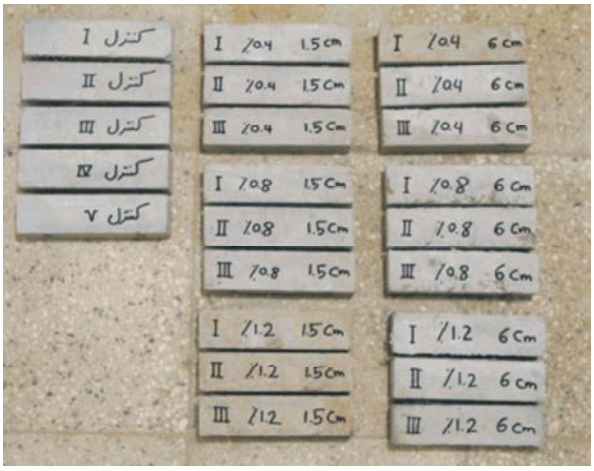

Fig. 4: The prepared samples

Measurement Tools: The primarily measurement was carried out by a meter length for each sample according to ASTM C596. According to calibration stage, it was stick the measuring scales device on each sample in 10 cm distance from each other. Samples were put on one table so it was not important changes of length and in order fixing temperature and wetness they were covered by a plastic film. The changes in length of samples on 4th, 11th, 18th and 40th day were determined.

Table 3: Obtained results from condensation test

Type of mortar	Mortar name	Hair length (mm)	Amount of fibers (%)	Number of sample	Degree of condensation (%) 4th day	11th day	18th day	40th day
Control sample		-	-	5	0.107	0.189	0.243	0.271
Reinforced mortar by hair	S1	15	0.4	3	0.068	0.14	0.231	0.244
	S2		0.8	3	0.126	0.152	0.162	0.211
	S3		1.2	3	0.147	0.168	0.181	0.218
	T1	60	0.4	3	0.172	0.211	0.251	0.258
	T2		0.8	3	0.01	0.02	0.023	0.023
	T3		1.2	3	0.082	0.112	0.118	0.135

RESULT AND DISCUSSION

The obtained results from tests are summarized in Table 3. Addition of hair fibers in two different sizes of 15, 60 mm and with 0.4 and 0.8 and 1.2 percent caused to decrease degree of mortar condensation. But, increasing the weight percentages of the fibers did not cause more decrease in strains resulted by mortar condensation.

In order to compromise the degree of condensation in different weight percents of mixture and also reinforced mortar by hair fibers in different sizes; results are illustrated in Figures 5, 6 and 7 for different weight percentages of hair 0.4, 0.8 and 1.2.

As shown in these figures forcing mortar by 0.4, 0.8 and 1.2 weight percent of hair have significant effect on decreasing degree of condensation. Also, it is shown that effectiveness level 0.4 weight percent of hair on condensation was less. It can be concluded that 0.4 and 0.8 weight percents of hair in size of 60 mm than 15 mm showed great effectiveness.

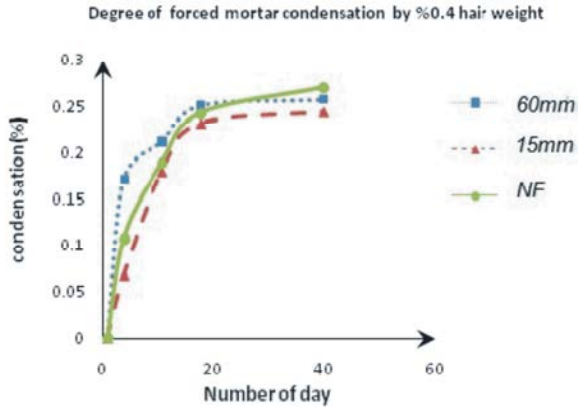

Fig. 5: Degree of forced mortar condensation by hair weight percentage of 0.4

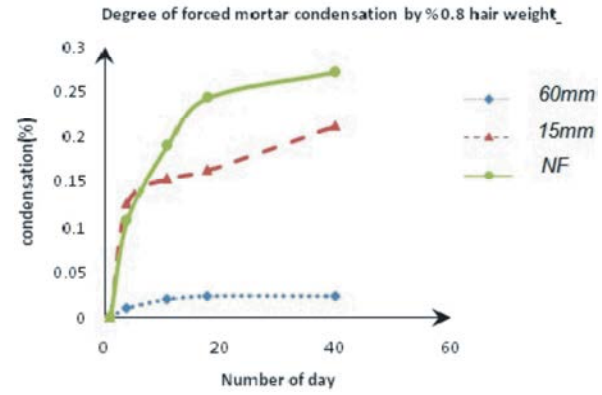

Fig. 6: Degree of forced mortar condensation by 0.8% hair

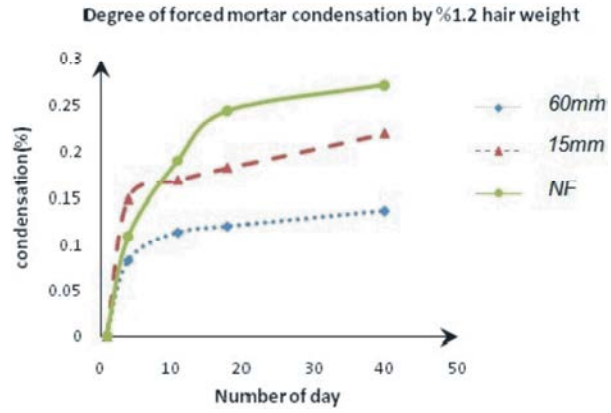

Fig.7: Degree of forced mortar condensation by 1.2% hairs

CONCLUSION

An effective way for controlling cracking caused by pasty condensation is to reinforce concrete by fibers. Surveying effectiveness of fibers on controlling condensation in mortar scale due to being simple in test and ability of obtained results popularization in concrete scale have well efficiency. One can see main results obtained from this research.

- Addition of fibers with certain limit low rate of controlling condensation occurred.
- According to experiments, addition of hair to concrete decreased 33% the condensation after 40 days. This rate declined for NHRC was 90.5 % for 0.8 weight percent hair fibers and mean length of 60 mm.
- Addition of 0.4 weight percent hair did not have significant effect on the control of condensation and the effect of the control of condensation for NHRC with 0.8 weight percent hair was more effective than NHRC with 1.2 weight percent hairs.
- Also for more than 0.4 weight percent hair, the hair length of 60 mm was more effective than hair with length of 15mm. This can be due to the ability of hair to improve the new mortar tensile ability and eliminate the cracks development.

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