



**DRYING SHRINKAGE OF GUNNY FABRIC
FIBER (GFF) CONCRETE**

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DRYING SHRINKAGE OF GUNNY FABRIC FIBER (GFF) CONCRETE

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ABSTRACT. *Gunny sack is made from natural fiber which is flexible, has high tensile strength, low extensive and environmentally friendly. All these advantages gave potential to gunny to be utilized in concrete as fiber. This paper discussed the potential of gunny fabric fiber (GFF) with size 1 cm and 4 cm as an additive fiber in concrete to improve drying shrinkage behavior. Drying shrinkage is the concrete long term behavior which could lead to crack problem. Three series of beam with size 500 mm x 100 mm x 100 mm were mix and batch according to Department of Environmental (DOE) and tested for 3, 7, 14, 28, 56 and 72 days. The series includes control mix, 1 cm GFF with addition of 1%, 3% and 5%, and 4 cm GFF with addition of 1%, 3% and 5% in concrete. Fly ash was added 10% to all series of concrete mix as cement replacement. It showed the addition of 1% of 1 cm GFF gave the lowest drying shrinkage value compared with all other series. This series of mix has the potential as discrete fiber reinforcement to reduce the concrete shrinkage hence minimize the concrete crack.*

KEYWORDS: Additive, DOE method, Drying shrinkage, Fiber reinforcement, Fly ash

INTRODUCTION

Fiber reinforced concrete has become the subject of many investigations since 1980's. A large number of studies and been implemented on the various types of loading as well as various sizes and shapes in fiber reinforced concrete with steel, plastic and glass fibers used as reinforcement. However, this reinforcement is specially manufactured and costs unfavorable. There are other types of potential fibers other than mentioned above have been carried out under study including organic fibers.. Besides the compressive strength, in engineering structures, the strength should be combined with toughness which is provided by fiber added into the concrete matrix which indirectly improves tension behavior compared to conventional concrete.

Many efforts has been devoted to the research of concrete mix designs aiming to produce concrete with better workability and flow ability at its fresh stage and produces a stronger and durable at hardened stage. In the case of fiber reinforced concrete, mix design and procedure of mixing is varying with type of fiber and to some extent with type of matrix. In order to get good collaboration between fiber and matrix and because of the brittleness of the matrix and the low fiber volume fraction, total fiber dispersion and full bond to all fiber surfaces is essential which is carried out during mixing and casting process. Addition of fine-particle pozzolans like pulverized fly ash (PFA) may improve the bond, provided that the fine particles are fully dispersed in the cement paste.

BASIC CONCEPT OF DRYING SHRINKAGE

In addition to deformation caused by the applied stress, volume changes due to shrinkage and temperature variation are considerable important because in practice these movements are usually partly or wholly restrained, and therefore they induce stress. Shrinkage is caused by loss of water by evaporation or by hydration of cement, and also by carbonation. The reduction in volume, i.e. volumetric strain, is equal to 3 times the linear contraction, and in practice we measure shrinkage simply as a linear strain. Its units are thus mm per mm usually expressed in 10^{-6} . (A.M. Neville et. al., 1995)

RESEARCH SIGNIFICANCE

By using recycle materials as fibers reinforced materials and fly ash as pozzolans, the most beneficial potential for the use of industrial by-product is the environmental values. This efforts will not only benefits to the government in reduction of providing land for disposal, but also increase the economy growth in various sectors especially amongst construction industry. By replacing certain amounts of OPC will significantly reducing the dependent on its large amounts; thus emission of CO₂ or green house gases will be reduced as well.

Fibers enhanced the mechanical properties especially fatigue and tensile stresses as well as cracking properties, ductility and impact resistance. The strengthening mechanism of fibers involves transfer of stress from the matrix to the fiber by interfacial shear or by interlock between the fiber and the matrix. As reported by Singh, the addition of fibers into concrete improves the engineering properties of the concrete such as static flexural strength, impact strength, tensile strength, durability and flexural toughness. In load-deflection curve, the area under this curve is termed as toughness. Fiber in the concrete matrix will restrain from the crack to disperse continuously.

SPECIMEN PREPARATION AND TESTING

Gunny fabric fiber as concrete reinforcement

The gunny used in this study was made from waste gunny sack and was processed manually to transform it to fiber. Gunny string was separated one by one and cut to act as discrete fiber reinforcement in concrete. It then been sieved to make sure it is free from any impurities and the fibers are assured to be loosen and prepared to be cut into required length for consistency in this study. The measured length of gunny fiber used is 1 cm and 4 cm, water absorption of 64% at 24 hours and density of 400 kg/m³.

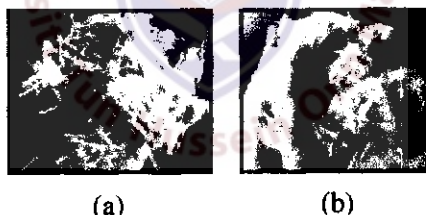


Figure 1 The gunny fabric fiber; (a) 4 cm length and (b) 1 cm length

Other concrete mix components

Crushed gravel was used as coarse aggregates and river sand was used as fine aggregate which has a fineness modulus of 2.56. Fly ash and Malaysian Ordinary Portland Cement with specific gravity of 2.66 and 3.15 respectively was used as binders. Fly ash was taken from TNB Kapar in Selangor. The physical properties such as water absorption, moisture content and bulk density are shown in Table 1.

Most pozzolanic materials, however, especially natural pozzolans like fly ash, tend to increase the mixing water requirements for concrete and lower the rate of strength development. Therefore, for structural applications, their proportion in blended Portland cement is generally limited to 30% or less. According to Neville, the optimum strength that can be achieved by replacing ordinary Portland cement content is 10%. A comprehensive review of the studies on the use of pozzolan as partial replacement for cement in mortar and concrete has recently been presented by several studies [3-5]. It is estimated that the world production of fly ash was about 600 million tones but only 9% got to be utilized. The use of high volume fly ash as a supplementary cementitious material in concrete production is much preferred however; in this case we replace a portion of OPC concrete with fly ash. There may be some essential amounts of chemical composition which is reduced, but Malhotra

reported that only 10% replacement of fly ash will gave the optimum results in term of strength and durability.

Table 1 Physical properties of coarse and fine aggregates used

Physical properties	River Sand	Crushed stone
Specific gravity (SSD condition)	2.65	2.60
Moisture content (%)	0.02	0.01
Water absorption (%)	1.65	0.79
Bulk density (kg/m ³)	1663.65	1585.23
Fineness Modulus	2.84	-

Test samples

Basically, the test can be divided into 3 major series; the first control series is the normal concrete without any addition of fiber, and second series, S1 and third series, S2 consists of same amount of fibers addition namely 1%, 3% and 5% but with different fiber length. S2 contain 1 cm fiber length and S3 is added with 4 cm fiber length. Those three series was designed to have the same mix proportion to compare the best mix proportion for each series. 10% of cement replacement was chosen because this amount of cement replacement will produced optimum strength in conventional concrete as reported by Neville. Series of conventional concrete without addition of gunny fibers used as reference (control) mixture.

Table 2 Series of gunny fabric fiber concrete mix

No.	Series	Description
1	Control	0% GFF
2	S1	A Addition of 1% of 1 cm GFF
		B Addition of 3% of 1 cm GFF
		C Addition of 5% of 1 cm GFF
3	S2	A Addition of 1% of 4 cm GFF
		B Addition of 3% of 4 cm GFF
		C Addition of 5% of 4 cm GFF

The mix design was carried out based on Department of Environmental (DOE Method) with targeted design strength of 40 N/mm². Other concrete constituent was fixed as follows with 0.45 of water cement ratio, 500 kg/m³ of cement, 225 kg/m³ of water, 742.5 kg/m³ of uncrushed fine aggregate, and 907.5 kg/m³ of crushed coarse aggregate. The addition of 1%, 3% and 5% of GFF in series 1 and series 2 mixes vary between limit 4 kg/m³ to 20 kg/m³. As the natural fires absorbs much water, the percentage of water absorption by gunny fabric fibers should be determined first and included in the mixing water content.

Description of mixing procedures

Initially, cement and fly ash (if applicable) were dry mixed properly. After all the constituent materials were mixed, about 1/5 of the required water was added to the mixture. Small quantities of loose fibers were fed in the mixer manually and gradually taking care that the fibers were not mixed in bundles. After adding about 1/3 of the quantity of fibers, about 1/3 of the remaining quantity of water was added to the mixer and the remaining quantity of fibers was added again slowly and in small quantities. Finally, the remaining water was added and the mixing was done until good homogeneous mixture, as visually observed, was obtained. If any lumping or balling was found at any stage, it was taken out, loosened and again added manually.

Testing

Shrinkage can be expressed as the reduction in volume, i.e. volumetric strain, is equal to 3 times the linear contraction, and in practice we measure shrinkage simply as a linear strain and the units are mm per mm usually expressed in 10^{-6} . The test is carried out by using 100 mm x 100 mm x 500 mm prisms specimens. Three identical test specimens were used for each series specified earlier. Beside shrinkage measurement, weight loss of the specimens was also recorded including temperature and relative humidity of the surrounding environment. The specimens were stored inside the lab (internal exposure) so that the changes in the humidity were insignificant. Drying shrinkage is discussed in BS8110: Part 2, section 7.4.

Twenty four hours after casting, the specimens were stripped and initial readings were taken; both sets of specimen were water cured at $27 \pm 1^\circ\text{C}$ for 28 days respectively. After water cured for 28 day, subsequence reading was taken and the specimens were stored in a controlled environment of $25 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ room humidity. Stainless steel stud were fixed onto the faces of the specimen using Epoxy adhesive resin. There were two studs on each face which is the Demountable Mechanical Gauge (DEMEC) point separated at a distance of approximately 200 mm along the centre axis. The measurements were taken by using the demountable DEMEC Mechanical Strain gauges which is a simple dial gauge mechanism incorporating a standard gauges length of 200 mm. Four readings of shrinkage strains were taken from each specimen and were averaged to determine the shrinkage strain. Measurements were taken at the age of 3, 7, 14, 28, 56 and 72 days. Figure 2(a) and 1(b) shows the equipment of strain gauge and shrinkage specimens with DEMEC points on them.

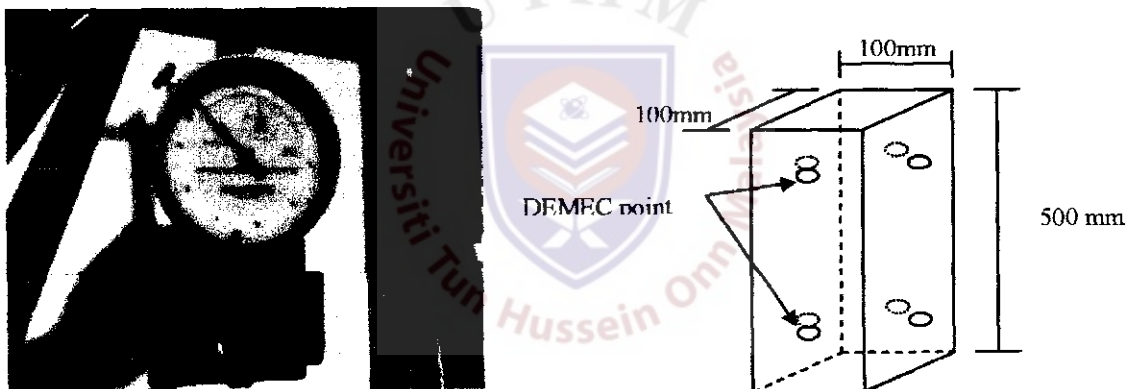


Figure 2 (a) DEMEC Mechanical Strain Gauge (b) Prism with DEMEC points at four sides

RESULTS AND DISCUSSION

The development on the performance of all the series been conducted in this study on shrinkage strain with drying period to 72 days under initial water curing condition of 28 days is shown from Figure 3. According to all series that been conducted, series 1A (1cm; 1% addition) shows the lowest value of shrinkage, followed by 2A series (4cm; 1% addition), 1B series (1 cm; 3% addition), control series, 2B series (4cm; 3% addition), 1C series (1 cm; 5% addition) and lastly, 2C Series (4 cm; 5% addition) which gave the highest value of shrinkage. 1A series has the potential as discrete fiber reinforcement to reduce the concrete shrinkage hence minimize the concrete crack. The increasing shrinkage value of concrete with GFF addition more than 1% compared with control sample shows that with 3% and 5% addition of GFF in concrete do not enough to compensate the concretes behavior. This is because larger amount and length of GFF can absorb much water during concrete mixing stage, and more water is required for workability, therefore when leave it under room temperature, the water will be absorbed from the concrete tremendously. The absorption of water will promotes the concrete to have more shrinkage.

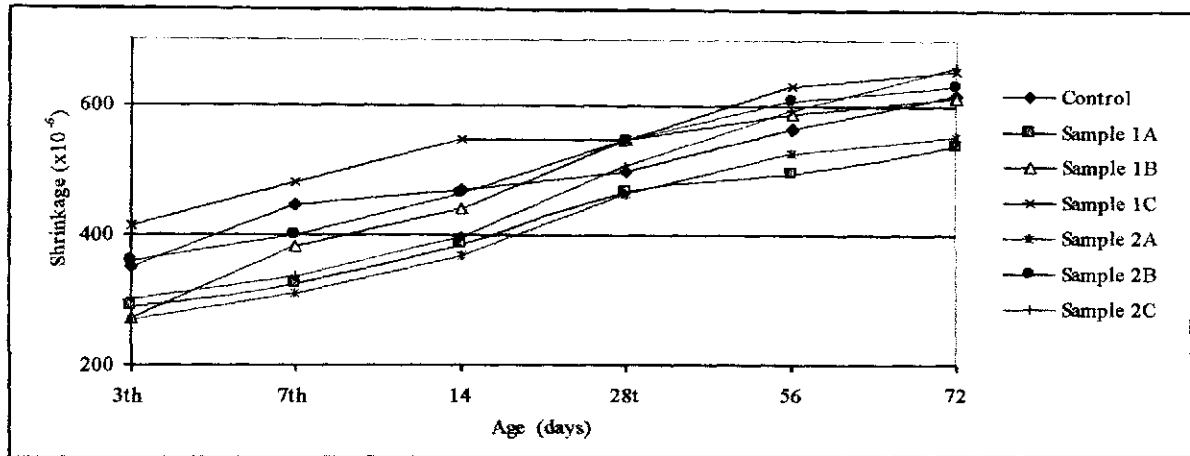


Figure 3 Development of shrinkage

Table 6 Drying shrinkage of cement replacement material series and control concrete under 28 days initial water curing days.

Series	Drying shrinkage at 72 days (ϵ_{sh})
Control	614.8×10^{-6}
S1A	538.8×10^{-6}
S1B	613.2×10^{-6}
S1C	653.2×10^{-6}
S2A	552.0×10^{-6}
S2B	632.0×10^{-6}
S2C	660.0×10^{-6}

Besides above parameters, the length of drying period and the humidity of the surrounding air also are the factors that influence the shrinkage. The shrinkage rate is reduced gradually with elapsed time for all series. The shrinkage rates of gunny fabric fiber concrete and the control concrete are quite different at earlier ages. In this experiment, we find that the most critical shrinkage value is within the first 28 days. Here, we can see that the rate of shrinkage risen rapidly. Based on the graph shown, after 28 days, the values of shrinkage have a smaller shrinkage rate. In this experiment, all samples are stored in a control room and therefore the relative humidity is assumed to be constant. However, theoretically, the rate of shrinkage is lower at higher values of relative humidity.

CONCLUSION

The following conclusions can be drawn from this investigation:-

1. The concrete series of 1% of 1 cm GFF addition shows lowest value of shrinkage followed by 2A series (4cm; 1% addition), 1B series (1 cm; 3% addition), control series, 2B series (4cm; 3% addition), 1C series (1 cm; 5% addition) and lastly, 2C Series (4 cm; 5% addition)
2. The shrinkage rates are high at earlier age; before 28 days age but reduced at the latter stages.

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