ABSTRACT

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Material Engineering

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Mechanical Properties of Gunny Sack Fiber Concrete

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Abstract: This paper summarizes the experimental investigation of gunny sack fiber concrete in the mechanical properties. Two batches of mix concrete with target of normal and high-strength concrete were used to cast a large number of control specimens. The dimension of gunny sack fiber used are 0,5 mm diameter and 20 mm length, with substitution of 0%, 0.5% and 1% to the volume of concrete. Information is given pertaining to compressive strength, tensile strength, modulus of elasticity, Poisson ratio, modulus of rupture, shrinkages and stress-strain response under uniaxial loading. From testing results shows that normal and high-strength concrete can be produced by gunny sack fiber concrete. The addition of 0.5% gunny sack fiber of the concrete volume is the most optimum in improving the mechanical properties of concrete, such as the tensile strength, ductility, shrinkage and fracture test. Significant differences were found in the compressive strength, modulus of elasticity and poisson ratio while gunny sack fiber concrete have tends the lower value compared with the properties of normal concrete
Keywords : concrete, fiber concrete, gunny sack, mechanical properties

1 Introduction

Concrete made with Portland cement is strong in compression but weak in tension and tends to be brittle. This properties cause cracks develop. The weakness in tension can be overcome by the use of conventional rod reinforcement and to some extent by the inclusion of a sufficient volume of certain fibers.

Based on researchs have been performed, it is well known that addition of fibers have found to be able to prevent or reduce the cracking caused by shrinkage deformations and that the fibers do not have any influence on the size of temperatures and shrinkage deformations [Cement & Concrete Institute, 2010]. Another properties that adding fibers to concrete greatly increases the ductility of the material. That is, fiber-reinforced concrete is able to sustain load at deflections or strains much greater than those at which cracking first appears in the matrix. In the existing design code (Indonesian National Standard for concrete design) have not provided enough information for the structural utilization of fiber concrete materials.

When fibers are added, the concrete becomes less workable and more rigid and integral depending of the quantity and type of fibers. It means that the concrete becomes harder to transport, to cast and to screed and at last the result can be a hardened fiber concrete with worse properties than intended.

Fiber reinforced concrete has various excellent properties as a composite material; for instance, flexural strength, tensile strength, shear strength, thoughness, crack resistance and resistance to frost damage are improved by the use of steel fiber. A number of different types of fibers have been found suitable for use in concrete i.e. steel, glass, organic polymers, polypropylene, Kevlar etc. Gunny sack fiber, produced through borrowers process of rosella plant from species of Hibiscus Sabdariffa, also can mixed with fresh concrete and produced gunny sack fiber concrete. This paper explain an information of experimental investigation on the mechanical properties of gunny sack fiber concrete.

2 Experimental Program

2.1 Materials

Two different concrete mixes were develop by trial to produce concretes of normal and high-strength concrete with water cement ratio are 0.53 and 0.32. The series of specimens consist of normal concrete or non-fiber concrete, denoted CN (Non-Fiber) as the control specimens, and fiber concrete denoted by CF while consist of two types fiber percentage (0.5 and 1% of volume).

Table 1. Concrete mix proportions

Series	Materials / m^3						
	w/c	Water (Kg)	Cement (Kg)	Fine aggregate (Kg)	Coarse aggregate (Kg)	Superplaticizer (Kg)	Gunny Sack Fiber (Kg)
CN-1							0,00
CF-2	0,53	217,00	410,00	695,26	1047,74	1,64	1,77
CF-3							3,54
CN-4							0,00
CF-5	0,32	200,72	633,33	620,65	935,30	3,80	1,77
CF-6							3,54

Note: CN = Normal concrete (Non-Fiber)
CF = Fiber Concrete

The sand and coarse aggregate used were from a local quarry. The Viscocrete was used to improved the workability of the concrete mix, with percentages 0.4% and 0.6% each for mix proportions of normal and high-strength concrete. Fifteen percent by weight of the Portland cement was repalaced by Fly Ash to produce the high-strength concrete. All testing was done according to ASTM standards for each test and carried out at 28 days, except for shrinkage evaluation was performed from one to seven days. Mix proportions are given in Table 1.

2.2 Properties of Gunny Sack Fiber

Properties of Gunny Sack used as fiber material in concrete were analyzed, and summary information is given in Table 2. From the table shows that very high of water absorbtion of this material and the result of tensile test is 47.28 MPa. The example of Gunny Sack Fiber showed in Figure 1.

Tabel 2. Properties of Gunny Sack

Characteristic	Gunny Sack
Water absorbtion	49,70 %
Water content	33,16 %
Density	0,354 gr/cm^3
Organic content	No. 11 (yellow-brown)
Tensile strength	47,28 MPa

3 Experimental Results and Discussion

The mechanical properties of Gunny Sack Fiber concrete from experimental results is shown in Table 3. It is seem from the table that Gunny Sack Fiber concrete can be produced both normal and high-strength concrete although the strength tends decrease with increasing the percentage of fiber. For normal strength concrete, specimen CF-2 and CF-3 decrease 15% and 30% the normal concrete (CN-1) in the compressive strength. But for high-strength concrete the less degradation compared for normal strength concrete, where the compressive strength of specimen CF-5 and CF-6 are 7.5% and around of 16% to the control specimen (CN-4). Workability of fiber concrete also excellent same with normal concrete caused the effect of addition the Viscocrete.

Table 3. Experimental results

Figure 1. Gunny Sack fiber

3.1 Mechanical properties under compressive strength

The development of normal and hingh strength concrete shows that an increasing in fiber percentage from 0.0 to 1%, the compressive strength decreased (see Figure 2).

Series	Fiber %	w/c	SP	Slump mm	Weight Kg/l	Compressive strengh f'_c		Tensile strength f'_t		Modulus of Rupture f_r		f_t/f'_c %	f_r/f'_c %
						kg/cm^2	MPa	kg/cm^2	MPa	Kg/cm^2	MPa		
CN-1	-	0,53	1,64	170	2,4493	411,95	41,20	23,37	2,337	58,67	5,87	5,67	14,24
CF-2	0,5	0,53	1,64	150	2,3786	347,43	34,74	27,22	2,722	66,67	6,67	7,84	19,19
CF-3	1	0,53	1,64	140	2,3583	289,55	28,96	25,92	2,592	61,63	6,16	8,95	21,28
CN-4	-	0,32	3,80	flow	2,4866	719,92	71,99	38,34	3,834	73,19	7,32	5,33	10,17
CF-5	0,5	0,32	3,80	flow	2,4735	665,82	66,58	43,96	4,396	90,07	9,01	6,60	13,53
CF-6	1	0,32	3,80	flow	2,4498	608,95	60,90	41,44	4,144	87,11	8,71	6,80	14,30

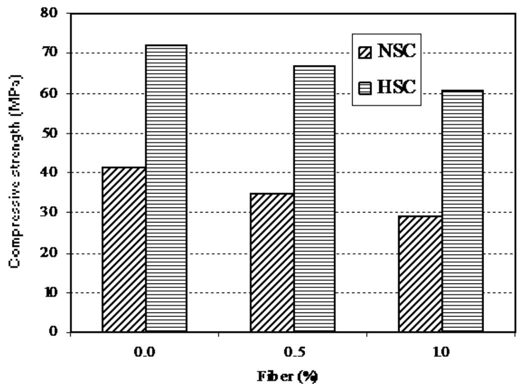


Figure 2. Effect Gunny Sack Fiber content to the compressive strength

3.1.1 Cracking under compressive loading

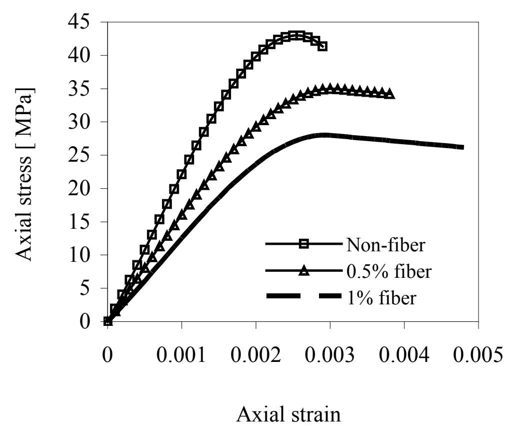
The results of observation on cracking are shown in Figure 3. A network of hair cracks were observed on specimens with added of 1% Gunny Sack fiber. With further increases develop for 0.5% Gunny Sack fiber, a considerable number of hair cracks were found and become deeper when percentage of Gunny Sack fiber 0% (without fibers).

a. 0% fiber b. 0.5% fiber c. 1 fiber

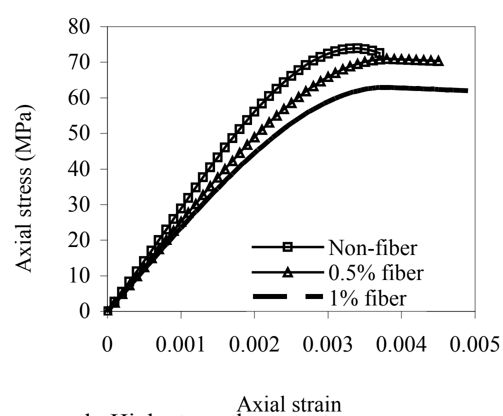
Figure 3. Cracking of cylinder specimens under compressive loading

3.1.2 Stress-strain behaviour

Stress-strain curve for normal and high strength concrete are shown in Figure 4 for specimens made with non-fiber and Gunny Sack fiber concrete, respectively. Six specimens were tested from each concrete mix. The tests were done under strain control, with 2000 kN capacity.



a. Normal strength concrete



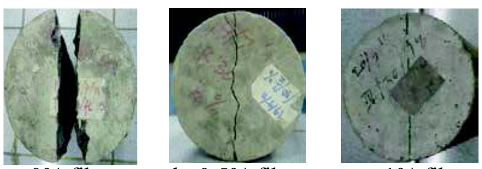
b. High-strength concrete

Figure 4. Stress-strain curves under compressive loading

It is clear from Figure 4 that the shape of the stress-strain curve up to maximum stress for both normal and high-strength concrete without Gunny Sack fiber, has a steeper slope and is more nearly linear and the explosive manner in the post peak. For fiber concrete with added Gunny Sack shows that the descending branch are more ductile.

3.2 Mechanical properties under tensile loading

Table 3 also summarizes the properties of the concrete under tensile loading. The loading method applied to the specimens under splitting test. As can be seen for fibers concrete specimens, the ratio of the tensile strength to the compressive strength between 5 to 9%. This value is still the inner that assumed for normal concrete. Failure modes of specimens under tensile loading illustrated in Figure 5, while the manner of failure is similar with the behaviour under compressive loadings above.

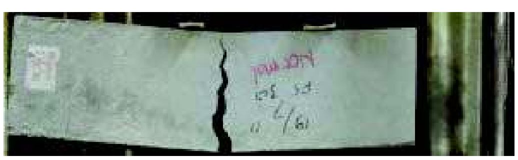


a. 0% fiber b. 0,5% fiber c. 1% fiber

Figure 5. Mode of failure under splitting test

3.3 Flexural strength test

The flexural strength test is also known as the modulus of rupture test.



a. Non-fiber

b. 0,5 % fiber

c. 1 % fiber

Figure 6. Failure mode under flexural loading

In this test, a concrete beam is subjected to flexure using symmetrical two-point loading until failure occurs as illustrated in Figure 6. Each figure below represents the ultimate failure of three specimens under flexural loading.

A progressive failure for the concrete specimens without fiber as showed in Figure 6a. It is can be seen from Table 3 that the percentage of 0.5% Gunny Sack (CF-2 and CF-5) are the optimum value of the modulus of rupture. Thus, the percentage has better performance in flexural strength compared with other specimens.

3.4 Static Modulus of Elasticity

Table 4 contains the measured values for modulus of elasticity for normal and Gunny Sack fiber concrete. measurements of the static modulus of elasticity were made according to ASTM C469–94 (1996) at 40 percent of ultimate load, using 150x300 mm concrete cylinders tested in uniaxial compression.

The greater modulus of elasticity of normal concrete (non-fiber) compared the Gunny Sack fiber concrete, thus the stiffer of the specimens. The lower modulus of elasticity for fiber concrete both normal and high-strength.

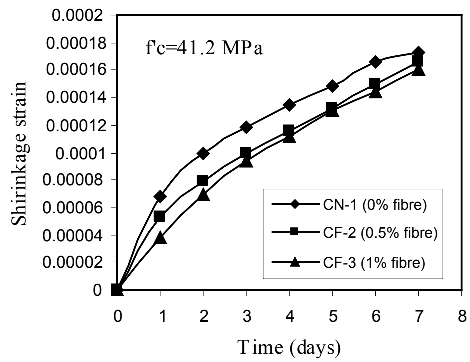
Poisson's ratio tends smaller of higher percentage of Gunny Sack fiber. The lower Poisson's ratio at increasing Gunny Sack percentage shows higher the lateral restraint by Gunny Sack, thus cause the higher strain at peak response (see Table 4).

Table 4. Modulus of elasticity, Poisson's ratio

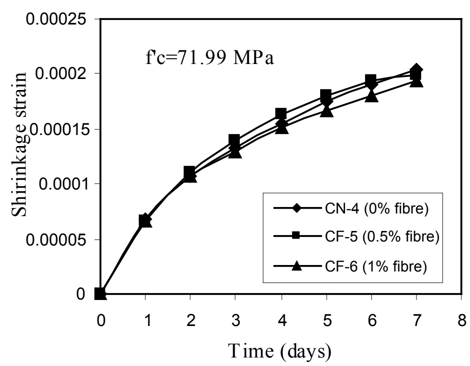
Specimen	Modulus of elasticity (MPa)	Poisson's ratio	Strain at maximum stress
CN-1	22551.98	0.23	0.0026
CF-2	20660.19	0.22	0.0028
CF-3	18485.69	0.21	0.0028
CN-4	24464.94	0.22	0.0031
CF-5	25051.26	0.21	0.0033
CF-6	23378.08	0.20	0.0035

3.5 Shrinkage behaviour

It can be seen in Figure 7, the shrinkage rate increases with decreasing Gunny Sack fiber percentage. Thus, there are uncracking in the microstucture for fiber concrete caused by Gunny Sack.



a. Normal strength concrete



b. High strength concrete
Figure 7. Shrinkage behaviour

4 Conclusions

Based on tests of Gunny Sack fiber both normal and high-strength concrete, the following conclusions are drawn:

1. Gunny Sack is the potential fiber for concrete mixing as one of fiber concrete, while can produced normal and high-strength concrete.
2. Gunny Sack fiber concrete have tends the lower value for compressive strength, modulus of elasticity and poisson's ratio compared normal concrete (non-fiber).
3. Gunny Sack fiber concrete have more ductile behaviour on the stress-strain response although several mechanical properties decrease compared non-fiber concrete as explained above. This properties shows that Gunny Sack fiber concrete also can used as one of the earthquake resistant material.
4. The addition of 0.5% of gunny sack is the optimum value for tensile strength and modulus of rupture.

Recommendation

This research is an initial investigation on Gunny Sack fiber concrete and need to be continued and developed for other behaviour or properties more widely, i.e. the behaviour under cyclic loading, time-dependent behaviour, thermal properties, adding variables (percentage of Gunny Sack), etc.

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