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EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF TEFF STRAW AS A FIBER IN REINFORCED CONCRETE

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Abstract — Concrete has high compressive strength, corrosion and weathering effect are minimal. However, concrete has low tensile strength and easily can be crack due to its characteristics which is brittle. Synthetic fibers were used to one of the effective additives to improve the tensile strength of concrete. But now the construction industry searches environmental friendly and economical construction material. For this specific research, Teff straw fibers were used as a fiber-reinforced concrete material because it's natural, cheap, widely available especially in Ethiopia and it is used to mud plastering for the majority of Ethiopian dwelling traditional houses which is familiar and easy to use as a fiber in conventional concrete to improve its mechanical properties. The main objective of this study is to see the effect of teff straw fiber on compressive, flexural and tensile strength, teff fiber reinforced concrete cubes, cylinders and beams have been tested. On comparing the results with plane concrete cubes, cylinders and beams, strength in 28 days testing become significantly improved its tensile and flexural strength.

Keywords — Teff, Straw, Teff Straw Fiber Reinforced Concrete

I. INTRODUCTION

Teff straw is one of the oldest natural fibers which is used for mud plastering and mud-brick baking as a reinforcement fiber since ancient time in Ethiopia. Natural fibers are cheap and locally available in abundance in many countries. Hence, its use as a construction material costs very little, in fact almost nothing when compared with the total cost of composite. In this way, huge savings can be made by using natural fibers. The benefit of natural fibers over artificial fibers may also include the easy handling of fibers due to their flexibility. This study showed that teff straw fiber reinforced concrete significant improvement in flexural and tensile strength when compared to plane concrete and also teff straw fiber reinforced concrete is a potential alternative light construction method at a low cost.

II. EXPERIMENTAL WORK

In this experimental program, three sets of the experiment have been conducted one is on cubes the second is on cylinder and the other one is on beams.

1. Three 150mm cube samples for each percentage addition of teff straw fiber by weight of concrete (0.00%, 0.10%, 0.20%, and 0.30%); 24 cubes in total for 7th and 28th-day Compressive strength testing were cast.

2. Three cylindrical samples each for percentage addition of teff straw fiber by weight of concrete (0.00%, 0.10%, 0.20%, and 0.30%); 24 cylinders in total for 7th and 28th day split tensile strength testing were cast.

3. Two prismatic (beam) samples each for percentage addition of teff straw fiber by weight of concrete (0.00%, 0.10%, 0.20%, and 0.30%); 16 beams in total for 7th and 28th-day flexural strength testing were cast. Figure 3.6 below shows cube samples, cylindrical samples and prismatic samples cast for testing.

Tests have been conducted to assess the properties of the material used in the experimental program; the results are summarized in Table I.

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TABLE I

PROPERTIES OF MATERIAL USED

Cement	
1. Normal consistency	30%
2. Initial setting time	32 minutes
3. Compressive strength	42.5N/mm^2
4. Tensile strength (after 7 days)	2.55N/ mm^2

Aggregate	
1. Fineness modulus of fine aggregate (river sand)	2.60%
2. Bulk density of 20 mm coarse aggregate	1679.67 kg/m3
3. The specific gravity of coarse aggregate	2.89

Mix Design	
1. Grade of concrete	C 25
2. Water cement ratio	0.59

Teff straw	
1 Density of teff straw fiber	989.67kg/m3

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Mix proportions

The main aim of mix proportioning is to determine the optimum combination of concrete ingredients that will satisfy the performance requirement under a particular condition of use.

Mass of ingredients per unit volume has been the usual concert mix proportion measurements.

Proportioning of concrete by absolute volume method involves calculating the volume of each ingredient and its contributions to making 1m3 of concrete. Volumes are subsequently converted to design weights. These conversations to weights are accomplished by taking the known volumes of ingredients and multiplying by the specific gravity of ingredients and again multiplying by the density of water.

In this specific study mix design of teff fiber reinforced concrete with determined ratios of cement, sand, water, coarse aggregate, and teff fiber were proportioned for C25 concrete grade based on the DOE mix design method. The completed mix design table with the DOE mix design procedure is shown in

Appendix A of this thesis. The wet density of 1m3 of concrete from the DOE mix design method was determined to be 2400Kg/m3. Table 3.5 below of teff fiber by weight of concrete namely 0%, 0.10%, 0.20%, and 0.30%.

Table 3.4; Quantities of materials for each mix in Kg for 1m3 concrete

Mix code	Teff fiber (%)	W/C ratio	For 1m3 of concrete				
			Cement(kg)	Water(kg)	Sand(kg)	Coarse agg.(kg)	Teff fiber (kg)
M0	0.00%	0.59	325	202.7	685	1192.4	0.00
M1	0.10%	0.59	325	202.7	685	1192.4	2.40
M2	0.20%	0.59	325	202.7	685	1192.4	4.80
M3	0.30%	0.59	325	202.7	685	1192.4	7.20

Figure1: Teff straw chopped washed and air-dried

Figure2: Hand Chopping

Testing

The most important experiment which gives an idea about all characteristics of concrete is that compressive strength test. Test for compressive strength is carried out either on cube or cylinder specimens. Various standard codes recommend a concrete cylinder or concrete cube as the standard specimen for the test. ASTM C39/C39M provides a standard test method for compressive strength of cylindrical concrete specimens, for cube test two types of specimens either cubes of 150mm*150mm*150mm or 100mm*100mm*100mm depending upon the size of aggregate are used. In this specific study cubes of 150mm*150mm*150mm size were preferred due to the availability of mold type in the laboratory. These specimens were tested with a compression testing machine after 7 days curing and 28 days curing. The load was applied gradually at the rate of 140 kg/cm2 per minute until the specimens fail. Load at failure divided by area of specimen gives the compressive strength of concrete.

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an amount of stress or force that a beam or slab can withstand from bending failures. The flexural strength is expressed as Modulus of Rupture in (Mpa) and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C293 (center-point loading). Beam samples having 100mm*100mm*500mm sizes were tested after 7 days and 28 days of curing according to ASTM C 78 (third-point loading) standard test methods in this specific thesis.

Splitting tensile strength tests on the concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to

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determine the tensile strength of concrete by finding the load at which the concrete members may crack. Split tensile strength of cylindrical samples having 300mm height and 150mm diameter were tested after 7days or 28 days of curing in accordance with ASTM C496 standard testing methods.

Figure3: Compressive and split tensile strength testing machine & cube and cylinder under loading.

Figure4: Flexural strength testing machine and beam under third-point loading.

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III. ANALYSIS OF RESULTS

These chapter presents, compressive strength, split tensile strength and flexural strength test results of teff straw fiber reinforced concrete with different proportions of teff straw fiber and plain concrete.

3.1 Split tensile strength test

The splitting tensile strength test is an indirect tension test for concrete. It is carried out on a standard cylindrical specimen, tested on its side in diametric compression. In split tensile strength testing, four different percentage addition of teff straw fiber by weight of concrete namely; 0.00%, 0.10%, 0.20%, and 0.30% were undertaken. Three cylindrical samples were tested for each percentage addition of teff straw fiber. Typical failure loads the tensile strength of 28th day TFRC under tensile loading was presented in Table 3.1 as shown below.

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Table 3.1: 28th day split tensile strength test results

Mix-code	Sample No.	Failure load (KN)	Splitting Tensile Strength (Mpa)
M0	1	168.9	2.389
	2	156.6	2.215
	3	152.1	2.151
	Mean	159.20	**2.252**
M1	1	179.8	2.545
	2	185.4	2.622
	3	161.3	2.000
	Mean	175.5	**2.389**
M2	1	220.9	2.746
	2	193.8	2.410
	3	190.0	2.362
	Mean	201.57	**2.506**
M3	1	131.9	1.867
	2	128.2	1.813
	3	138.4	1.957
	Mean	132.83	**1.879**

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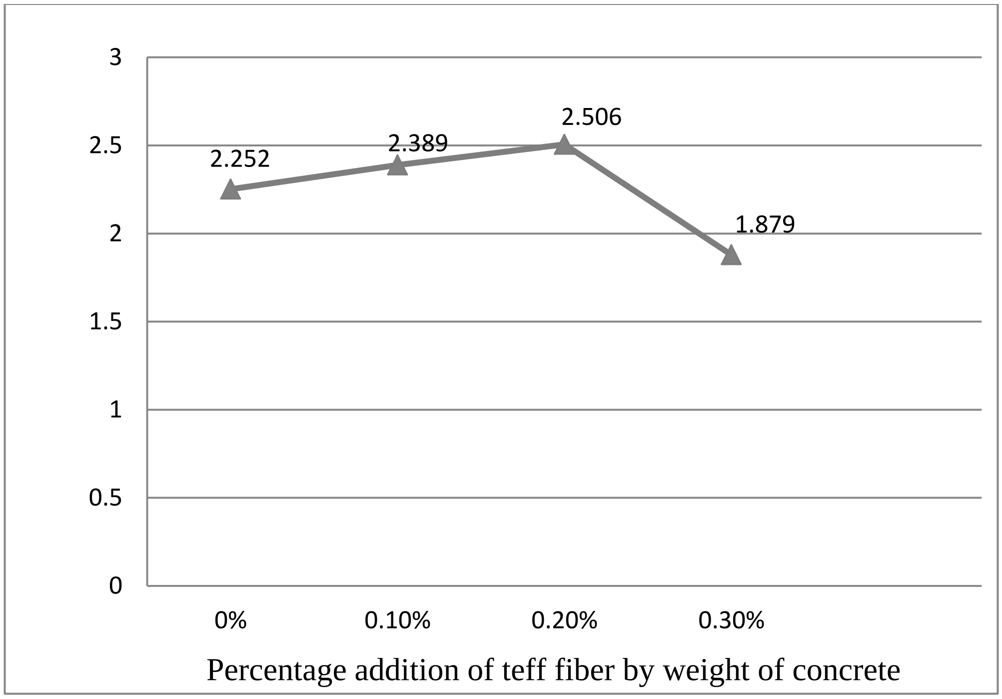

Figure 3.1: Tensile strength chart for each percentage of teff straw fiber addition.

3.2 Flexural Strength test

The flexural strength test gives another way of estimating the tensile strength of concrete. During pure bending, the member resisting the action is subjected to internal stresses (shear, tensile and compressive). For a bending force applied downward for a member simply supported at its two ends, fibers above the neutral axis are generally subjected to compressive stress and those below the neutral axis undergo tensile stresses. For this load and support system, portions near the supports are subjected to relatively higher shear stresses than tensile stresses. For the sake of testing two prismatic samples each for percentage addition of teff straw fiber by weight of concrete namely; 0.00%, 0.10%, 0.20%, and 0.30% were tested with third-point loading in accordance with ASTM C78 standard. Typical failure loads and bending strength of 28th day TFRC samples under third-point loading are presented in Table 3.2 as shown below.

GSJ: Volume 7, Issue 10, October 2019
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Table 3.2: 28th-day flexural strength test results.

Mix-code	Sample No.	Failure load (KN)	Bending Strength (Mpa)
M0	1	7.384	6.646
	2	7.421	6.679
	Mean	7.403	6.662
M1	1	7.501	6.751
	2	7.681	6.913
	Mean	7.591	6.832
M2	1	7.690	6.921
	2	7.784	7.006
	Mean	7.737	6.963
M3	1	8.071	7.264
	2	7.632	6.869
	Mean	7.852	7.066

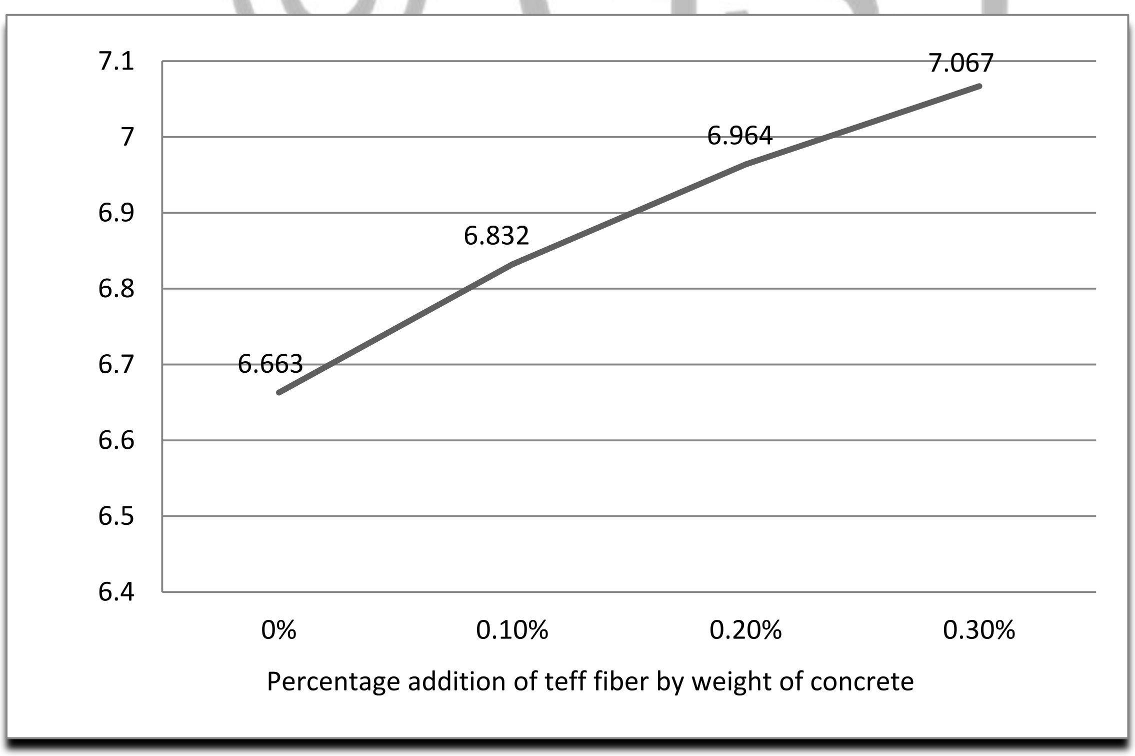

Figure 3.2: Flexural strength chart for each percentage of teff straw fiber addition.

3.3 Compressive Strength test

Three 150mm sized cube samples were tested for each percentage addition of teff straw fiber in this specific thesis. A correction factor is not used in the European standard and 100, 150 or 200mm cubes can be used without correction to the compressive strength obtained from the test when checking for strength class conformity. Typical failure loads and compressive strength of TFRC by the 28th day of 150mm cube samples are presented in Table 3.3 as shown below.

Table 3.3: 28th-day compressive strength test results

Mix-code	Sample No.	The Failure load of 150mm cubes (KN)	Compressive Strength of 150mm cubes (MPa)
M0	1	549.1	24.40
	2	568.2	25.25
	3	572.9	25.46
	Mean	563.4	25.04
M1	1	532.1	23.64
	2	549.4	24.41
	3	542.6	24.11
	Mean	541.37	24.05
M2	1	510.2	22.67
	2	514.9	22.88
	3	517.1	22.98
	Mean	514.07	22.84
M3	1	405.2	18.00
	2	419.4	18.64
	3	422.3	18.76
	Mean	415.63	18.47

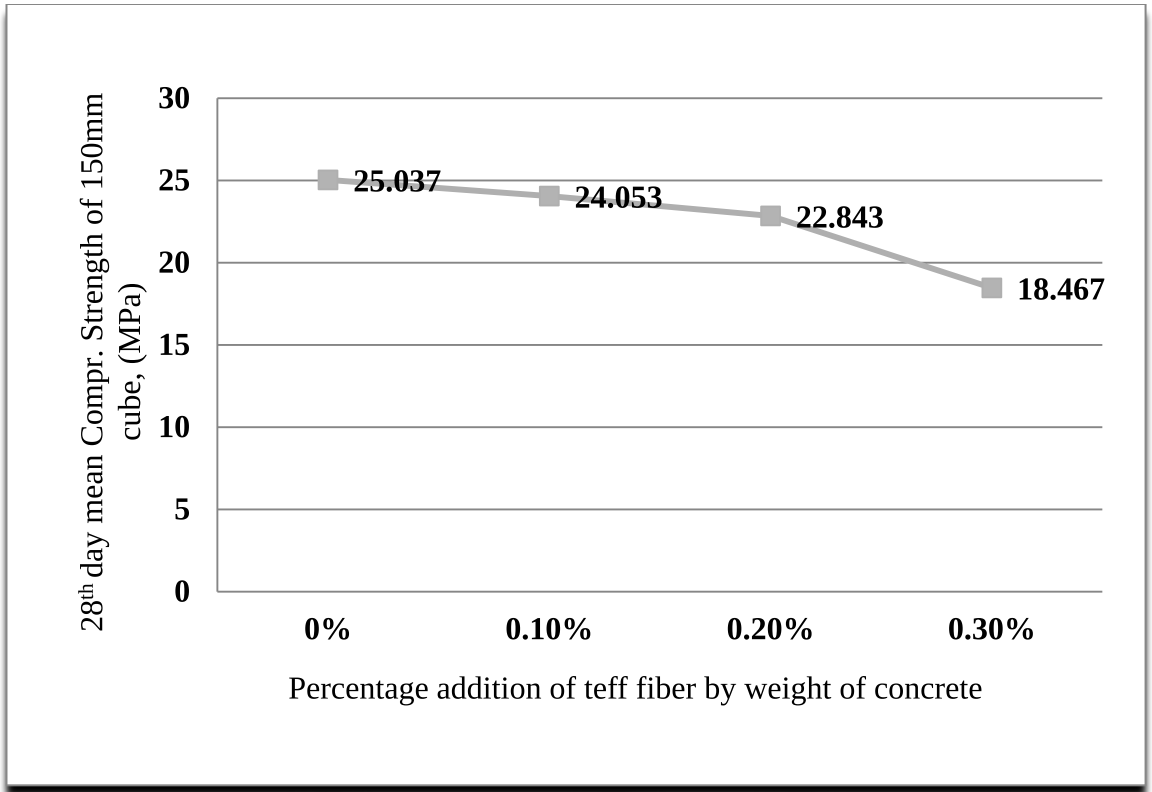

Figure 4.3: Compressive strength chart for each percentage of teff straw fiber addition.

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3.4 Fresh concrete properties

Among the fresh concrete properties slump, test and fresh concrete density tests are investigated for each concrete mixture incorporating 0.00%, 0.10%, 0.20% and 0.30% addition of teff fiber by weight of concrete. Table 4.4 below shows slump and fresh concrete densities for each mix.

Table 3.4: Slump and fresh concrete density test results

Mix-code	Slump (mm)	Fresh Concrete density (Kg/m3)
M0	55	2409.7
M1	30	2362.6
M2	30	2358.5
M3	25	2343.1

Slump results for mixes M1 and M2 in the table above are reduced by 45.45% and 54.55% for mix M3. Slump results of all the mixes presented in the above table comply with the slump range originally assumed in the mix design i.e. (30-60mm and hence do not cause workability problems with the amount of teff straw fiber used in the experiment.

Fresh concrete density for mix M1 (mix with 0.10% teff straw fiber) was reduced by 1.95%, mix M2 (mix with 0.20% teff straw fiber) reduced by 2.12% and mix M3 (mix with 0.30% teff straw fiber) was reduced by 2.76% compared to a reference plain concert.

The balling effect during the mix happened due to high volume percentages of teff straw fiber addition size and quality of coarse aggregate, water-cement ratio, and method of mixing. The balling effect in teff straw fiber reinforced concrete occurred in mixes M2 and M3. Most fiber balling occurs during the fiber addition process and this can be eliminated by care in the sequence and rate of fiber addition.

Even though the slump test reveals that all mixes are workable, increases in aspect ratio, the volume percentage of fibers, size, and quantity of coarse aggregates intensified balling tendencies. Friction between fibers and aggregates controls fiber orientation and distribution.

IV. CONCLUSIONS

Based on the experimental program conducted on mechanical properties of teff straw fiber reinforced concrete (TFRC) regarding laboratory investigations of slump test, fresh density, compressive strength, flexural strength and split tensile strength; conclusions are drawn and recommendations are forwarded on the effect of teff straw fiber addition in concrete.

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5.1 Conclusions

1. There is a significant increase of mean split tensile strength of a teff straw fiber reinforced concrete of 11.28% by 28th day at 0.20% teff straw fiber addition. The split tensile strength of TFRC with 0.10% teff straw fiber has shown an increment of 6.20% which is significant compared to plain concrete. A higher percentage addition of teff straw fiber has not improved the split tensile strength as in the case of 0.30%; which showed a reduced tensile strength result compared to the plain concrete.
2. The 28th-day test results of TFRC incorporating 0.10%, 0.20% and 0.30% teff straw fiber showed flexural strength increment of standard prisms by 2.55%, 4.52%, and 6.06%; respectively, compared to the reference plain concrete.
3. Compressive strengths with 0.10%, 0.20% & 0.30% addition of teff straw fiber by weight of concrete were decreased by 3.95%, 8.79% & 26.23%; respectively, compared to a plain concrete.
4. Among the three teff straw fiber additions under investigation, 0.20% teff straw fiber addition by weight of concrete showed a maximum strength increment in split tensile strength.
5. The slump test of concrete mixes with 0.10% and 0.20% teff straw fibers addition showed reduction by 45.45%; at a constant water-cement ratio and mixes with 0.30%, teff straw fibers showed a slump

reduction of 54.55 compared to the reference plain concrete.

6. The slump values for the three mixes are yet within the acceptable range and workable according to the assumption from the DOE mix design. Fresh concrete density for TFRC with 0.10%, 0.20% and 0.30% teff straw fiber showed reductions of 1.95%, 2.12% and 2.76% respectively, compared to the reference plain concrete. These reductions are not significant and are due to the lesser specific gravity of the teff straw fiber used as a reinforcement.

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