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Original Article

Evaluation of strength properties of concrete using recycled short fibers

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ABSTRACT

This paper deals with the experimental investigation of the use of recycled short fibers in structural concrete to investigate the strength properties of concrete. The study aims to evaluate the differences in strength properties of concrete containing no fibers and concrete with fibers. This investigation has been carried out by conducting a compressive and tensile strength test. The mix batches of concrete containing 0%, 0.25%, 0.75%, and 1.25% dosages rates of recycled steel and nylon fibers were tested to determine the enhancement of the strength properties of concrete. To create cost-efficient fiber-reinforced structures, these changes on fibers are vital to the design and construction. This study results in an increasing rate of compressive strength with the increasing rate of fibers. However, the tensile strength decreases by the increasing rate of nylon wherever steel fiber gives the expected result. However, the concrete with recycled short fibers cannot be used in major structures.

Keywords: Fibers, nylon, strength, universal testing machine

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INTRODUCTION

Many researches have been conveyed using different short fibers such as plastic, hook-ended steel fiber, crimped type steel fiber, jute fiber, and coconut fiber.[1] Special type of fiber such as hook ended and crimped type are costly to form. Organic fiber such as jute[2] and coconut fibers cannot resist tensile force.

An investigation on the properties of concrete with jute fibers was conveyed to effective usage and to reduce the usage of polymer fibers which interns an environmental harm. In that study, raw jute fibers cut to 10 mm were used with the proportionate mix of cement, coarse aggregate, and sand with the water-cement ratio of 0.45. The mixed specimens were casted for different volume content of jute fibers and cured for 3, 7, and 28 days. Compressive strength of casted concrete was increased due to the addition of jute fibers. The highest compressive strength is obtained for fiber content of 0.4%.[3]

Steel fiber reinforced concrete is widely used around the world because it improves the ductility and the energy absorption capacity of the concrete. The steel fiber reinforced concrete results in densed matrix with better bonding between steel and concrete. An incorporation of steel fibers (both long and short) successfully enhances the toughness of fibrous concrete mixtures. The hardness and toughness properties of concrete with steel fibers provide better results against abrasion. That investigation shows that the short steel fiber-concrete mixtures perform better than the long steel fiber mixtures with the same fiber dosages.[4]

An investigation on polyvinyl alcohol (PVA) fibers has been used in geo-polymer concrete to study the toughness and impact properties. PVA provides good chemical bonding with hydration products and good mechanical properties. That paper presented a study of the dynamic behavior of PVA short fibers reinforced geopolymer concrete (PFRGC) PFRGC under Split-Hopkinson Pressure Bar test. The effects of different contents of low-calcium fly ash and PVA fibers on the dynamic mechanical properties of PFRGC were studied. The investigation showed that the ultimate stress of PVA short fibers reinforced geopolymer concrete decreases with increasing PVA fiber volume content. The paper showed the effects of different mass ratios of fibers on the mechanical properties. The

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effect of admixtures on the mechanical properties was studied by scanning electron microscope. The damaged blocks sizes decreased with increasing strain rate.[5]

Nylon fibers have been used because of its more elastic and strength properties than polyester fibers. It has more toughness and abrasion resistance because of its smooth, soft, and lightweight properties, it has been used in concrete.[6] An experimental program to investigate the impact and penetration resistance of concrete, steel fibers, with different shapes, and combined with the use of basalt as a coarse aggregate was used. Polypropylene fibers were used which result in significant effect on penetration depth, entrance crater area, and crack width compared with concrete test panel without internal fibers. Steel fibers also have a significant effect on penetration depth, entrance crater area, and crack width.[7]

Blast furnace slag and fly ashes also have been used as admixtures in concrete. All industrial byproducts which are suitable for use as admixtures in concrete.[8] An investigation on concrete with Regen Ground Granulated Blast furnace Slag (GGBS) and different polycarboxylate ether super plasticizer was used as water reducing admixture. The tests on compressive strength and workability of the concrete with ordinary Portland cement and Portland pozzolana cement with GGBS were done. Admixture was carried out at different curing periods for high grade of concrete to conclude its behavior.[9]

The influence of different plasticizers such as NFS, LSP, and silica fume on cement paste for high-strength concrete production is investigated in a research. These admixtures affect the cement hydration. Different strength properties and porosity of hardened cement paste with the admixtures were tested which results in high-strength concrete production.[10]

A research work has been conveyed out for formation of modified polystyrene concrete. The objectives of work were to get mechanical properties of reinforced concrete wall panels, flat slabs, short span slabs, etc. The laboratory test analyzes result in rational ingredient compositions of a polystyrene concrete mix.[11] Another research on various types of aggregate and admixture to have higher ultimate compressive strength and workability of concrete was conveyed. The compressive strength and workability of concrete were got by using different water-cement ratio.[12] The properties of the composite concrete modified with plastic waste were done to conserve waste from environment. The wastes are utilized in the green concrete.[13]

Concrete is weak in tension that is why the short fibers have been used to evaluate the tensile properties. Cement is used as a binder in concrete. Aggregates are used as inert material. Short fibers have been used as percentages of the weight of concrete. Shorts fibers are thoroughly mixed with other components. In this paper, the waste fibers have been used to recycle and mix with concrete to evaluate the strength properties.

MATERIALS USED IN INVESTIGATION

Since this investigation intends to observe the strength properties of concrete, short fibers have been used as a percentage of the weight of cement. Aggregates of average sizes of ¾ inches have been used. Portland cement has been used as a binder. Short fibers of steel and nylon have been used as a modifier.

Significance of Short Fibered Reinforced Concrete

To resist the defects of concrete, many researchers have done a lot of investigation to improve the properties of concrete. The toughness of concrete is especially improved. It has been investigated that the use of fibers improves the mechanical properties and durability of concrete. The fibers used in concrete materials include steel fiber, glass fiber, polyethylene fiber, polypropylene fiber, polyester fiber, and natural fiber. The effects of fibers on concrete include reinforcing, anti-cracking, and toughening. The anti-cracking indicates the ability to restrict and reduce the formation of shrinkage cracks in the concrete. The reinforcing action decreases the adverse effect of the defects inside the concrete on the strength. Fibers across the cracks inside the concrete improve the toughness of the concrete after cracking.

Steel Short Fiber

This investigation uses the steel fiber dumped after use for construction purposes. Steel fibers [Figure 1] of 1 mm diameter and 2 inches of length were used. Steel provides more tension than other materials. Steel fibers have been chosen to increase the tensile properties of concrete.

Nylon Fiber

Nylon is a completely synthetic fiber that does not contain any organic matter. It is a polyamide having chains of amide groups (-CO-NH-). Its breaking extension is 25–45%. The softening point of nylon-6 is 220°C. The melting point of nylon-6 is 215°C. These are highly shining to dull, white, and colored. These are soluble in HCL. Nylon fiber was cut by 2 inches each [Figure 2].

Figure 1: 2 inches steel and nylon fiber

Tests Conducted in Investigation

Compressive strength test

The compressive or crushing strength of concrete is measured by the compression test [Figure 3]. The test measures the resisting capacity of concrete of external loads which compress it. It is evaluated by crushing cylindrical concrete specimens in universal testing machine (UTM). The cylindrical specimens follow ASTM C-39. Practically, the crushing strength of concrete ranges from 2500 psi to 4000 psi for residential purposes. For some special purposes, 10000 psi is also used.

Compressive Strength Test Specification

Specimen

Cylindrical concrete specimen having diameter 6 inches and height 12 inches. Sulfur capping was done on both sides of the cylinder.

Loading

The loading machine can apply a constant load range of 1.2–2.4 MPa/min. (In general, the test is conducted on the UTM)

Curing period

The test was conducted at the age of 28 days.

Number of specimen

For better results comparison, three samples were tested.

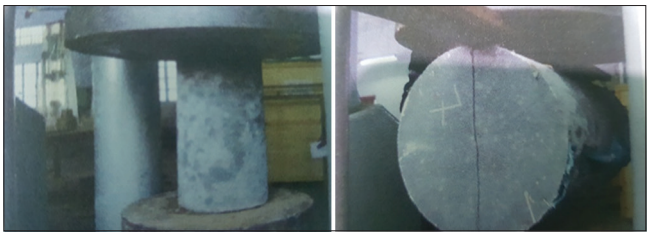


Figure 2: Crushing and tensile strength test

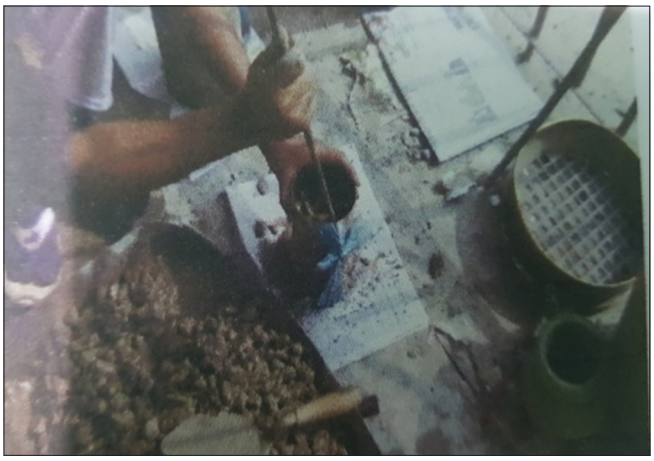


Figure 3: Tamping of aggregate after mixing fibers

Tensile Strength Test

The tensile strength of concrete is the measure of tension resisting capacity. It is measured by the splitting test [Figure 3] of cylinders. The tensile strength is expressed by the units of force per cross-sectional area (N/mm^2 or MPa). Concrete is not solid material like steel which is strong in both tensions as well as compression. Since concrete is a mixture of cement materials, water, and aggregate, it cannot resist more tensile stress. That is why steel and nylon fiber has been used to evaluate whether it improves the tensile properties or not. The tensile strength of concrete is one-tenth of its compressive strength generally.

Tensile Strength Test Specification

Specimen

Cylindrical concrete specimen having diameter 6 inches and height 12 inches.

Loading

Loading was applied axially on the specimens at the rate of 140 kg/cm^2/min till the specimen collapsed.

Curing period

The test was conducted at the age of 28 days.

Specimen quantity

Three samples were tested for better results comparison.

Working Scenario in Laboratory

Short fibers have been mixed thoroughly with aggregates [Figure 4] in mixer machine. Aggregates are mixed in a mixing machine by revolving for 10 min. Fibers are mixed at short intervals. After mixing, the mortar is tamped in the cylinder by a tamping rod [Figure 3]. The aggregates with fibers are tamped by three layers. The sample is failed diagonally in crushing test [Figure 5]. The failure surface is not uniform.

Figure 4: Mixing of short fibers

Curing of Specimen

Concrete curing is done to maintain adequate moisture to control the temperature effect in cement hydration at early ages. Curing is done by ponding [Figure 6], spraying water, covering with wet clothes, etc. A chemical reaction between cement and water called hydration contributes to setting and hardening. The hydration process is affected by the early concrete temperature, the dimensions of the aggregates, and the mix design.[14]

Disadvantages of Improper Curing of Concrete

- Chlorides and other chemicals ingression are increased
- Compressive strength and flexural strength become less
- Cracks in concrete are formed due to shrinkage and thermal effects
- Durability decreases due to higher permeability
- Frost and weathering resistance are decreased
- The carbonation process is increased.

Sulfur Capping

During compression test, sulfur capping [Figure 6] is done to:

- Give a plane and level surface
- Apply force evenly to the entire end surface
- Use for capping because it melts quickly and cools even more quickly, and
- Bond the specimen itself, not moving or sliding around during the breaking process.[15]

Figure 5: Crushed sample after the collapse

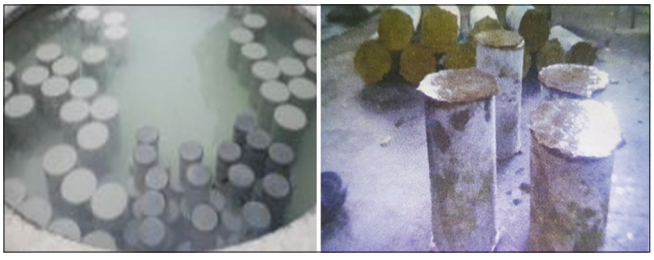


Figure 6: Curing and sulfur capping of the specimen

Data Analysis

After the 28 days curing, the samples were prepared for testing. Compressive strength is found by crushing test by UTM. The crushing strength found from the laboratory is given in Table 1 and tensile strength is found by splitting test by UTM machine. The tensile strength is given in Table 2.

RESULTS AND DISCUSSION

Now-a-days, concrete structures are broadly used all over the world. Many researches have been conveyed to improve the quality of RCC structures. Many admixtures have been used to improve the strength properties of concrete structures. Recently, fibers of jute and coconut have been used, but these are not tension resisting. This research has been conveyed to use recycled tension resisting materials that decrease the amount of dumped wastage of construction materials. Only three proportions of fibers such as 0.25%, 0.75%, and 1.25% have been used. Laboratory investigation concludes that at 0.75% and 1.25%, both the compressive and tensile strengths have been increased more. However, the strength of steel fiber reinforced concrete is more than nylon fibered concrete. From the laboratory test, it is clear that tensile strength is approximately one-tenth of compressive strength. Another

Table 1: Compressive strength test results from laboratory test

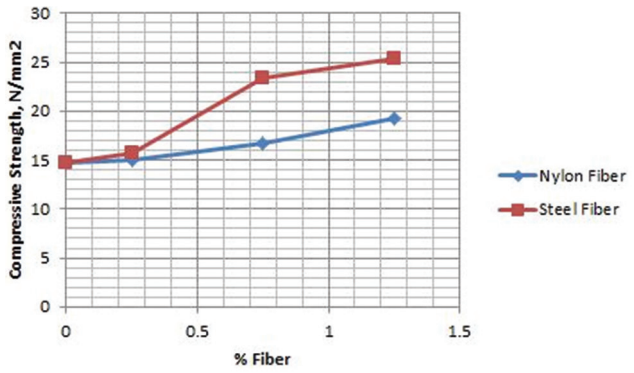
Specimen	% Fibers	Load (KN)	Strength (N/mm^2)	Average (N/mm^2)
None	0	122	15	14.66
		120	14	
		122	15	
Steel	0.25	136	17	15.66
		130	14	
		135	16	
	0.75	175	22	23.33
		178	23	
		182	25	
	1.25	222	27	25.33
		220	26	
		215	23	
Nylon	0.25	128	16	15
		126	15	
		125	14	
	0.75	139	17	16.66
		135	15	
		140	18	
	1.25	165	20	19.33
		162	18	
		165	20	

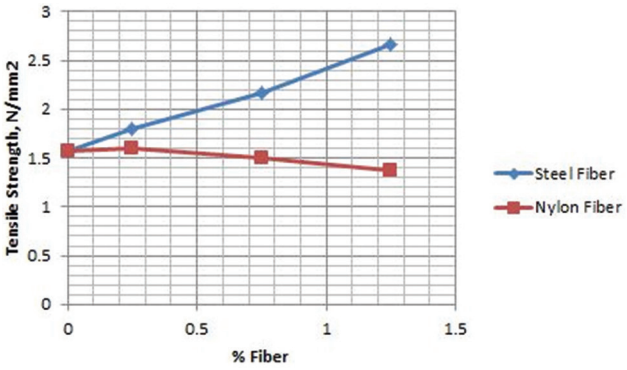
Table 2: Tensile strength test results from laboratory test

Fiber type	% of Fiber	Average Load (KN)	Compressive Strength (N/mm²)	Average (N/mm²)
None	0	125	1.7	1.57
		124	1.6	
		120	1.4	
Steel	0.25	130	1.8	1.8
		132	1.7	
		133	1.9	
	0.75	160	2.2	2.17
		155	2.0	
		162	2.3	
	1.25	198	2.7	2.67
		196	2.6	
		198	2.7	
Nylon	0.25	118	1.6	1.6
		120	1.7	
		116	1.5	
	0.75	108	1.5	1.5
		104	1.4	
		110	1.6	
	1.25	99	1.4	1.37
		96	1.3	
		93	1.1	

more percentages of fiber can be used to evaluate the strength properties of concrete. A small percentages of fibers have been used in this research which is not satisfactory to evaluate the accurate strength properties. However, under the above experimental investigation, it has come to know that strength is increasing with the addition of increasing proportion of fibers that is satisfactory.

Changing of Compressive and Tensile Strength with Respect of % Fiber





CONCLUSION

Steel and nylon fibers dumped after on-site use have been used to recycle. Two tests have been conveyed to investigate the strength properties of fiber-modified concrete. Fibers have been used to mix thoroughly with concrete. It is clear that tensile strength has been increased by the increasing rate of steel fiber inclusion. However, the increasing rate of nylon fiber has decreased the tensile strength. That indicates that nylon fiber can be used in small percentages, but steel fiber can be used in large percentages. More percentages of fiber can be used to investigate the strength properties of fiber-reinforced concrete. Recycled fiber-reinforced concrete cannot be used in major construction, but it can be used in construction of bloc, road divider, etc.

REFERENCES

1. Dahake AG, Charkha KS. Effect of steel fibers on strength of concrete. J Eng Sci Manage Educ 2016;9:45-51.
2. Nishat FM. Effect of Jute Fiber on the Mechanical Properties of Concrete using PCC. Bangladesh: Bangladesh University of Engineering and Technology; 2018.
3. Dayananda N, Gowda BS, Easwara GL. A study on compressive strength attributes of jute fiber reinforced cement concrete composites. IOP Conf Ser Mater Sci Eng 2018;376:012069.
4. Weli SS, Abbood IS, Hasan KF, Jasim MA. Effect of Steel fibers on the concrete strength grade: A review. IOP Conf Ser Mater Sci Eng 2020;888:012043.
5. Xiao SH, Liao SJ, Zhong GQ, Guo YC, Lin JX, Xieb ZH, *et al*. Dynamic properties of PVA short fiber reinforced low-calcium fly ash-slag geopolymer under an SHPB impact load. J Build Eng 2021 44:103220.
6. Orasutthikul S, Unno D, Yokota H. Effectiveness of recycled nylon fiber from waste fishing net with respect to fiber reinforced mortar. Construction and building materials 2017;146:594-602.
7. Aliabdo AA, Abd-Elmoaty AE, Hamdy M. Effect of internal short fibers, steel reinforcement, and surface layer on impact and penetration resistance of concrete, structural engineering department, faculty of engineering. Alex Eng J 2013;52:407-17.
8. Mehta PK. Pozzolanic and Cementitious Byproducts as Mineral

Admixtures for Concrete-a Critical Review. Vol. 79. United States: Symposium Paper; 1983.
9. Anitha J, Pradeepa S, Soni L, Rakshit KB. Influence of admixtures on behavior of concrete. Int J Res Adv Technol 2016;4:16-23.
10. Skripkiūnas G, Rudžionis Z, Vaitkevičius V. Complex admixtures for high-strength concrete. J Civil Eng Manage 2012;8:276-80.
11. Belyakov V, Bannikova L. Study of the effect of recent chemical admixtures on the modified polysterene concrete properties. Proc Engineering 2016;150:1446-51.
12. Gill S, Kumar R. Development of compressive strength and workability of concrete use admixture. Int J Latest Res Sci Technol 2018;7:28-32.
13. Jagadeesh P, Chunchu BR. Influence of admixtures on plastic wastes in an eco-friendly concrete-A review. Int J Civil Eng Technol 2017;8:388-97.
14. Pepe M, Toledo Filho RD, Koenders EA, Martinelli E. A novel mix design methodology for Recycled Aggregate Concrete. Construction and Building Materials. 2016;122:362-72.
15. Wei S, Guo C, Wang L, Xu J, Dong H. Bacterial synthesis of PbS nanocrystallites in one-step with l-cysteine serving as both sulfur source and capping ligand. Scientific Reports. 2021;11(1):1-7.