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Flexural Strength Improvement using Human Hair Fibre (HHF) in Reinforced Concrete

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Abstract: Fibre reinforced concrete contains fibrous material which may increase its structural integrity. It is practically more economical and provides an alternative measure to overcome concrete deficiencies including its weaknesses in tension. In this study, Human Hair Fibre (HHF) is used as the admixture in concrete mix design to reinforce the concrete. With one of the characteristics of HHF as strong in tension, its potential to become alternative concrete reinforcement is significant. Experiments were conducted on concrete beams with the addition of varied percentages of HHF, i.e., 0, 0.5, 1.0, 1.5 and 2.0% by weight of concrete. Flexural strength is investigated. From the testing, it is found that there is an increment of up to 24% of the flexural strength of the concrete with the addition of 2.0% HHF as fibre reinforcement.

Key words: Fibre Reinforced Concrete (FRC), Human Hair Fibre (HHF), flexural strength, structural design, strength, concrete

INTRODUCTION

Observations of concrete cracks is one of the most common in concrete structures. It happens due to various factors includingin consistent weather, load from a permanent load and non-permanent load from one building and shrinkage. To mitigate such problem, Fibre Reinforced Concrete (FRC) has been widely accepted as potential aid to the conventional concrete mixture. FRC enhances concrete durability by keeping the crack tightly closed. It reduces crack width which are due to plastic shrinkage, long-term drying shrinkage and thermal changes. HHF is added during batching and mixing process to allow them to be uniformly distributed throughout the concrete mixture in order to improve the concrete properties in all directions. Other than its abundance availability, HHF is selected as fibre reinforcement in concrete due to its high tensile strength. It is also a non-degradable matter in which the usage of HHF will give benefits to the environment while saving costs. In this study, specimens of five beams were casted to test the flexural strength each with different proportion of HHF; 0, 0.5, 1.0, 1.5 and 2.0%, respectively. For the testing, M-20 grade concrete was used. The curing started 24 h after casting for a period of 7-28 days. The specimens were subjected to flexural test under universal testing machine.

Problem statements: One of the challenges faced in construction activity is to provide more alternatives of material in which it is available at a lower cost and have less impact to the environment. In a demanding construction industry worldwide, it is important to address these issues. HHF has shown its potential usage to strengthen FRC but there is still lack of literature to promote its viability. Thus, this study identifies the impact of using HHF in concrete mixture for a beam of standard size, 150×150×700 mm.

Objectives: The goal of this study is to determine the flexural strength of concrete grade M-20 with and without HHF in its mixture. The HHF is added to the concrete mixture with 0.5% increment from 0-2%. The samples will be tested using universal testing machine.

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Scope and limitation of study: This research covers experimental laboratory work which was conducted at Universiti Teknologi MARA. Limitation comes in the form of limited samples. Due to the several constraints, only flexural strength is tested and recorded with small number of samples.

Significance of study: The findings highlighted from this study may contribute in improving the quality of construction industry. Thus, it helps to promote the usage of green construction material and increase the awareness towards the construction key players in adapting a more environmental-friendly material in their project.

Literature review: On-going studies have been conducted by previous researchers that is related to the application of HHF in concrete mixture. Some of the findings by the mare inclusive of its durability, strength and other benefits such as costing and availability of the HHF. Table 1 shows the summary of previous findings.

Most of the previous studies focussed on the concrete strength through laboratory testing, particularly compressive and flexural strength. This has helped to setup the aim of this study which is to determine the flexural strength of concrete beam of grade M-20. The HHF is added up to 2% by cement weight and compared with the control mix.

Table 1: Summary of previous findings

Researchers	Previous findings
Alyousef (2018)	Studied improvements in mechanical properties of fibred reinforced concrete matrix in terms of compressive and flexural strengths as well as cracking patterns and mode of failure. Experiments were conducted on concrete cubes with varying percentage of Human Hair Fibre (HHF) up to 3% by weight of cement. Outcomes suggest increase in different properties of FRC as the amount human hair fibre reinforcement is increased
Khan and Ali (2018)	Explored the mechanical properties of Hair Fibre Reinforced Concrete (HFRC) and Wave Polypropylene Fibre Reinforced Concrete (WPFRC) used in concrete roads. Found that the compressive, flexural and splitting-tensile strength of HFRC are improved by 12.4, 16.2 and 19.1%, respectively and that WPFRC are increased by 11.7, 21.5 and 17.5%, respectively. With these improvements shown, the concrete road thickness can be reduced by 12.5 mm which may reduce the overall costing
Sancheti and Pais (2018)	The length of hair fibre and its proportion in the concrete matrix has been investigated. The concrete specimens tested at the period of 7 and 28 days. It shows an increase in the flexural strength as compared to the control mix. The results indicated the possibility of using human hairs as fibres in the concrete mix for sustainable construction practices
Vadivel and Jeyakumar (2017)	Conducted experimental work on human hair fibre-based concrete. Recorded remarkable increment in M-20 concrete properties, according to the percentages of hairs by weight (0, 2, 4, 6, 8, 10%). There is an increase of compressive strength and tensile strength. 10% addition gives highest compressive strength and tensile strength compared to other composition
Sreevani and Ajitha (2017)	Conducted experiments on concrete cubes, cylinders and beams of standard sizes with addition of various percentages of human hair fibre, i.e., 0, 0.5, 1 and 1.5% and the results have been compared with plain cement concrete of M-20 grade. The addition of human hairs modifies properties of concrete including tensile strength, compressive strength, binding properties, micro cracking control and spalling resistance
Hiwarkar *et al.* (2017)	Investigated the behaviour of Hair Fibre Concrete (HFC), Fibre reinforced Concrete (SFC) and Plain Cement Concrete (PCC). The load carrying capacity of steel fibre reinforcement concrete is more than hair fibre cement concrete. But as compared to HFC and PCC, the load carrying capacity of HFC is more than PCC. As they used the human hair as fibre reinforcement in concrete, there is an increment in various properties and strength of the concrete
Jain and Hindoriya (2016)	Recorded that the maximum increase in compressive strength is noticed in the addition of 2% hair fibres by weight of cement. Flexural strength of the concrete is found to increase up to 5-15% than normal concrete when hair fibres are used up to 1.5-2% by weight of cement. Crack formation and propagation are very much reduced showing that FRC can have its applications in seismic resistant constructions. However, the use of hair fibres in concrete reduced the workability up to 15-35% than normal concrete
Agrawal *et al.* (2016)	Human hairs were added to the plain cement concrete in 0-5 by weight of cement and is compared for 7,14 and 28 days curing period. For every combination of proportions of concrete cubes and beams were tested for their compressive and flexural strength. Compressive strength increased more than flexural strength when compared with conventional concrete. Average increment in the compressive and flexural strength of FRC is 9 and 6.5%, respectively when compared with Plain Cement Concrete (PCC)
Ali *et al.* (2018)	Focused on the effect of human hair mixture with plain cement concrete with regards to its compressive strength. Based on the test performed to concrete cubes, it shows that there is an increment in properties of concrete depending on the percentages of hairs by weight of cement in the concrete mixture. However, during the laboratory work, the main challenges will be to uniformly distribute the hair fibre in concrete mixture
Nila *et al.* (2015)	Performed laboratory work. Recorded increase of 1-12% in the compressive strength of concrete and up to 5% in the flexural strength of concrete test specimens. It is well observed that the maximum increase is noticed in the addition of 2% hair fibre by weight of concrete, in all the mixes. Crack formation and propagation are very much reduced showing that hair fibre reinforced concrete can have various applications in seismic resistant and crack resistant constructions, road pavement constructions, etc.
Kumar *et al.* (2015)	Studied the effect of human hair on plain cement concrete of M-40 grade. Found that the optimum content of human hair fibre to be added to M-40 grade of concrete is 1.5%. Also observed there has been improvement in terms of compressive strength, flexural strength and split tensile strength corresponding to the percentages of hair by weight of cement in concrete. Human hair fibres enhance the binding properties, micro cracking control, imparts ductility and increases spalling resistance
Jain and Kothari (2012)	Found that the addition of human hairs to the concrete improves various properties of concrete such as tensile strength, compressive strength, binding properties, micro cracking control and increases spalling resistance. Therefore, human hairs are in relative abundance in nature and are non-degradable provides a new era in field of fibre reinforced concrete

Table 2: Concrete mix proportion

Ingredients	Cement	Water	Fine aggregate	Coarse aggregate	Water cement ratio
Weight	375 kg/m^3	225 kg/m^3	649.17 kg/m^3	1059.16 kg/m^3	0.6

Table 3: Details of specimens

		Specimen number	
Items	Descriptions	7 days	28 days
Beam	Without HHF as mixture	5	5
Beam	HHF added in percentage as 0, 0.5, 1.0, 1.5 and 2.0%	5	5

Table 4: Flexural strength of HHF concrete

		Average flexural strength (MPa)	
Specimen	HHF (%)	7 Days	28 Days
Control	0	3.23	4.57
1	0.5	3.28	4.67
2	1.0	3.43	4.83
3	1.5	3.52	5.52
4	2.0	3.59	5.68

MATERIALS AND METHODS

Ingredients used in concrete mix design are Ordinary Portland Cement (OPC), coarse aggregate, fine aggregate, water and HHF as part of the mixture. The handling of mixture is very important as when the fibre is not properly mixed, clump of fibre known as balling effect could occur. Cement content for M-20 grade is 375 kg/m^3 which satisfy the minimum requirement of 300 kg/m^3 of cement content. Design mix proportions of M-20 grade used in the laboratory work are shown in Table 2.

In this study, the total numbers of specimens casted are 20. They were casted with varying proportion in a form of percentage of hair by weight of cement. The flexural strengths of the specimens were tested on day 7 and 28. Table 3 shows the detail of specimens prepared for the testing.

For the concrete beams casting, standard size of 150×150×700 mm wasused and tested under a universal testing machine. The load is increased until the specimen fails. Then, the maximum value of load applied is recorded.

Findings: The flexural strength of concrete grade M-20 have been tested with and without HHF in its mixture. The percentage of HHF added is varying from 0-2% with 0.5% increment for each sample. Table 4 shows the average of the flexural strength recorded from the experiments for the reading on day 7 and 28.

RESULTS AND DISCUSSION

For control mix with 0% of HHF, the average flexural strength recorded on day 7 is 3.23 MPa. Other specimens were added with 0.5, 1, 1.5 and 2% HHF recorded gradual increment on its strength with mixture of 2% HHF as the highest, 3.59 MPa on day 7. As for day 28, the results show a similar trend of steady increases towards the average flexural strength. The control mix recorded 4.57 MPa and again the specimen added with 2% HHF produce the highest reading of 5.68 MPa.

During the laboratory work, it is important to uniformly distribute the HHF in concrete mixture which is a big challenge in this study. It may be improved by shaking the fibres into the mix through a screen after all other ingredients have been added. Another way is to stack and create strands from the HHF to produce reinforcement bars. With more research and findings from this area, the waste from human hair can also be managed effectively by utilizing the HF in construction projects.

Overall, the use of HHF improves the beam flexural strength and will increases by the addition of fibre with most notably 2% of HHF. FRC is well known worldwide but there are still lacking in terms of its application particularly at construction site. Plain concrete is a weak in tension and has a brittle character, thus, FRC may improve the existing practice while enhancing the quality of work at lower cost with little impact to the environment.

CONCLUSION

Based from the tests that have been conducted, the use of HHF improves the beam flexural strength and will increases by the addition of fibre with most notably 2% HHF added produce 5.68 MPa flexural strength of reinforced concrete on day 28. HHF has shown its capability to improve the characteristics of FRC to become a potential aid of conventional materials used at construction site. It gives more alternatives to the industrial key players as it givesmultiple benefits including cost reduction as well as saving the environment by recycling human hair waste. This FRC also has many potential areas of applications including mass concrete structures, pavements, bridge decks, airport runways, tunnel linings, defense installations and other precast products. The fact that a lot of researchers have put effort to prove its applicability as alternate construction material should get more supports from shareholders to ensure that the benefits can be fully utilized in modern construction project.

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