



# EFFECT OF HUMAN HAIR FIBER ON MECHANICAL PROPERTIES OF CONCRETE

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**Abstract-** In the whole world tons of hair are wasted annually, which creates many health problems by damaging our ecosystem. Thus, it is very fruitful for us to use concrete and increase its properties of concrete and save the environment from future crises. The construction industry needs a lot of natural assets like limestone, aggregate, sand etc. to make concrete. These resources are finite and have to consume/expand someday, so an alternative must be adopted to overcome the needs. This paper presents the mechanical properties of concrete when human hair fiber is used as a fiber. A detailed experiment was carried out on three types of concrete specimens i.e. cube, beam and cylinder having different percentages of human hair fiber such as 0%, 1%, 2% and 3 % by weight of cement. In addition in research different lengths of human hair fiber which varied from 20mm to 60mm were used. All the specimens were cast at two different concrete mix proportions i.e 1:2:4 and 1:1.5:3 with a 0.50 water-cement ratio. Furthermore, specimens were tested in Universal Testing Machine at 28 days curing period, for compressive strength, splitting tensile strength and UPV test and flexural strength of concrete. The conclusion from the experiments shows that there is a reduction in the workability of fresh concrete besides that there is an increment found in density and water absorption. Moreover, with increasing the percentage of the human hair fiber, mechanical properties were enhanced.

**Keywords-** Workability, human hair, compressive strength, ultrasonic pulse velocity, flexural and split tensile strength.

## 1 Introduction

Concrete is the most ubiquitous material used after water. Same as water, it is also the need of every person. Because of its high durability, ingredients are easily available, resistant to water and wind, it can be cast in any desired shape and is also economical material and has a low maintenance cost. Nevertheless, it possesses low tensile strength, less ductility and micro cracks. [1] For improving the strength and different properties, in this project, hair fiber is used as fiber in concrete. The purpose of using human hair fiber is to increase tensile strength and it increases the physical and mechanical properties of concrete. Concrete is a brittle material, it is weak in tension and after hardening, it has micro-cracks, which decrease the life span of the concrete structure. [2] Hair is non-degradable material, it causes environmental pollution, which directly affects humans and animals as well. Hence, sometimes using human hair as a fiber in the concrete can increase the properties of concrete. Human hair is used for increasing its strength in tension and reducing the micro-cracks helps, to increase the life period of the structure [3] It is defining characteristic of mammals. Human fiber has recently become eye-catching to researchers, scientists, and engineers as a replacement or with reinforcement in fiber-reinforced concrete composites Human hair is a non-degradable material and is present in a very amount. The cost of Human fiber is almost zero or very cheap cost. [4] Thus, most developing countries also face the same problems as poor countries regarding their disposal and handling. Recent research exposed that the growth speed of hair is 1.25 per month. In a year it is 15cm or 6 inches. By weighting, it is approximate 80 to 100gm per year (Shankar Lal Meghwar2016) [5]. Now consider that annually every Pakistani cuts 80gm hair and the population of Pakistan is 22 million's, its mean production of hair is 17600 tons annually and annually the whole world produces  $6.4 \times 10^6$  tons and now think about those who already dumped in past



years. And same as in past, in future the amount of hair will increase by enhancing in population for controlling this pollution, the researcher took initiative and did research about to how to control earl dangerous evil and then in 1963 human hair invented as a natural fiber and after 2012s it is the part of the construction industry on the specific area. Hair is added to concrete to increase its mechanical properties of concrete. [6] Recent research revealed that if the proportion of hair and concrete ingredients is correct as well as the method of distribution of hair fiber into concrete is correct then the mechanical and physical properties of concrete are easily enhanced. These properties of concrete are changed after adding hair to plain cement concrete [7]. Some countries are working on that used hair in medicine and agricultural industries but the amount of hair is too high. Thus, the remaining part affects our environment. Many types of fibers are used in concrete as fiber but the problem is, that they are all not renewable. Human hair is waste material in most of the world. Some countries are working on that used hair in medicine and agricultural industries. Therefore, it directly damages to people in future Therefore, it directly damages people in future. That's why the global wise now trend changed toward hair, as fiber in concrete. [8] This study was checked the effect of hair Fibers on the mechanical properties of concrete. Environmentally friendly, sustainable & economic concrete. For improving the strength and different properties, in this project, human hair is used as fiber in concrete. The purpose of using human hair fiber increases the mechanical properties of concrete. This study is found that by using human hair not just mechanical properties are increased same as physical properties. This study is of interest to clients, concrete manufacturers, concrete additive manufacturers and designers' specifiers who need to know what effect human hair as fiber additives have upon the final compressive strength, split tensile strength and flexural strength.

## 2 Experimental Procedures

The experimental work was performed in the laboratory. In this experimental work two categories of tests are performed by "ASTM" procedures. First for fresh concrete and second for hardened concrete. Moreover, the complete detail of each material used in the whole project is also explained. The concrete laboratory of UET TAXILA is used for all experiments work. [9] Ordinary Portland cement was used as the main binding material followed by ASTM C150 Properties of Ordinary Portland cement are shown in table 1 properties of inert material in table 2 and properties of human hair fiber in table 3.

Table 1 Properties of OPC

Chemicals	SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	P <sub>2</sub> O <sub>3</sub>	LOI
Ordinary Portland cement	17.4	-	10.2	3.6	-	1.8	62.3	0.9	1.4		0.9

Table 2 Properties of inert materials

Properties	Fine aggregate (F.A)	Coarse aggregate (C.A)
Specific gravity	2.7	2.65
Water Absorption (% age)	1.2	0.54
Fineness modulus	2.99	-

Table 3 Properties of the human hair fiber

Properties	Ranges
Hair length	20mm to 60mm
Hair Diameter	80 to 150 μm
Tensile Strength of human hair fiber	359 Mpa



### 3 Research Methodology

#### 3.1 Specimen preparation

In this extensive research work, all specimens are made and cured. The materials used during casting were also the same as ASTM standards. The purpose of this code is to cast the specimen's accurate control of the material and gain high strength. This standardized requirement provides the way how to prepare the sample, mixing of concrete and the curing of concrete test specimens under laboratory condition. All specification is done then the stipulated strength is achieved. The treatment of human hair is essential for gaining the required properties. [10] Most of the time hair is oily. This oil can be effective during bonding between materials of the concrete and not good for bonding. Besides, same as wastage and dust are also affected by it. Hair was collected from different barbershops and parlours. While collecting many wastages (tissue paper, blade and paper) were present [11] Thus, it is a very important step to clear all hair from these wastages and just used hair during mixing time as a filler in concrete. The sorting method is very important for concrete. Grouping is done on the base of the cooler, length and diameter of the hair. Color and diameter are checked randomly done by eyes but the length is checked according to the required length by scale. In this project, the required length is 20mm to 60mm. By giving a lot of time hair was categorized accurately in length. Scaling and grouping of human hair fiber are shown in Figure 1. The third step of the hair treatment is washing. In which head & shoulder shampoo is used. The intention of using this chemical it gives very good results for hair to remove all types of impurities. After the washing hair is dry in the oven and sunlight. Washing of hair and drying of hair are shown in Figure 2.



Figure 1: human hair treatment, a. Scaling of hair, and b. Grouping the human hair



Figure 2: human hair treatment, a. washing of human hair, and b. drying the human hair



Casting Procedure in this work, the casting of cylinders and beams and cubes was done. But it depends on proportion to proportion and conventional concrete samples and human hair fiber samples were cast for 28 days are the curing span. The different concrete mixes ratio 1:2:4 proportion and 1:1.5:3 proportion with the water /cement ratio is 0.50 with the percentage of human hair fiber was 1%, 2% and 3%. used. Casting and testing of beams are shown in Figure 3, Casting and testing of cylinders are shown in Figure 4, and Casting and testing of cubes are shown in Figure 5.

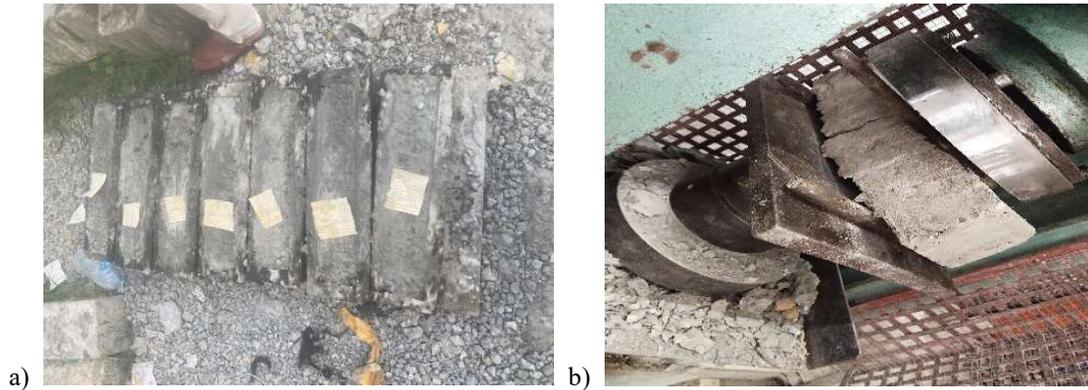


Figure 3: Beam, a. casting of the beam, and b. testing of beam

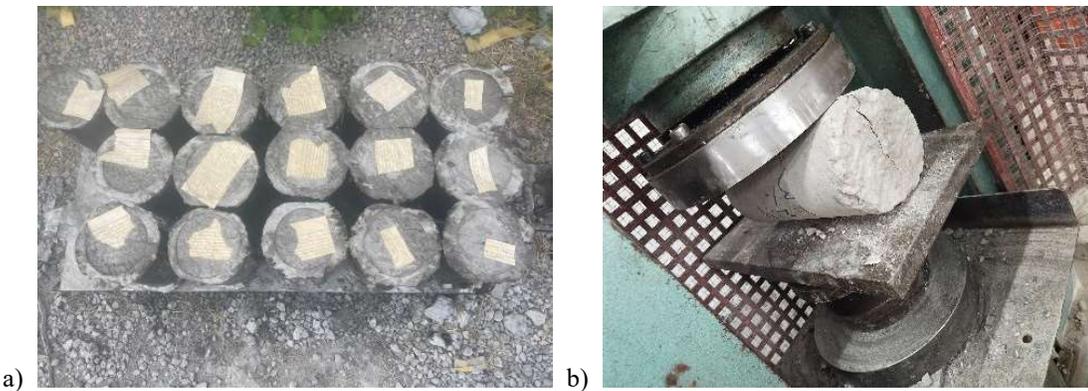


Figure 4: Cylinders, a. casting of Cylinders, and b. testing of cylinder



Figure 5: Cubes, a. casting of cubes, and b. testing of cube



## 4 Results

The practical work was done in the laboratory for checking the mechanical properties of the concrete. The experiment results show the strength of the concrete is increased. Not just the mechanical properties, but the physical is also enhanced. The results of all tests show, that the optimum value of hair is 2%. The maximum values of all tests are noted on the point of 2% hair. And all values are compared with conventional concrete and the value of human hair use in concrete is more as compared to normal concrete. The workability of the concrete is decreased by increasing the percentages of the hair. For workability slump test is conducted as the hair increase, workability decreases and the balling effect is also increased while mixing. During filling the cone of the slump, hair makes more voids than the hammer is used for good compaction. Different types of tests and properties investigate workability, density, Modulus of elasticity, compressive strength, splitting tensile strength and UPV test and flexural strength of concrete and the result is given below.

### 4.1 Workability

The workability of concrete in the terms of the slump test was investigated. Results showed a decrease in the slump values with an increase's percentage of the human hair fibre. The value of Slump is noted as higher and lower at 1:1.5:3 mix proportion of 90mm and 30mm than 1:2:4 mix proportion of 50mm and 9mm at 0% of human hair and 3% of human hair fiber respectively. Graph show comparison between both mix respectively increases the percentage of hair a), and reduction of slump value increases the percentage of hair b) are shown in figure 6.

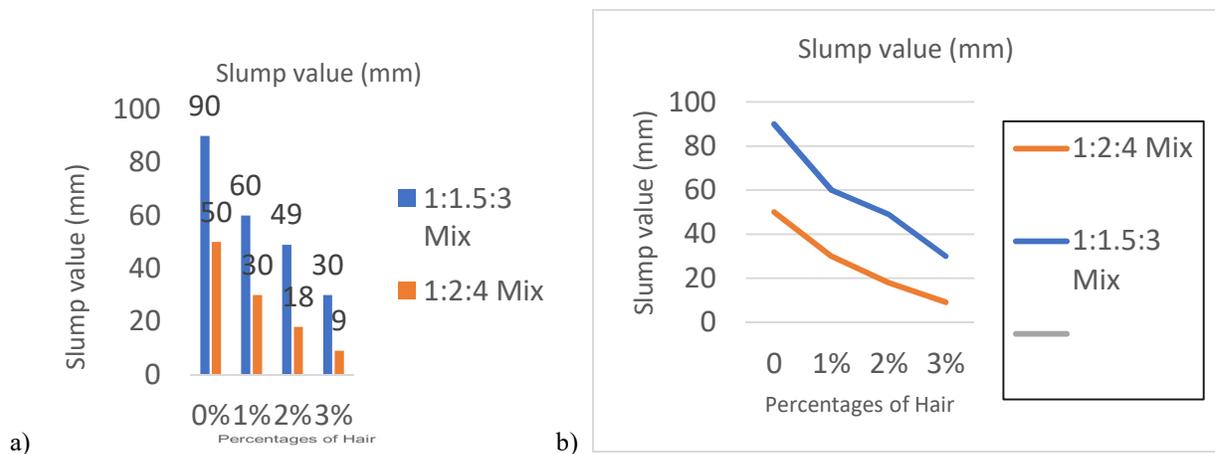


Figure 6: Slump value of concrete, a. graphically comparison between both mix, and b Reduction of slump value by increasing hair

This experiment results of both mixes proportions 1:2:4 mix proportion and 1:1.5:3 mix proportion respectively are shown in table 4.

Table 4 Result of Slump cone test

Mix percentage of hair	Slump value (mm) 1:2:4 Mix	Slump Value (mm) 1:1.5:3 Mix
0 % of hair	50	90
1 % of hair	30	60
2% of hair	18	49
3% of hair	9	30

### 4.2 Density of concrete

The density of the concrete is measured at each percentage of the human hair fiber to know the relationship between the strength and density of concrete. The maximum density is noted at 0% of the human hair fiber, while the minimum at 3%



of human hair fiber both mix proportions 1:2:4 and 1:1.5:3 respectively. Results showed the decrease in the density values with an increase's percentage of the human hair fiber. Graph show comparison between both mix respectively increases the percentage of hair a), and reduction of density value increases the percentage of hair b) are shown in figure 7.

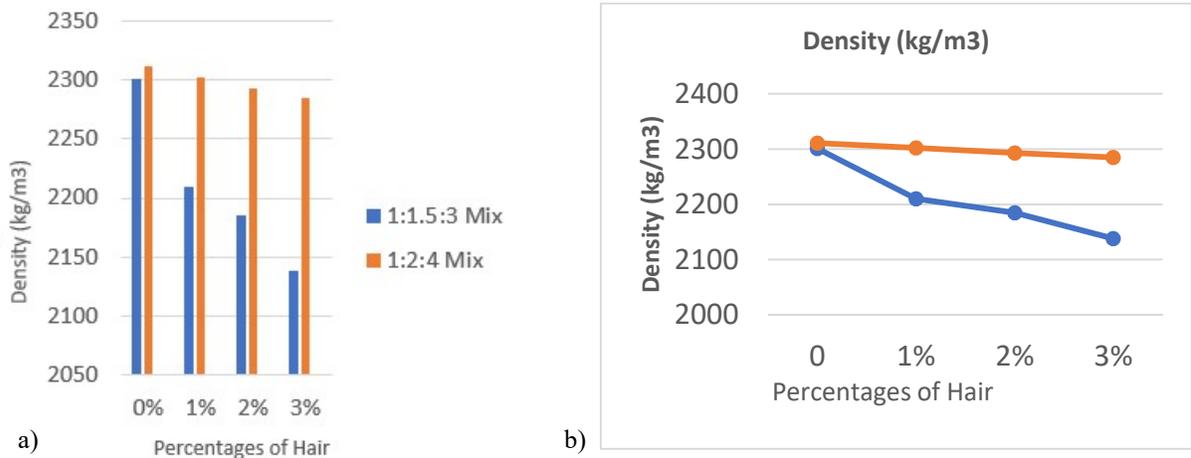


Figure 7: Density of concrete, a. graphically comparison between both mix, and b reduction of density value by increasing hair

This experiment results of both mixes proportions 1:2:4 mix proportion and 1:1.5:3 mix proportion respectively are shown in table 5.

Table 5 Result of density of concrete

Mix percentage of hair	Density (kg/m <sup>3</sup> ) 1:2:4 Mix	Density (kg/m <sup>3</sup> ) 1:1.5:3 Mix
0 % of hair	2311	2301
1 % of hair	2302	2210
2% of hair	2293	2185
3% of hair	2285	2138

### 4.3 Compressive strength of Concrete

The test was performed on cubes of size 150mmX150mmX150mm to check the compressive strength of concrete by using human hair fibre. The compressive strength of concrete is investigated during 28 days curing period. The compressive strength of concrete is determined by the following ASTM C39/C 39M – 03. The standard cube specimens were placed in the Universal Testing Machine and the load applied all specimens at each proportion of human hair fiber was tested and then the average is taken. The compressive strength increases gradually with an increase in the percentage of Human hair fiber in both concrete mix proportions as compared to plain concrete, till it increases the compressive strength by increasing the human hair fiber and maximum value achieved at 2% of human hair fiber in both Mix ratio 1:2:4 and 1:1.5:3 respectively. After that increasing the compressive strength to 5.84% at 1 % human hair fiber and 9.59 % at 2% human hair fiber and 3.13% at 3% human hair fiber by using a concrete proportion 1:2:4 mix and 5.96 % at 1% human hair fiber and 8.15% at 2 % human hair fiber and 3.58% at 3% human hair fiber by using 1:1.5:3 mix ratio respectively. Results showed an increase in the compressive strength with an increase's percentage of the human hair fibre. Graph show comparison between both mix respectively increases the percentage of hair a), and increment of compressive strength increases the percentage of hair b) are shown in figure 8.

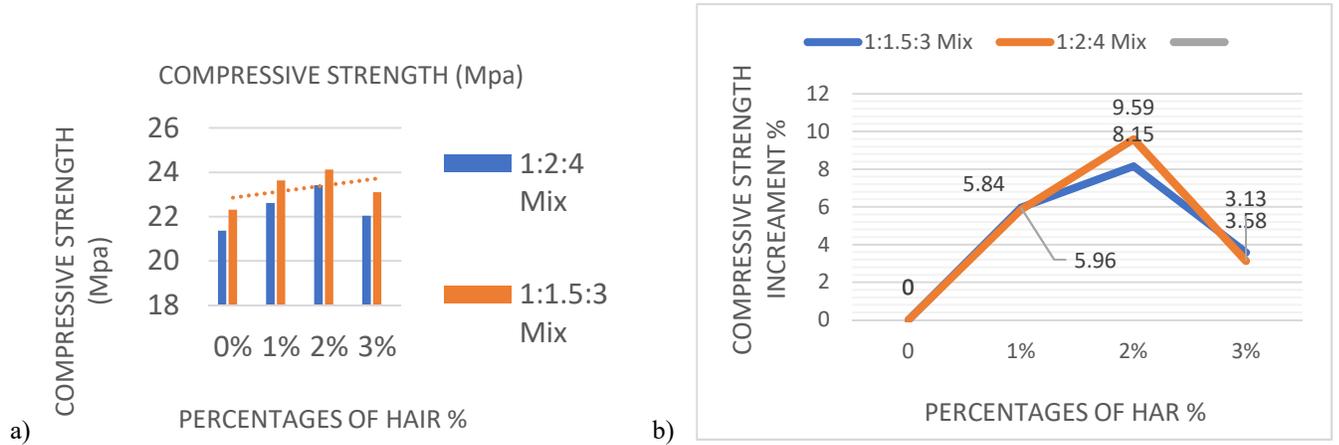


Figure 8: Compressive strength, a. graphically comparison between both mix, and b Increment of compressive strength by increasing hair

This experiment results of both mix proportion 1:2:4 mix proportion and 1:1.5:3 mix proportion respectively are shown in table 6.

Table 6 Result of compressive strength

Mix percentage of hair %	Compressive strength (Mpa) 1:2:4 Mix	Compressive strength (Mpa) 1:1.5:3 Mix
0 % of hair	21.37	22.31
1 % of hair	22.62	23.64
2% of hair	23.42	24.13
3% of hair	22.04	23.11

#### 4.4 Splitting tensile strength of Concrete

The Splitting tensile strength of the concrete is indirectly to tensile strength of concrete. This test was performed on the concrete cylinders. The maximum tensile strength value has been noted at 2% of hair and code by following the ASTM code C-496. After that increasing the Splitting tensile strength to 16.58 % at 1 % hair and 19.9 % at 2% hair and 9.95% at 3% hair by using a 1:2:4 mix ratio and 3.47 % at 1% hair and 6.56 % at 2 % hair and 1.58% at 3% hair by using 1:1.5:3 mix ratio respectively. As compared to both mix ratios percentage of increase in Splitting tensile strength in mix ratio 1:2:4 is more than compared mix ratio 1:1.5:3 respectively. Results showed an increase in the Splitting tensile strength with an increase's percentage of the human hair fibre. Graph show comparison between both mix respectively increases the percentage of hair a), and increment of Splitting tensile strength increases the percentage of hair b) are shown in figure 9.

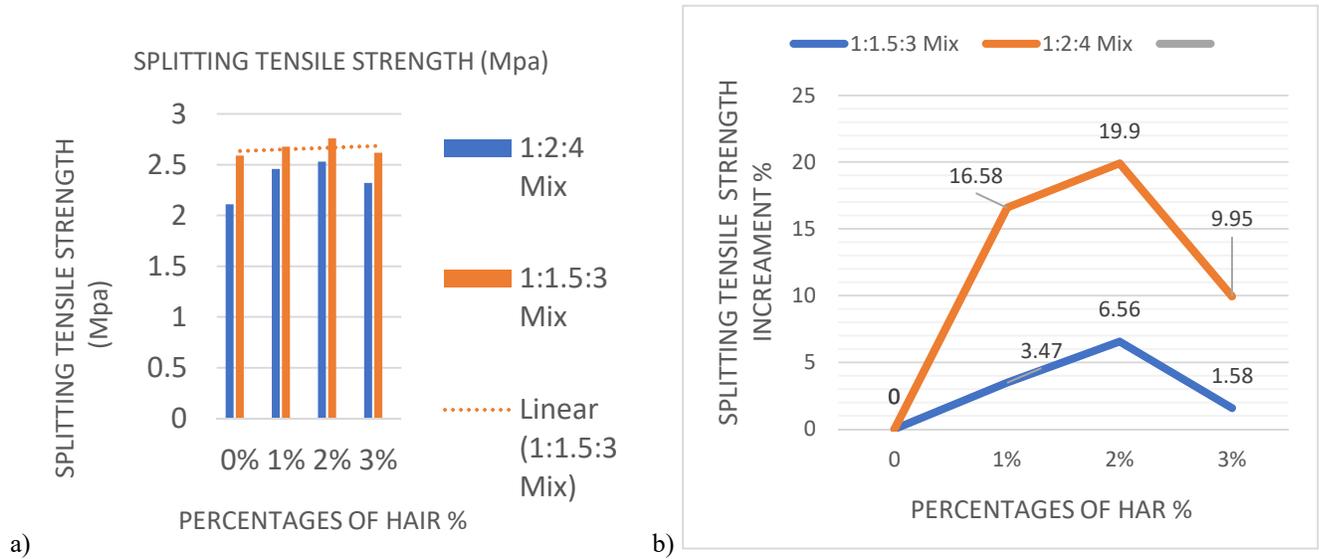


Figure 9: Splitting tensile strength, a. graphically comparison between both mix, and b Increment of Splitting tensile strength by increasing hair

This experiment results of both mixes proportions 1:2:4 mix proportion and 1:1.5:3 mix proportion respectively are shown in table 7.

Table 7 Result of Splitting tensile strength

Mix percentage of hair %	Splitting tensile strength (Mpa) 1:2:4 Mix	Splitting tensile strength (Mpa) 1:1.5:3 Mix
0 % of hair	2.11	2.59
1 % of hair	2.46	2.68
2% of hair	2.53	2.76
3% of hair	2.32	2.62

#### 4.5 Flexural Strength of Concrete

The flexural strength of the concrete test is performed on the beam. By using the center point loading method. This method also gives the indirectly tensile strength of the concrete. The ratios of hair were used 0%, 1%, 2% and 3% and the curing span were 28 days. After that increasing the flexural strength by 15.9% % at 1 % hair and 21.1 % at 2% hair and 10.3% at 3% hair by using a 1:1.5:3 mix ratio and 11.98 % at 1% hair and 17.8 % at 2 % hair and 9.93 % at 3% hair by using 1:2:4 mix ratio respectively. The optimum value is 2% of human hair. Results showed an increase in the flexural strength with an increase's percentage of the human hair fiber. Graph show comparison between both mix respectively increases the percentage of hair a), and increment of Flexural strength increases the percentage of hair b) are shown in figure 10.

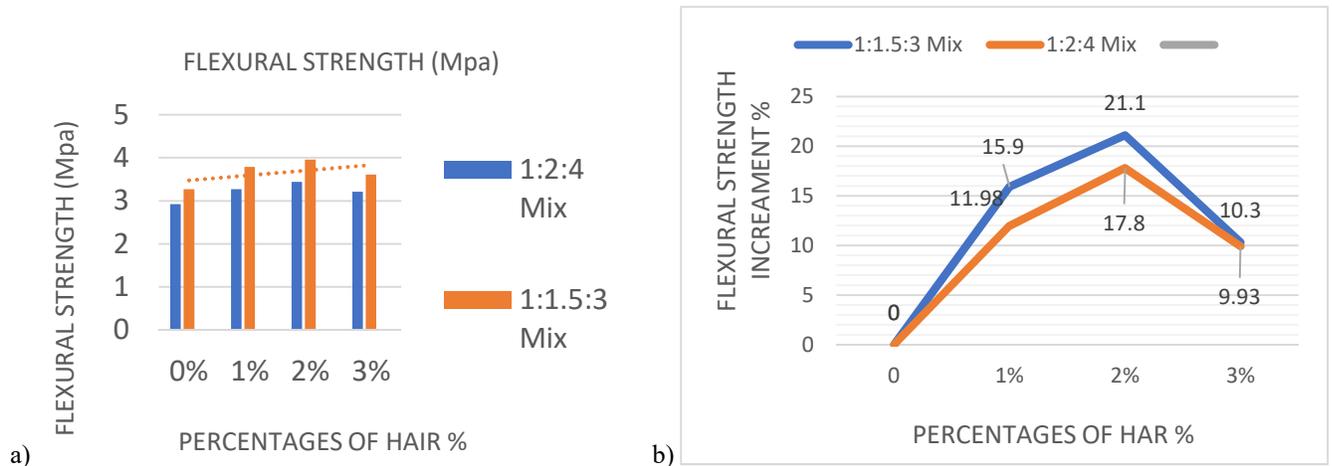


Figure 10: Flexural strength, a. graphically comparison between both mix, and b Increment of Flexural strength by increasing hair

This experiment results of both mixes proportions 1:2:4 mix proportion and 1:1.5:3 mix proportion respectively are shown in table 8.

Table 8 Result of Flexural strength

Mix percentage of hair %	Flexural strength (Mpa) 1:2:4 Mix	Flexural strength (Mpa) 1:1.5:3 Mix
0 % of hair	2.92	3.27
1 % of hair	3.27	3.79
2% of hair	3.44	3.96
3% of hair	3.21	3.61

#### 4.6 Ultrasonic Pulse Velocity (UPV) Test of Concrete

The quality of concrete was determined by a non-destructive UPV test by using directly the method. Results Shown an increase in the UPV value with an increase's percentage of the human hair fiber. Graph show comparison between both mix respectively increases the percentage of hair a), and increment of Ultrasonic Pulse Velocity increases the percentage of hair b) are shown in figure 11.

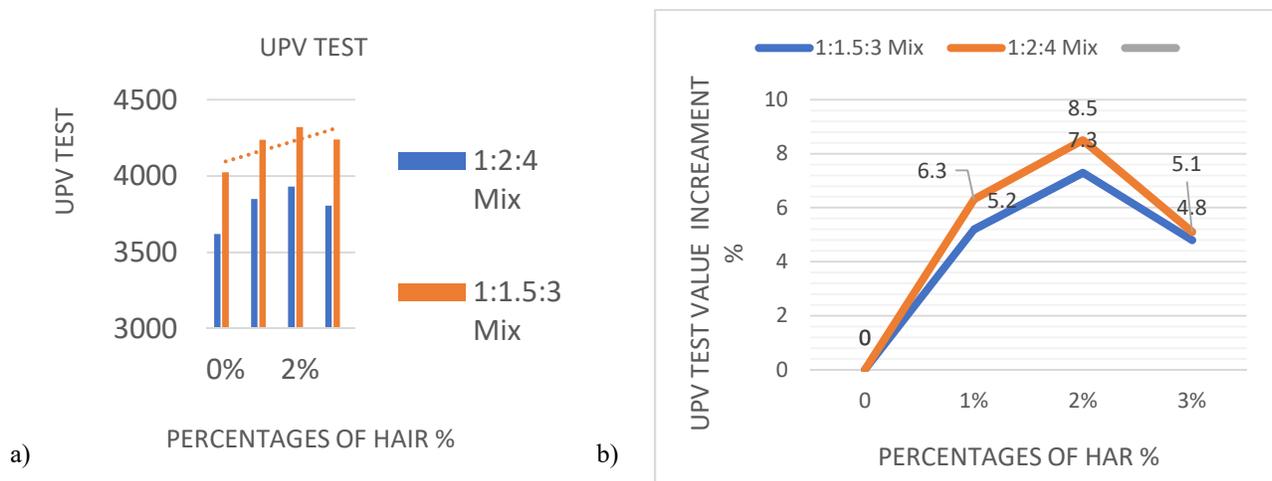


Figure 11: Ultrasonic Pulse Velocity, a. graphically comparison between both mix, and b Increment of Ultrasonic Pulse Velocity by increasing hair



This experiment results of both mixes proportion 1:2:4 mix proportion and 1:1.5:3 mix proportion respectively are shown in table 9.

Table 9 Result of Ultrasonic Pulse Velocity

Mix percentage of hair %	Ultrasonic Pulse Velocity 1:2:4 Mix	Ultrasonic Pulse Velocity 1:1.5:3 Mix
0 % of hair	3620	4024
1 % of hair	3850	4238
2% of hair	3930	4320
3% of hair	3805	4240

#### 4.7 Modulus of elasticity of Concrete

The Modulus of Elasticity is checked concrete resistance and elastic deformation and elasticity module defines stiffness higher elasticity modulus of the material, The optimum value at 2% of human hair. Results Showed the increase Modulus of elasticity with an increase's percentage of the human hair fiber. Graph show comparison between both mix respectively increases the percentage of hair a), and increment Modulus of elasticity increases the percentage of hair b) are shown in figure 12.

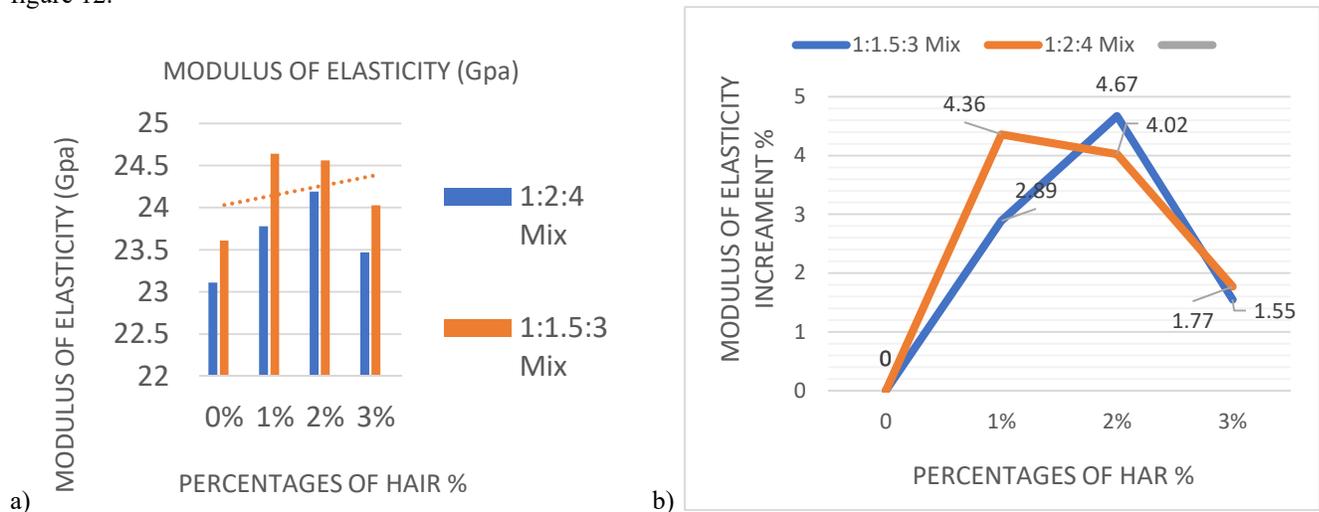


Figure 12: Modulus of elasticity, a. graphically comparison between both mix, and b Increment of Modulus of elasticity by increasing hair

This experiment results of both mixes proportion 1:2:4 mix proportion and 1:1.5:3 mix proportion respectively are shown in table 10.

Table 10 Result of Modulus of elasticity

Mix percentage of hair %	Modulus of elasticity 1:2:4 Mix	Modulus of elasticity 1:1.5:3 Mix
0 % of hair	23.11	23.61
1 % of hair	23.78	24.64
2% of hair	24.19	24.56
3% of hair	23.47	24.03



#### 4.8 Water Absorption of Concrete

The concrete samples were tested water absorption of concrete and water absorption property was increased with increasing the percentage of human hair, addition to the water absorption in concrete may be human hair absorbs more water as compared to the control mix of concrete. Graph show comparison between both mix respectively increases the percentage of hair a), and increment water Absorption increases the percentage of hair b) are shown in figure 13.

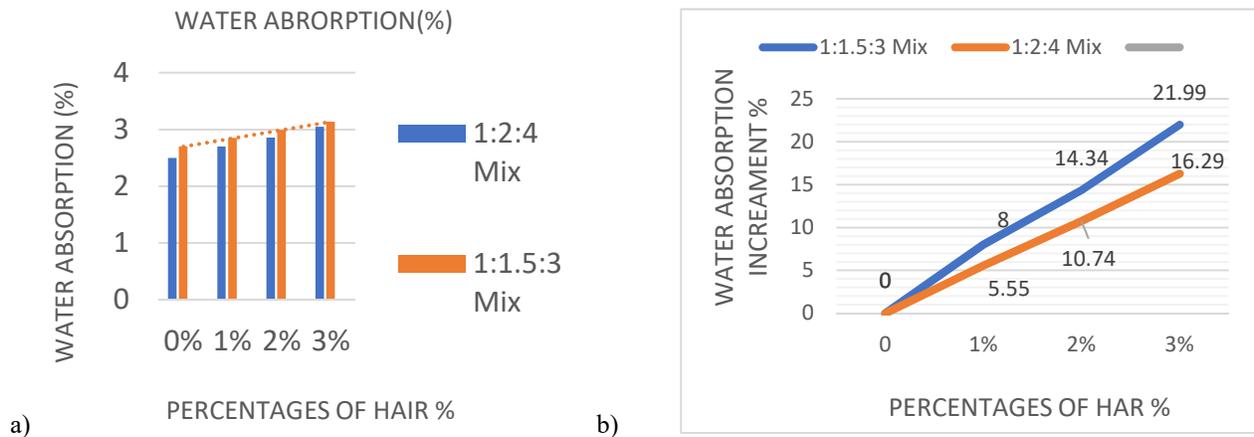


Figure 13: Water Absorption, a. graphically comparison between both mix, and b Increment of Water Absorption by increasing hair

This experiment results of both mixes proportion 1:2:4 mix proportion and 1:1.5:3 mix proportion respectively are shown in table 11.

Table 11 Result of compressive strength

Mix percentage of hair %	Water Absorption (%) 1:2:4 Mix	Water Absorption (%) 1:1.5:3 Mix
0 % of hair	2.50	2.70
1 % of hair	2.70	2.85
2% of hair	2.86	2.99
3% of hair	3.05	3.14

## 5 DISCUSSION

The practical work was done in the laboratory for checking the mechanical properties of the concrete. The experiment results show the strength of the concrete is increased. Not just the mechanical properties, but the physical is also enhanced. The results of all tests show, that the optimum value of hair is 2%. The maximum values of all tests are noted on the point of 2% hair. And all values are compared with conventional concrete and the value of human hair use in concrete is more as compared to normal concrete. The workability of the concrete is decreased by increasing the percentages of the hair. For workability slump test is conducted as the hair increase, workability decreases and the balling effect is also increased while mixing. During filling the cone of the slump, hair makes more voids than the hammer is used for good compaction.

## 6 Conclusion

These are the following conclusions are shown at the end of this comprehensive research work:

- 1 Workability in terms of slump value decreases with an increase in the percentage of human hair fiber a lower value is recorded at 3% of the human hair fiber. Comparatively, a higher slump value is noted at 1:1.5:3 mix proportion.



- 2 The density of concrete decreases as the percentage of human hair fibers increases. Reduction in density is 1.12% and 7.15% at 1:2:4 and 1:1.5:3 mix proportion respectively.
- 3 The compressive strength increases to 9.59 % and 8.15% in 1:2:4 and 1:1.5:3 mix proportion respectively at 2% addition of human hair fiber and it decreases at other percentages of hair fibers and the same as Modulus of Elasticity of concrete is maximum noted at 2 % addition of human hair fiber.
- 4 The splitting tensile strength of concrete increases to 19.9 % and 6.56% in 1:2:4 and 1:1.5:3 mix proportion respectively at 2% addition of human hair fiber and it decreases at other percentages of hair fibers.
- 5 The flexural strength of concrete by using human hair fiber in concrete increases to 17.8% and 21.1% in 1:2:4 and 1:1.5:3 mix proportion respectively at 2% addition of hair fibers. It decreases at other percentages of human hair fibers.
- 6 The UPV value of concrete by using human hair fiber in concrete increases to 8.5% and 7.3% in 1:2:4 and 1:1.5:3 mix proportion respectively at 2% addition of hair fibers.
- 7 The concrete samples were checked the water absorption of concrete and maximum water absorption was noted 16.29 % at 3% of hair mix ratio 1:1.5:3 and 21.99 % at 3% of hair mix ratio 1:2:4 respectively, and minimum water absorption was noted by at 0% of hair after 28 days. After that increasing the water absorption to 8 % at 1 % human hair fiber and 14.34 % at 2% human hair fiber and 21.99% at 3% human hair fiber by using a concrete proportion 1:2:4 mix and 5.55 % at 1% human hair fiber and 10.74% at 2 % human hair fiber and 16.29% at 3% human hair fiber by using 1:1.5:3 mix ratio respectively.
- 8 Comparatively, a higher value in both strengths was recorded at a 1:2:4 mix proportion rather than a 1:1.5:3 mix proportion at the same water/cement ratio.

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