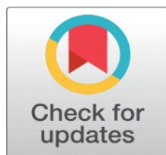


# EFFECT OF HEMP FIBER RATIO ON COMPRESSIVE STRENGTH

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## ABSTRACT

Material science has been developed day by day in the construction industry. Therefore, solutions must be easily applicable, ecological, and economic. Within the scope of this study, with the addition of hemp fiber additive at different rates (0.25%, 0.50%, and 0.75%) the effect of the fibrous concretes formed on the 7 and 28 days concrete compressive strength was investigated experimentally. Reference samples (3 for 7-day strength, 3 for 28-day strength) and a total of 24 10x10x10 cm cube samples were prepared, 18 of which were hemp fiber reinforced. As a result, It was observed that the desired compressive strength was exceeded in the 0.25% added samples, and the targeted compressive strength was not reached in the other fiber-added samples.

**Keywords:** Compressive Strength, Concrete, Fiber, Hemp Fiber

## 1. INTRODUCTION

With the increasing population in our country, the need for construction is increasing day by day. Resulting of these global waste problems, environmentally friendly approaches, prompted research on sustainable materials [Dai & Fan \(2010\)](#). In today's construction institute ecology and sustainability are of great importance. In this context, producing ecological concrete and to minimizing energy consumption the use of sustainable materials in concrete should be increased. In this context, when we consider hemp, which is a sustainable material; environmentally friendly, low cost, easy to process and due to its high mechanical properties, it has become an important material day by day [Demirbek & Bulut \(2021\)](#).

Hemp fibers are used as a building material since it is natural and recyclable, carbon emissions will be less and the environment will be more damaged. Concrete; is the most widely used material in the building industry. Due to the brittleness of this material, capillary cracks were constantly observed on its surface [Erdoğan & Erdoğan \(2006\)](#).

To prevent capillary cracks, the use of fiber, which has been around for a long time, has been found as a solution. Fibers; until they reach their tensile strength It minimizes the formation of numerous capillary cracks that will occur from concrete compressive and tensile stresses [Aslan & Aydın \(1999\)](#). In fibrous concretes; the most important parameters are the slenderness ratio (fiber length/fiber diameter) and is the amount of fiber [Yaprak et al. \(2004\)](#).

Hemp is a woody plant belonging to the cannabinaceae family. There are two subspecies of cannabis. These; are Cannabis sativa and Cannabis indica. The type used industrially is Cannabis Sativa [Gedik et al. \(2010\)](#). Cannabis sativa species; In a study, it was seen that it was also used in construction 1500 years ago. As a result of archaeological excavations, the history of cannabis dates back to 8000 BC [Açıkgenç et al. \(2012\)](#), [Aksoy et al. \(2019\)](#). Hemp has a long history and different uses.

### 1.1. STRUCTURE OF HEMP FIBER

Hemp; to your gang, is known as hemp It is an annual woody plant species belonging to the Cannabinaceae family. Hemp fibers are found in bundles in the bark of the stem. Hemp fiber cells are 2-7 angular. The lengths of these cells are 5 – 100 mm, an average of 40 – 55 mm, and their thickness is between 18 – 50 microns. The fiber cells are tapering towards the tip.

**Figure 1**



**Figure 1** Primer Fibers [Gizlenci et al. \(2019\)](#).

Fiber yield is higher in female hemp. The fibers are in 3 different shapes in the shell. The spindle-shaped fiber cells come together to form fiber bundles. The bright hemp fibers are yellow-brown in color [Gedik et al. \(2010\)](#), [Manai et al. \(2019\)](#). The properties of the fiber vary according to the harvesting period [Gedik et al. \(2010\)](#).

### 1.2. CHEMICAL PROPERTIES OF HEMP FIBER

The structure of hemp fibers; contains 70-74% cellulose, 3.5-5.7% lignin, 15-20% hemicellulose and 0.8% pectin. Hemp fibers are defined as coarse fibers due to

the lignins in them [Gedik et al. \(2010\)](#), [Kaya & Öner \(2020\)](#), [Ula \(2018\)](#). It makes the fibers brittle and harder.

**Table 1****Table 1 Chemical Components of Hemp and Other Cellulosic Fibers** Karaduman et al. (2017), Karşın (2022)

Fiber	Cellulose (%)	Lignin (%)	Hemicellulose	Fiber
Hemp	70-74	3.5-5.7	15-20	0.8
Jute	61-72	61-72	18-22	0.2
linen	64-72	2-2.2	18-20	1.8-2.3
Kenaf	45-57	22	8-13	0.6
Cotton	85-90	-	5.7	0-1

### 1.3. PHYSICAL PROPERTIES OF HEMP FIBER

After ramie fibers, hemp fiber is in the class of the most durable natural fibers. Fibers are not affected by temperature and withstand high temperatures [Gedik et al. \(2010\)](#), [Özdemir & Tekoğlu \(2012\)](#).

**Table 2****Table 2 Physical Properties of Hemp and Other Cellulosic Fibers** Manaia et al. (2019)

Fiber	Length	Intensity (g/cm <sup>3</sup> )	Tensile strength (MPa)	Moisture content (%)
Hemp	5-55	1.4	550-1110	0.8
Jute	2-120	1.3-1.5	393-800	0.2
Linen	5-900	1.5	345-1830	1.8-2.3
Ramie	900-1200	1.5	400-938	0.6
Glass fiber	5-55	2.5	2000-3000	0-1

## 2. MATERIAL AND METHOD

In this section, the materials used in the production of concrete, the properties of these materials and the compressive strength test are given.

### 2.1. MATERIAL

**Cement:** In the study, Cem II 42.5 R Portland cement was used. The physical and chemical properties of cement are given in [Table 3](#).

**Table 3****Table 3 Physical Properties of Hemp and Other Cellulosic Fibers** Manaia et al. (2019)

Physical properties	Chemical properties	Other properties
Socket start time 60	Sulfur trioxide (SO <sub>3</sub> ) %4	Specific surface 4500-4700 cm <sup>2</sup> /g
Expansion mm <10	Chloride <%1	Intensity 3-3.5 gr/cm <sup>3</sup>
2 days strength MPa >=20		
7 days strength MPa >=42.5		
28 days strength MPa <=62.5		

**Aggregate:** In the experimental study, 2 different aggregates, 0-4 mm crushed sand and 4-16 crushed stone, were used in concrete production. The largest grain

size used in the mixture was 16 mm and a constant granulometry curve was used in all concrete mixtures.

**Hemp fiber:** Within the scope of this study, hemp fibers were cut manually in 60 mm size (Figure 2). It was added to the concrete samples at the rates of 0.25%, 0.50% and 0.75% by volume.

**Figure 2**



**Figure 2** Manual Cutting of Hemp Fiber.

**Mixing water:** The Van city mains water was used in the production of concrete samples.

**Chemical additive:** Sika Viscocrete - 4050 Hi-Tech additives were used as superplasticizer additive in all concrete samples. The properties of the superplasticizer additive are given in Table 4 below.

**Table 4**

Table 4 Properties of Superplasticizer Material Aslan & Aydın (1999)				
Fiber	Length	Intensity (g/cm <sup>3</sup> )	Tensile strength (MPa)	Moisture content (%)
Hemp	5-55	1.4	550-1110	0.8
Jute	2-120	1.3-1.5	393-800	0.2
Linen	5-900	1.5	345-1830	1.8-2.3
Ramie	900-1200	1.5	400-938	0.6
Glass fiber	5-55	2.5	2000-3000	0-1

## 2.2. METHOD

The concrete mixture calculation, it was made according to the TS 802 standard. The concrete strength class was chosen as C30/37 and the water/cement ratio was taken as 0.45. The water/cement ratio was kept constant in all concrete samples. In the production of concrete, chemical additives at the rate of 0.5% of the cement ratio are used. The quantities of the materials used are given in Table 5.

In this study, 6 reference samples (3 reference cube samples for 7 and 28 days strength each) and 18 hemp fiber added samples were used to examine the effect on concrete compressive strength by adding hemp fiber added concrete samples at 0.25%, 0.50% and 0.75% by volume. A total of 24 10x10x10 cm cube samples were prepared. It was made according to the TS EN 12390-3 standard for the 7 and 28 days compressive strength of the produced concrete samples.

**Table 5**

<b>Table 5 1 m3 Amount of Material Required for Concrete Production</b>	
<b>Component</b>	<b>Quantity (kg/m<sup>3</sup>)</b>
Cement	504.4
Sand (0-4mm)	744
Coarse aggregate (4-12 mm)	909
Mixing water	227
Water / Cement	0.45
Superplasticizer	2.52

### 2.3. FINDINGS AND DISCUSSION

In this study, hemp fiber was added in different ratios (0.25%, 0.50% and 0.75%) into concrete samples and its effect on compressive strength was investigated.

**Compressive strength results:** To the TS EN 12390-3 standard for hemp fiber-added and non-added samples appropriate 7 and 28-day compressive strength test was carried out. The addition of hemp fiber to the concrete had both positive and negative effects on compressive strength.

As can be seen in [Table 6](#) and [Figure 3](#), where the 7 and 28-days compressive strength of the concrete samples are given, depending on the hemp fiber content, the desired target strength was exceeded in the 0.25% samples in the strength with the addition of hemp fiber, and a decrease was observed in the strength at other rates (0.50% and 0.75%).

**Table 6**

<b>Table 6 Reference 7 and 28-Days Concrete Reinforcement Samples (MPa)</b>		
<b>Test samples</b>	<b>7 daily compressive strength MPa</b>	<b>28 daily compressive strength MPa</b>
Reference sample	38.05	49.17
L 0.25	41.68	53.63
L 0.50	20.08	25.01
L 0.75	11.53	15.44

When [Figure 3](#) is examined, the 7-day compressive strengths; It was determined that while the reference sample was 38.05 MPa, the compressive strength of the hemp fiber reinforced samples ranged from 11.53 MPa to 41.68 MPa, increasing by 10% at first and then decreasing by 20.76% and 36.15%.

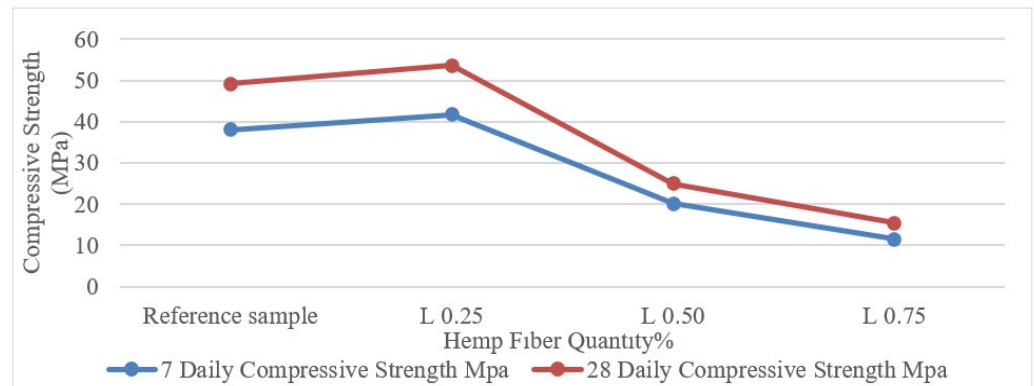
When the 28-days compressive strengths of the samples are examined; While the reference sample was 49.17 MPa, the compressive strength of the hemp fiber reinforced samples was observed to vary between 15.44 MPa and 53.63 MPa.

The 7 and 28 days compressive strengths of the reference and hemp fiber-added samples increased and decreased at the same rates. The desired target strength was exceeded in the concrete class of C30/37 in the samples with L 0.25 admixture, and the concrete class of C45/55 was approached. The desired target strength was not reached in the other fiber-reinforced samples.

According to the compressive strength values; It has been determined that the fiber content can be added to the concrete with a maximum of 0.25%. It is known that the workability decreases with the increase of the fiber amount at certain rates [Açıkgenç et al. \(2012\)](#).

With the increased amount of fiber; The emergence of agglomeration prevents the mortar from easily settling in the concrete, creating a hollow structure, and the concrete compressive strength has taken lower values compared to the witness sample.

**Figure 3**



**Figure 3** Concrete Compressive Strength of Reference and Hemp Fiber Added Samples (MPa)

### 3. CONCLUSION

In this study; The effect of hemp fiber in the concrete at the rates of 0.25%, 0.50%, 0.75%, and 60 mm length on the compressive strength was investigated and the following results were obtained.

When the 7 and 28-day compressive strengths of the reference and hemp fiber added samples are compared, the best results were obtained at 28-day strengths.

The highest compressive strength; It was observed in concrete with L 0.25 admixture with 53.63 MPa.

As a result of the compressive strength made on the hemp fiber reinforced samples, it was determined that the targeted compressive strength was exceeded by the L 0.25 added samples and pressure resistance was affected badly because of increased fiber material.

Compressive strength was observed in concrete samples with at least 0.75% admixture. The reason for this; It was observed that the workability decreased with the increase in the fiber content.

With the increase in the amount of fiber, the agglomeration has occurred. This has led to an increase in the void ratio in concrete.

### CONFLICT OF INTERESTS

None.

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### CONTRIBUTIONS OF THE AUTHORS

Corresponding author: Data curation, writing (original draft, review & editing), investigation, visualization methodology and interpretation of experimental results.

## COAUTHOR

Methodology, investigation, visualization, literature review, and interpretation of experimental results.

## STATEMENT OF RESEARCH AND PUBLICATION ETHIC

The study is complied with research and publication ethics.

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