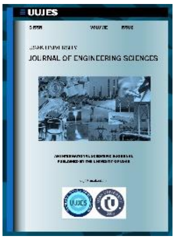

Usak University

Journal of Engineering Sciences

An international e-journal published by the University of Usak

Journal homepage: dergipark.gov.tr/uujes

Research article

THERMAL AND MECHANICAL PROPERTIES OF CONCRETES CONTAINING POLYPROPYLENE, KAPOK AND COCONUT FIBERS

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Received:23 December 2022 Revised: 26 February 2023 Accepted: 14 March 2023 Online available: 30 June 2022

Abstract

Concrete is a brittle material, this weak point of concrete can be eliminated by using different fibers for this reason, in this study, it is aimed to investigate both the concretes containing polypropylene, kapok and coconut fibers and their usage areas, and to investigate the physical, mechanical and thermal properties of the concretes obtained by using these fibers in different proportions by keeping the amount of cement in the concrete mixtures constant. 10x10x10 cm cubed samples for physical and mechanical properties, 8x4x1 cm concrete samples from the produced materials for thermal conductivity tests were cut and subjected to the test. Generally, the use of polypropylene, kapok and coconut fibers added concretes does not technically cause a troublesome situation, but provides numerous benefits to the concrete. As the fiber dosage increased, the water absorption rate and the ultrasonic velocity increased, but the thermal conductivity coefficient decreased. It was thought that the increase of fiber dosage will contribute to thermal insulation by decreasing the thermal conductivity value.

Keywords: *Concrete; polypropylene fiber; kapok fiber; coconut fiber; thermal; mechanical.*

1. Introduction

Concrete is the most frequently used building material for many years with its easy workability, low cost and easy availability. Conventional concrete is produced by mixing aggregate, cement and water [1].

Concrete is a material whose compressive strength is increasing day by day with the studies carried on it and this feature is greatly utilized. However, increased compressive

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DOI: https://doi.org/10.47137/uujes.1223453

strength does not cover other mechanical defects of concrete. In addition to its high strength, the tensile strength of concrete, whose compressive strength and durability has increased by minimizing the void ratio, has always remained at low levels. However, increasing compressive strengths made concrete an even more brittle material. As the strength of concrete increases, the axial deformation capacities increase, after the peak is passed, the stress drop is sudden and a brittle fracture occurs [2]. In addition to the developing compressive strength and durability properties of concrete, it was Hyatt from the USA who made the first studies in the early 1850s to increase the tensile strength, which is its only weakness. Later, J. Lambot was the person who patented the concretes containing fibers. In 1874, A. Berard received the first patent for fiber containing concrete. The use of today's concrete containing different fibers has developed as a result of the studies that started in the 1960s. [3]

Many high-rise buildings, bridges, tunnels, etc. in our daily life. High performance concretes have been used in mega structures in order to reduce the effects of earthquakes and structural safety. Concrete technology advancing in this way has developed fiber containing concrete, a solution that carries concrete to perfection. The fibers to be added to the concrete not only saved the concrete from the weakness of brittleness and carried it to ductility, but also made a high contribution to both its mechanical and thermal properties [4].

Fiber defines materials that have a very large length ratio relative to diameter, naturally found or man-made, and whose strength and modulus of elasticity are very high compared to the bulky form of the same material [5]. The fact that the modulus of elasticity and strength are very high compared to the state of the fibers in large formation makes the fibers the most advanced form of the material. In addition to the fibers used today, human beings have been using fibers since ancient times. In ancient times, natural fibers such as flax and hemp were used in fiber format in materials such as adobe and plaster used in buildings. Although man-made fibers first appeared at the end of the 19th century, the history of these fibers is not more than 60 years. However, synthetic fibers have become indispensable in such a short time [6].

Polypropylene fibers, which have a synthetic-based polymeric structure, were first used in concrete in the 1960. The hydrophobicity of polypropylene fibers causes weak bonding with the cement matrix. In addition, due to this structure, it has a low melting temperature, easily flammable and lower elasticity modulus than other synthetic fibers. The low tensile stress and low modulus of elasticity of polypropylene fibers lead them to plastic deformation. Among the synthetic fibers used in concrete, polypropylene fibers are the fibers that improve both cost-effectiveness and mechanical properties such as flexural strength, compressive strength, and toughness properties in high-performance concrete and give the best results [6-9].

Other fiber groups used in concrete technology are; are natural fibers used to improve both their mechanical and thermal properties. The oldest known natural fibers are straw and horse mane, while other natural fibers used with Portland cement consist of coconut fiber [5]. Kapok fibers, which have extraordinary properties that are not even found in many synthetic fibers, are not a fiber type known as textile fiber today. Kapok fibers are often compared to cotton fibers in terms of fiber structure and fiber properties, since cotton is the first natural fiber that comes to mind when it comes to seed fiber and both are seed fibers [10-21]. Kapok fibers, which stand out with their hollow fiber structure, lighter-than-water specific gravity, and oil-absorbing character, exhibit a very different profile from known natural fiber types [14,22,23]. In addition, kapok fibers; Being easily accessible, renewable, biodegradable and reusable, it has become an attractive research material in the construction industry in recent years to improve its sound and heat insulation properties. The fibers used in the study are shown in Fig. 1.

Therefore, the focus of this research is to investigate the effect of low additive pp, kapok and coconut fiber additions on the mechanical and thermal properties of concrete samples and to offer a new perspective on the use of a very important raw material resource in the production of construction textile materials.

Fig. 1 Polypropylene Fiber, Kapok Fiber and Coconut Fiber

2. Material and Method

2.1 Material

In the studies carried out in the Usak University Building Materials Laboratory, 10 series of concrete were produced. Maximum grain diameter of 16 mm was chosen in the mixtures and the granulometry of all the mixtures remained the same. In this study, concrete samples were produced by adding 1%, 2% and 3% (polypropylene, kapok and coconut fiber) in 1, 2 and 3 % ratios by keeping the cement amount constant. The chemical properties of cement, normal aggregate and polypropylene, kapok and coconut fibers used are shown in Table 1 and the mechanical and physical properties of the polypropylene, kapok and coconut fibers are shown in Table 2.

Table 1 Chemical Properties of Cement, Aggregate and Polypropylene, Kapok and Coconut Fiber Used in Concrete Mixtures [24-28]

Components	CEM I 42,5 R (%)	Normal Aggregate (%)	Polypropylene Fiber (%)	Kapok Fiber (%)	Coconut Fiber (%)
SiO_2	20.02	2.75	0.38	-	12.92
Fe_2O_3	3.52	1.29	0.06	-	2.60
Al_2O_3	5.16	-	-	-	0.96
CaO	63.46	0.2	53.85	-	4.88
MgO	1.03	2.8	0.34	-	0.03
SO_3	2.74	-	-	-	-
Loss of ignition	2.35	-	-	-	-
Cellulose	-	-	-	35	36-43
Lignin	-	-	-	21.5	41-45
Hemicellulose	-	-	-	-	0.2
Ash	-	-	-	1.05	2.69
Wax	-	-	-	2.34	-

Table 2 Mechanical and Physical Properties of Polypropylene, Kapok and Coconut Fiber Mixtures [29-32]

	Polypropylene Fiber	**Kapok Fiber**	**Coconut Fiber**
Density (g/cm^3)	0.91	0.389	1.2
Tensile Strength N/mm^2 (MPa)	450-700	189	105-175
Initial Modules (MPa/GPa)	3000-3500 MPa	4-11 GPa	4.6 GPa
Strain (%)	18-22	1.83-4.23	30
Nem (%)	0-0.05	0-11	10
Length (mm)	6-19	8-35	20-150
Diameter (μm)	18-40	20-43	100 – 450

2.2 Method

In this study, 300-dose concretes were produced in 10 different mixing ratios. The mixing ratios of the produced concrete samples are shown in Table 3. Natural water was used as mixing water. Concrete mixing process was done with the help of mixer. The slump test was performed to determine the consistency of the samples. While the samples were placed in the mold, they were subjected to vibration process. 10 cm x 10 cm x 10 cm cube samples were produced for each series. After the samples were kept in the mold for 24 hours, they were removed from the mold. The samples were kept in the curing pool until 1 day before the experiment.

Table 3 Mixture ratios of the produced samples

Mix	**Cement (% wt)**	**Polypropylene Fiber (%)**	**Kapok Fiber (%)**	**Coconout Fiber (%)**
NB	100	-	-	-
NL1	99	1	-	-
NL2	98	2	-	-
NL3	97	3	-	-
NK1	99	-	1	-
NK2	98	-	2	-
NK3	97	-	3	-
NC1	99	-	-	1
NC2	98	-	-	2
NC3	97	-	-	3

According to TS EN 12350-22, for the slump test, a truncated cone-shaped funnel made of metal with open lower and upper ends, and a rounded steel rod are used to skewer the concrete to be placed inside the cone. The diameter of the bottom of the settling funnel is 20 cm, the diameter of the upper end is 10 cm, and the height is 30 cm. Before starting the experiment, the inside of the funnel is wiped with a damp cloth and the funnel is placed on a flat and water-proof surface. The prepared fresh concrete is placed in approximately one third of the concrete volume, that is, in 3 layers, to fill the inside of the funnel with the help of a trowel. Each layer is skewered separately 25 times with an iron bar. Immediately after all these processes, the funnel is slowly pulled up vertically by holding its side handles. The drawing process of the mold should be completed at a constant speed and in 5 to 10 seconds. The concrete that is freed from its mold shows a small or large amount of slump depending on the degree of wateriness. The empty funnel is placed next to the completely collapsed concrete pile and placed horizontally on the iron bar, and the distance between the lower level of the bar and the average height of the upper face of the collapsed concrete is measured with a ruler to the nearest 0.5 cm. The measured value is expressed as the slump value of the concrete [33].

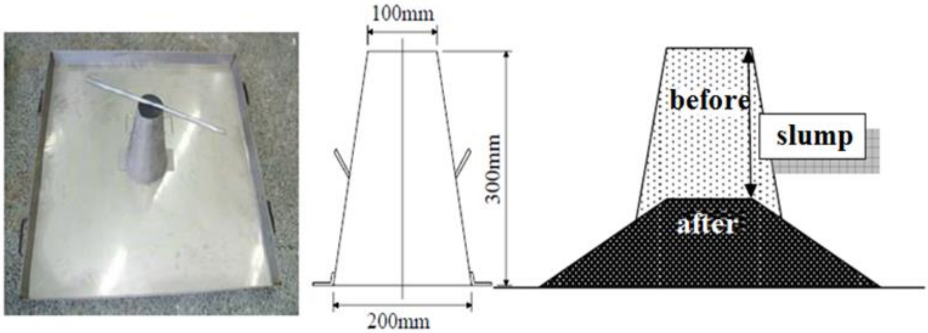

Fig. 2 Tools used in the slump test and experimental procedure [4]

In order to determine the thermal conductivity coefficient of the concrete specimens that are produced, the experiments were carried out on 80 x 40 x 10 mm samples at Mechanical Engineering Laboratory of Faculty of Engineering of Ege University (Fig. 4). When the difference between the two surface temperatures is 1 ° C under the conditions that have reached equilibrium, the amount of heat passing through "unit time, unit area and unit thickness in perpendicular direction" is the thermal conductivity of a homogeneous material. The measurement of the thermal conductivity of the structure and various thermal insulation materials are done by two methods, in steady state and transition state. The usual method is the heated plate method in steady state. The average thermal conductivity of the plate-shaped examination specimen, which is placed symmetrically on both sides of a heated plate, is found by this method. Measuring devices can detect the thermal conductivity of smaller materials in a shorter time during the transition.

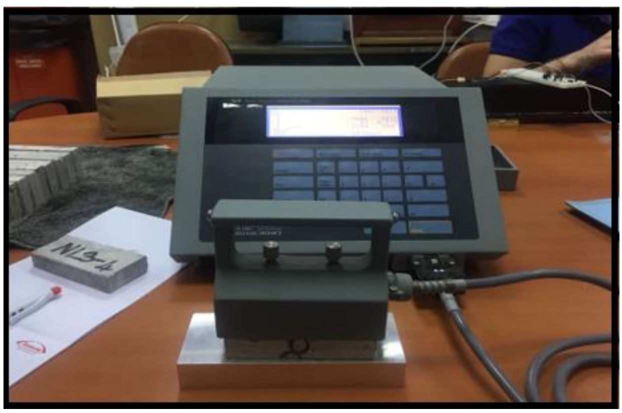

Fig. 3 Thermal conductivity measuring device

Compressive strength test was carried out in the destructive test method. For this experiment, a concrete device with a capacity of 30 tons, located in the Building Materials laboratory of the Civil Engineering Department of the Faculty of Engineering of Uşak University, was used. For this purpose, 3 of the previously prepared concrete samples were broken on the 7th day and 5 each on the 28th day to reach the compressive strength values. (Fig. 4).

Fig. 4 Compressive strength test device

3. Results and Discussion

The results of the experiments on the concrete samples produced within the scope of this study are given in Table 4. The results of the concrete samples containing polypropylene, kapok and coconut fibers are shown in Figs. 5-8.

Table 4 Physical properties of of concrete samples containing polypropylene, kapok and coconut fibers

Mix	Dry Unit Weight (kg/m^3)	Water Absorption (%)	Slump (mm)	7 Days Compressive Strength (MPa)	28 Days Compressiv e Strength (MPa)	Thermal Conductivity Coefficient (W/mK)
NB	2.419	1.80	170	40.70	49.76	2.96
NL1	2.395	1.82	45	38.50	45.88	2.66
NL2	2.375	1.85	30	38.38	45.17	2.40
NL3	2.365	1.95	20	38.12	44.19	2.23
NK1	2.390	1.99	45	41.85	46.55	2.55
NK2	2.377	2.01	35	41.55	45.22	2.45
NK3	2.371	2.02	25	40.88	45.01	2.33
NC1	2.402	1.88	40	42.11	47.01	2.61
NC2	2.388	1.91	30	42.01	46.56	2.42
NC3	2.381	1.94	20	41.56	45.55	2.25

3.1 Water Absorption Test Results

Based on standard TS EN 1097-6 the values obtained from the water absorption test results are given in the Fig. 5 [34].

As shown in Fig. 5 in the samples; As the fiber dosage increases, water absorption increases. While NL3, NK3 and NC3 has the highest value, NB has the lowest value.

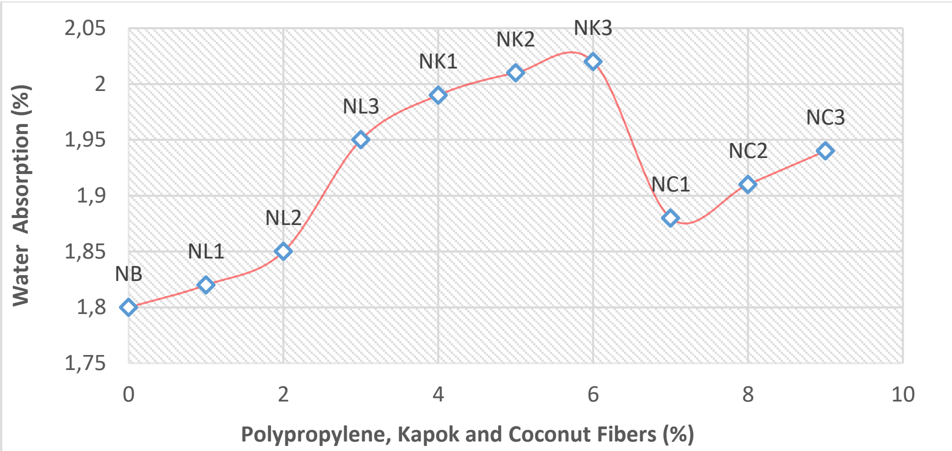

Fig. 5 Water absorption test results of concrete samples containing polypropylene, kapok and coconut fibers (%)

3.2 Slump Test Results

Based on standard TS EN 12350-2 the values obtained from the slump test results are given in the Fig. 6 [33].

As shown in Fig. 6 in the samples; As the fiber dosage increases, slump decreases. While NB has the highest value, NL3, NK3 and NC3 has the lowest value.

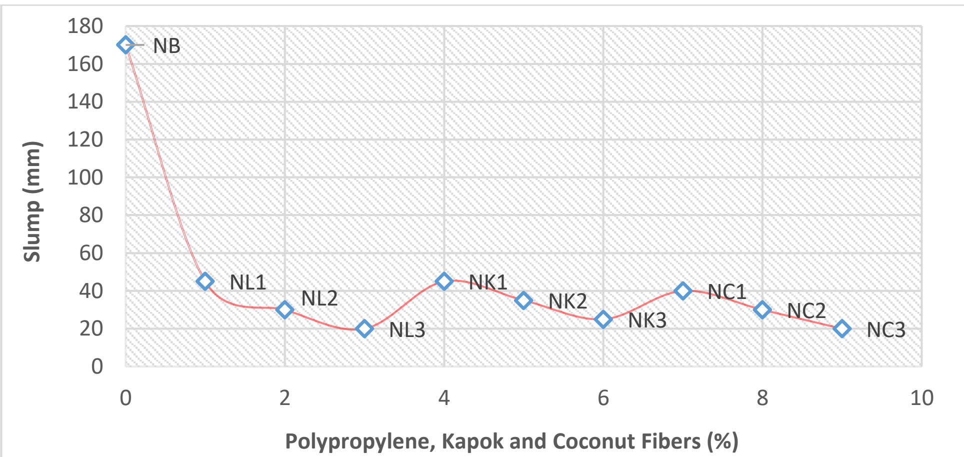

Fig. 6 Slump test results of concrete samples containing polypropylene, kapok and coconut fibers (mm)

3.3 Compressive Strength Test Results

Based on standard TS EN 12390-4 the values obtained from the compressive strength test results are given in the Fig 7 [35].

As shown in Fig. 7 in the samples; As the fiber dosage increases, compressive strength decreases. Both 7 and 28 days, the highest value is NB, while the lowest value is NL3.

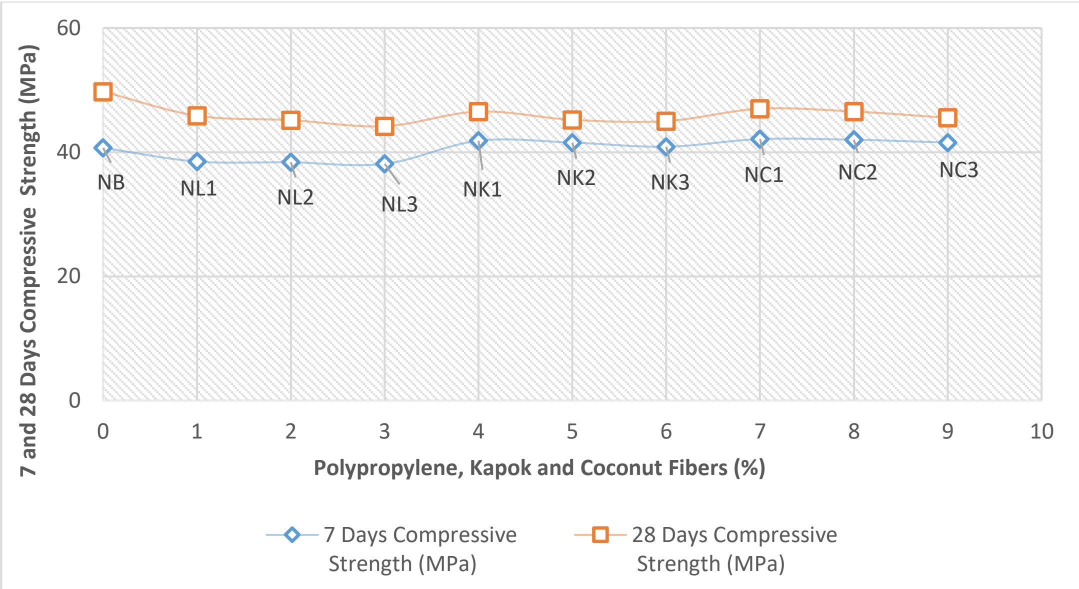

Fig. 7 7 and 28 days compressive strength test results of concrete samples containing polypropylene, kapok and coconut fibers (MPa)

3.4 Thermal Conductivity Coefficient Test Results

Based on standard TS 825 the values obtained from the thermal conductivity coefficient test results are given in the Fig. 8 [36].

As shown in Fig. 8 in the samples; As the fiber dosage increases, thermal conductivity coefficient decreases. While NB has the highest value, NL3 has the lowest value.

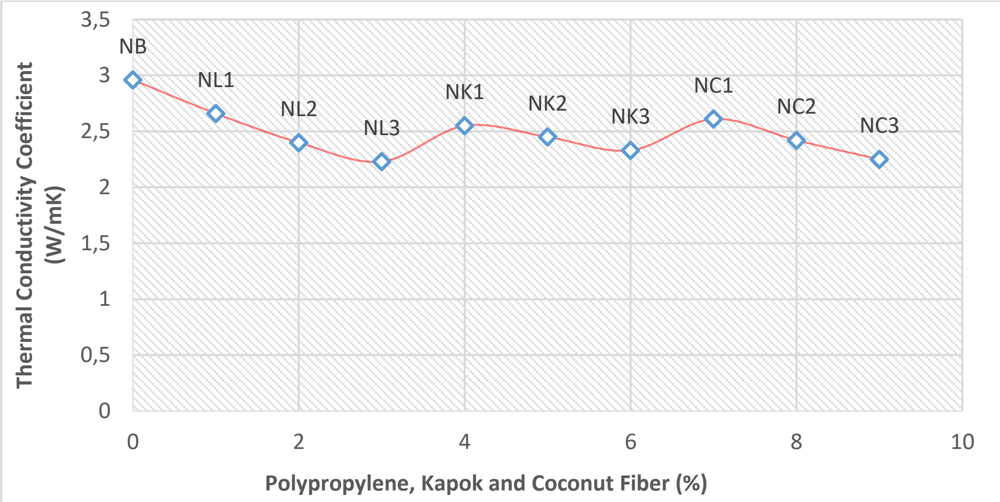

Fig. 8 Thermal conductivity coefficient test results of concrete samples containing polypropylene, kapok and coconut fibers

4. Conclusion

- As a result, the use of fiber added concrete technically provides numerous benefits to concrete, different usage rates cause different properties and different costs.
- Although the workability of fiber added concrete is low, the mechanical properties of fiber added concrete gain more importance, especially in the challenging geographical and environmental conditions. Increasing fiber dosage in fluid concrete brings about a decrease slump. This is an important feature in terms of the cohesion of fresh concrete, even if it is seen as a negative effect on the workability.
- Increasing fiber dosage brings about a decrease in 7 and 28 days compressive strength results.
- As the fiber dosage increases, water absorption rate and thermal conductivity coefficient decreases. It is thought that the increase of fiber dosage will contribute to thermal insulation by decreasing the thermal conductivity value.
- It can be said that the use of fiber added concretes can be used especially in concretes with high surface area such as airfields and road concretes, which can provide improvement in plastic shrinkage cracks.
- As a result, when fiber added concrete is used instead of unit concrete, it does not affect the compressive strength and thermal insulation values, but reduces its weight and thermal conductivity coefficient. It can be used in insulation concrete applications in cold climate regions due to the low thermal conductivity coefficients of fiber-containing concretes.

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