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Effects of Hemp Fibers on Durability and Strength Properties of Concrete to be Used in Agricultural Buildings

Ahmet Ozan AKINCI[1], Sedat KARAMAN[2]✍
[1]Tokat Gaziosmanpasa University, Graduate Education Institute, Tokat/Türkiye, [2]Tokat Gaziosmanpasa University, Faculty of Agriculture, Department of Biosystem Engineering, Tokat/Türkiye
[1]https://orcid.org/0000-0001-5464-7692, [2]https://orcid.org/0000-0003-3986-5944
✉: sedat.karaman@gop.edu.tr

ABSTRACT

Concrete is the most common construction material used worldwide. It is also commonly used in construction of agricultural buildings. With the rapid developments in technology, different building materials with superior properties are being researched in order to improve different properties of concrete and eliminate its disadvantaged aspects and to obtain lighter, insulated, more economical and useful construction materials. One of the applications to improve the negative properties of concrete with low tensile strength is to add various fibers into the concrete mixtures. Hemp stalks play an important role in recycling vegetable wastes. Therefore, it is highly significant to recycle or transform these materials. In this study, hemp fibers were supplemented into concrete mixtures in different ratios (1, 2.5 and 5%). Slump and unit weight tests were conducted on fresh samples and compressive strength, tensile strength, water absorption, freeze-thaw resistance, thermal conductivity and ultrasound pulse velocity tests were conducted on 28-day cured cube specimens. Slump values of the concrete samples varied between 3.50-12.00 cm, unit weights between 2262-2370 kg m^{-3} and water absorption values between 2.42-5.91%. Compared to the control concrete, maximum decrease in compressive strength (24.09%) was seen in 5% fiber-supplemented concrete samples (average 33.44 MPa). The highest splitting tensile strength (11.15%) was obtained from 1% fiber-supplemented samples. Compressive strength, specific gravity, ultrasound pulse velocity and thermal conductivity coefficients decreased, but tensile strengths and water absorption ratios increased with increasing hemp fiber ratios. As a result, by using hemp fibers in concrete production, a material with high tensile strength, suitable for cold climate conditions and low thermal conductivity was produced. Present mechanical and physical experiments revealed that hemp fiber-supplemented concretes, which are economical, sustainable, environment-friendly, recyclable and have low carbon emissions, could reliably be used in agricultural buildings and further improvements could contribute to the economy and reduce environmental pollution

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Anahtar Kelimeler
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Kenevirin Tarımsal Yapılarda Kullanılan Betonun Bazı Özelliklerine Etkisi

ÖZET

Yapı malzemeleri arasında dünyada en fazla kullanılan beton, tarımsal yapılarda da en fazla karşılaşılan malzemelerin başında gelmektedir. Gün geçtikçe artan teknolojideki hızlı gelişmelerle birlikte betonun farklı özelliklerini iyileştirerek sakıncalı yönlerini giderebilmek, daha hafif, yalıtımlı, ekonomik ve kullanışlı betonlar elde etmek amacıyla, üstünlükleri yüksek farklı yapı malzemeleri araştırılmaktadır. Organik bir atık olan kenevir bitkisinin saplarından elde edilen lifler, agregalar, bağlayıcı olarak çimento ve karışım suyu olarak musluk suyu kullanılarak kenevir lifi takviyeli beton numuneleri üretilmiştir. Çekme dayanımı düşük betonun olumsuz özelliklerini iyileştirmek için yapılan uygulamalardan biri de beton karışımına çeşitli lifler ilave etmektir.

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Bitkisel atık

Bitkisel atıkların tekrar ekonomiye kazandırılmasında kenevir sapı atıkları önemli yer tutmaktadır. Bu nedenle söz konusu malzemelerin yeniden kazanımı ya da dönüştürülmesi oldukça önemlidir. Kenevir liflerinin beton üzerine etkilerini inceleyerek yapı malzemelerinde kullanılabilirliğini belirlemek, inşaat sektöründe yapı malzemesi olarak değerlendirilmesine yardımcı olmak ve ekolojik dengenin korunmasına katkıda bulunmak amacıyla yapılan bu çalışmada, beton içerisine katılan kenevir liflerinin taze ve sertleşmiş beton üzerindeki etkileri incelenmiştir. Çalışmada kontrol karışımı ve lif uzunlukları 4-6 cm arasında olacak şekilde hacimce %1, %2.5, %5 oranlarında kenevir lif katkılı beton örnekleri üretilmiştir. Örneklerin slump değerleri, birim hacim ağırlığı, basınç dayanımı, yarmada çekme dayanımı, su emme, donma-çözülme, ultrases geçiş hızı ve ısı iletkenlik katsayıları belirlenmiştir. Üretilen beton örneklerinin çökme değerleri 3.50-12.00 cm, birim ağırlıkları 2262-2370 kg m^{-3}, su emme değerleri %2.42-5.91 arasında belirlenmiştir. Kontrol betonu ile kıyaslandığında örneklerin basınç dayanımlarındaki azalma en fazla %24.09 (%5 lif katkılı beton) olarak (ortalama 33.44 MPa) bulunmuştur. En yüksek yarmada çekme dayanımı %11.15 artış ile %1 katkılı örnekte belirlenmiştir. Elde edilen sonuçlara göre artan lif miktarı ile birlikte birim hacim ağırlık, basınç dayanımı, ultrases ve ısı iletkenlik katsayısı azalmış, yarmada çekme dayanımları artmıştır. Sonuç olarak çalışmada kenevir liflerinin beton üretiminde kullanılması ile çekme dayanımı yüksek, soğuk iklim koşullarına uygun, ısı iletkenliği düşük malzeme üretilmiştir. Sonuç olarak; yapılan mekanik ve fiziksel deneyler sonucunda ekonomiye katkı sağlamak ve çevre kirliliğini azaltmak amacıyla, ekonomik, sürdürülebilir, çevre dostu, geri dönüştürülebilir ve düşük karbon salınımına sahip kenevir lif katkılı betonların tarımsal yapılarda güvenle kullanımının uygun olduğu ve geliştirilerek kullanılabileceği söylenebilir.

Yalıtım malzemesi

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INTRODUCTION

Yield levels of agricultural products should be increased to meet the demands of ever-increasing world population. Agricultural structures including animal housings, animal shelters, warehouses, conservation structures and processing facilities used for various purposes in agricultural enterprises should be so designed and constructed as to improve animal performance, quantity and quality of resultant products. Construction materials and structural members play an important role in providing optimum environmental conditions for livestock operations.

Agricultural structures are often single or two-story buildings and constitute a significant part of the total capital in agricultural enterprises. They need to be constructed economically in accordance with their capacities, avoiding excessive load-bearing requirements. Selected materials should have adequate strength and durability, ensure safety and ideal environmental conditions and allow cost-effective manufacturing. In the realm of building materials, there exist both naturally sourced materials and those that are artificially manufactured. It is possible to learn about production procedures as well as the physical, chemical and mechanical qualities of raw materials and to use them in the most appropriate placement within the structure by carefully selecting construction materials.

Material physico-chemical characteristics, resistance to external forces, ease of use, durability, hardness, heat conduction, ease of processing, economy and availability at the point of use play a great role in selection of construction materials (Karaman, 2007). Mechanical and durability attributes can be improved by appropriately modifying the materials that make up concrete, which has been used as a building material for thousands of years. The most practical way to ensure concrete integrity and increase physical strength is to incorporate fibrous materials into the concrete mortar (Manan & Ganapathy, 2002; Shahzad, 2011).

Fibrous concrete is made by combining cement, aggregates, water and fibers in specific proportions. It was reported in previous studies that there was a significant increase in mechanical properties of concrete and mortar, in tensile strength and load carrying capacity of fibrous concretes (Ganesh-Babu &Pavan-Kumar, 2004; Shahzad, 2011; Walker et al., 2014).

Concrete has a brittle structure, but gains flexibility with fibrous admixtures and can withstand greater loads without cracking. Fibrous concrete has a higher energy absorption capacity during fracturing than non-fibrous concrete. Addition of various fibers into traditional concrete mixtures meets stress resistance requirements, transfers deforming forces from inside-out or outside-in and increases bending strength through prevention of cracks. Furthermore, fiber supplements provide the ability to withstand impact loads without breaking. Fibers also offer some advantages such as being economical, making building members lighter, providing noise and heat insulation, reducing the risk of shrinkage cracks, increasing surface wear resistance and freeze-thaw resistance, preventing shrinkage, crumbling-dusting, flaking and rusting, increasing high alkali, ductility, fatigue, impact resistance and durability (Anonymous, 1982; Ganesh-Babu &Pavan-Kumar, 2004; Açıkel et al., 2005; Kurt, 2006; Atashafrazeh, 2013; Cengiz, 2015; Ağaoğlu, 2018; Mujadidi, 2020; Anonim, 2022a).

Vegetable residues are abundantly available in rural areas. These residues may offer low-cost construction materials and allow farmers to construct higher-quality agricultural structures. Thus, suitable and low-cost structures can be built to improve living standards in rural areas. The qualities desired are lightness, high insulation, freezing, abrasion, high resistance to chemical effects, sufficient pressure and tensile strength, vapor diffusion resistance, resistance to water and moisture, plaster retention, process ability, longer service life, low cost and so on. Besides several benefits such as use of these residues in various areas, ensuring ecological balance, eliminating environmental problems and producing lighter and stronger concrete, agricultural residues offer significant inputs to country economy through reduction of concrete, then construction costs accordingly.

In recent years, there has been an increase in research on potential use of plant residues as building materials. Studies have been conducted to examine the effects of climate change and global warming induced by increased carbon emissions on renewable and effective systems of carbon sequestration. Use of industrial residues known as green materials can help to achieve global economic growth while also improving people' living conditions. Hemp concrete is one of the most important of these studies.

Hemp is a recyclable, renewable and biodegradable substance; hence it is more frequently suggested in construction industry. Use of fibers produced from agricultural operations in the production of polymer composite materials is becoming more common (Candoğan et al., 2022). Previous studies have shown that walls made of hemp concrete can provide good indoor air quality and energy savings in winter (Tran Le et al., 2009; Jami et al., 2019). In recent years, interest in industrial hemp (*Cannabissativa* L.), which is a source of fibers and oilseeds that has lightness, high strength, water absorption as compared to tight structured fibers and has been used in a wide variety of fields from the past to the present, has been increasing throughout the world. Therefore, hemp has started to be cultivated in many places. High-yielding hemp can be produced at a lower cost than other industrial crops. It is an environment-friendly crop and has a wider range of applications. All these attributes distinguish it from the other industrial crops. Recovery or conversion of these materials is essential since hemp stalk wastes are crucial in returning vegetable wastes to the economy. In recent years, hemp, whose production and usage has been permitted under specific restrictions in Türkiye, has been identified as a material that can be used in concrete mixtures due to its fibrous structure.

The main objectives of this research are (i) to determine the effects of hemp fibers on concrete properties, (ii) to determine potential use of hemp fibers as a construction material, (iii) to actively contribute to preservation of ecological balance.

MATERIAL AND METHODS

Material

As a research material, stems of hemp plant, an organic waste, were used to produce hemp fiber-reinforced concrete samples with conventional aggregates, cement as a binder and tap water from Tokat municipal supply as mixing water. The study employed Portland Limestone Cement (CEM I/42.5 R) produced by Yurt Cement Industry and Trade Inc., which is widely used in the region and comply with Anonim (2012a) standard. Hemps used as a fiber additive in preparation of samples were obtained from a registered hemp producer in Vezirköprü district of Samsun province. The fibers, obtained by separating the hemp bast from the fibrous stem, were naturally dried and then cut to a length of 40-60 mm. Technical fiber length of hemp fiber is 100-300 cm, processed fiber length is 65-75 cm, dry specific strength is cN/dtex, wet specific strength is 105% (dry), Elasticity Modules is 12.7 Mpa and annual fiber yield is 3000 kg ha^{-1} (Gedik et al., 2010). For all samples, coarse and fine crushed stone aggregates sourced from Güğümlü location within the boundaries of Tokat province were used in accordance with Anonim (2009a) standard. In the research, the samples were prepared using tap water from the municipal supply of Tokat province's central district, which met the standards for drinking water quality and was provided by the university laboratory.

Method

Experiments were conducted at Agricultural Structures Laboratory of Tokat Gaziosmanpaşa University Faculty of Agriculture and Building Laboratory of Faculty of Engineering and Architecture Department of Civil Engineering. Some preliminary experiments were conducted on concrete components to determine the structural properties of the components to be used in concrete samples and to determine optimum quantities to be used in concrete mixtures. In addition, since there is no standard set for the mixture calculations to be made for fibrous concretes, the studies on fibrous concretes were used to determine the ratios of aggregate, cement and fiber additives to be used in the mixture. As a result of the preliminary trials, hemp fiber ratios to be added were determined as 1%, 2.5% and 5% in volume. Amount of hemp fiber (with a bulk density of 1.4 g cm^{-3}) to be added to 15×15×15×15 cm cube samples was then calculated as 4.72 g for 1%, 11.81 g for 2.5% and 23.62 g for 5% (Zollo, 1997). Quantities of the materials for 1 m^3 concrete were determined as 1899.26 kg aggregate, 474.07 kg cement, 222.22 kg water for each mixing ratio. All materials were weighed and prepared separately and fiber quantities were determined as 14 kg m^{-3}, 35 kg m^{-3} and 70 kg m^{-3}. A total of 40 samples were prepared, including control samples, with three replicates of each hemp fiber ratio. Hemp fibers have quite a high water absorption capacity and such a case can lead to insufficient water content of concrete mixture and affect proper setting and hydration of concrete. Thus, hemp fibers were soaked into water until they reached a saturated state before to use them in mixtures.

The materials to be used in mixtures were weighed on a precision scale under laboratory conditions and homogeneously mixed. Then, hemp fibers kept in water were added to the mixtures and they were all blended together (Şişman & Alkaya, 2019). To prevent the clustering of fibers within the concrete and comply with the requirement for the narrowest dimension of the structural members, maximum particle size of the aggregate was chosen as 16 mm. The mixture proportions were determined based on the particle size distribution curves of the aggregates, following the concrete mix design calculations (Anonim, 2012b) (Figure 1). The proportions of coarse and fine aggregates were determined as approximately 49% and 51%, respectively, while their fineness module were calculated as 5.45% and 3.63%, respectively.

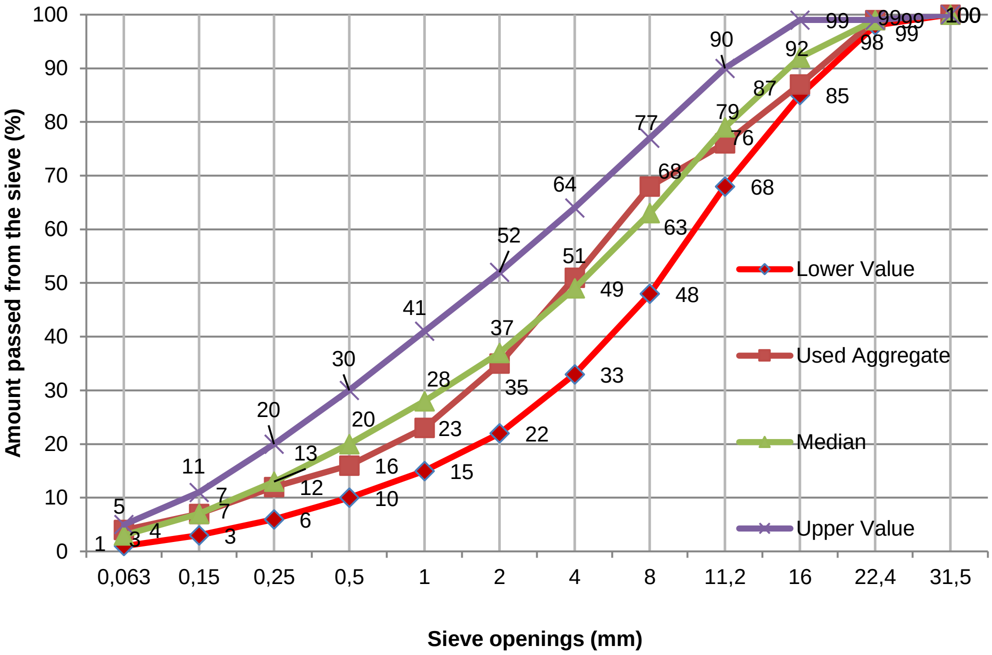

Figure 1. Mixing ratios used for concrete samples
Şekil 1. Beton örnekleri için kullanılan karışım oranları

Slump and unit weight tests were performed on fresh concrete (Anonim, 2019a; Anonim, 2019b; Anonim, 2012c). Aggregate gradation was maintained at a specific surface-to-volume ratio (s v^{-1} ratio) of 0.44 during concrete mixture preparation in accordance with Anonim (2018) requirements. Workability test for the prepared fresh concrete samples involved conducting a slump test, which measured qualities such as cohesion and stability (Anonim, 2019c). To determine the unit weights of the concrete specimens, unit weight tests were performed in accordance with Anonim (2019d), Anonim (2019e) and Anonim (2022b) standards. Cube specimens were subjected to curing for 28 days. Compressive strength tests were conducted on cured specimens (Utest / UTC-4710 with 1500 kN capacity computer-controlled hydraulic compressive strength tester) in accordance with Anonim (2012c), Anonymous (2015), TS EN Anonim (2019b), Anonim (2019f) and Anonim (2020) standards. Tensile strength tests were performed in accordance with Anonim (2012c), Anonymous (2015), Anonim (2019b), TS Anonim (2019f) and Anonim (2020) standards. Frost resistance test was conducted in accordance with Ekmekyapar & Örüng (2001); water absorption with Anonymous (1997a), Anonymous (1997b); Anonim (2019e) and Anonim (2022b) standards, thermal conductivity (thermal conductivity heat flux technique with Thermtest HFM-100 device capable of measuring between 0.005-0.5W Mk^{-1}) with Anonim (2002), Anonymous (2003) Anonim (2003) and Anonim (2009b) standards and finally Ultrasonic Pulse Velocity tests with Anonymous (1986), Anonymous (2016) and Anonim (2021) standards.

RESULTS

Slump and unit weight tests were conducted on fresh samples and compressive strength, tensile strength, water absorption, freeze-thaw resistance, thermal conductivity and ultrasound pulse velocity tests were conducted on 28-day cured cube specimens. Test results are provided in Table 1.

Table 1.Test results for fresh and 28-day cured samples
Çizelge 1. Taze ve sertleşmiş beton deneyi sonuçları

Concrete tests		Mixing ratios			
		Control (0%)	1%	2.5%	5%
Slump (mm)		120± 2.89	65± 2.89	45± 2.89	35± 0.00
Unit weight (kg m^{-3})		2369± 6.43	2341± 6.69	2295± 9.68	2268± 3.48
<Compressive strength (MPa)		44.05± 0.45	41.11± 0.97	40.53± 2.84	33.44± 2.01
Tensile strength (MPa)		5.83± 0.18	6.48± 0.45	6.04± 0.45	5.66± 0.27
Water absorption (%)		2.44± 0.03	2.81± 0.11	4.50± 0.54	5.82± 0.11
Freezing-thaw	Compressive strength (MPa)	39.46± 2.28	38.29± 1.18	33.97± 2.43	31.88± 1.42
	Water absorption (%)	3.95± 1.17	5.00± 0.30	5.47± 0.73	6.72± 0.42
	Weight change (%)	1.52± 0.14	2.24± 0.35	1.12± 0.15	1.06± 0.46
Thermal conductivity (W m^{-1} K^{-1})		2.52	2.48	2.39	2.04
Ultrasound pulse velocity		4.80± 0.15	4.74± 0.11	4.50± 0.01	4.49± 0.01

Slump Test: Slump values of concrete samples varied between 3.50 - 12.00 cm. Addition of hemp fibers resulted in formation of clusters, which adversely affected the workability, a significant property of fresh concrete, leading to a decrease in workability as the fiber content increased. Therefore, workability, an essential characteristic of fresh concrete, decreased with increasing fiber ratios. It was reported in previous studies that amount of mixing water required in concrete mixtures increased with the inclusion of plant waste, such as hemp fibers (Manan & Ganapathy, 2002; Şişman & Alkaya, 2019).

Unit Weight: Unit weights of concrete samples varied between 2262 - 2370 kg m^{-3}. Decreasing unit weights were seen with increasing hemp fiber ratios. Such decreasing unit weights were attributed to lower specific gravity of the fibers and the voids created. However, unit weights of produced fiber-supplemented concretes were higher than 2200 kg m^{-3}, which does not classify them as light-weight concrete (Ekmekyapar & Örüng, 2001; Anonim, 2017; Anonim, 2019d). Previous studies also reported a significant decrease in unit weights with hemp fiber supplementations into concrete mixtures (Neville, 2012; Jami et al., 2019).

The decrease in concrete unit weight reduces the dead load of the structure and increases heat and noise insulation properties. Due to low specific gravity of the fibers and resultant voids, unit weights of fiber-supplemented samples decreased by up to 4.26% (in samples with 5% hemp fiber additives) as compared to control samples without any fibers. Such a slight decrease in unit weight was found to be significant. Such decreases also offer some advantages, such as reduced structural loads and enhanced heat and noise insulation properties. By reducing the building loads, it provides cost savings, particularly in agricultural structures and helps minimize economic losses resulting from natural disasters. By utilizing fiber-reinforced concretes with light-weight aggregates, it is possible to achieve lighter, more cost-effective and well-insulated concretes.

Compressive Strength: Compressive strengths decreased with increasing hemp fiber ratios since hemp fibers absorbed and retained more water, resulted in low specific gravity and reduced surface smoothness. Compressive strength of the samples was found to be reduced by up to 24.09% (5% fiber-supplemented concrete) (average 33.44 MPa) as compared to control samples. Figure 2 illustrates the relationship between compressive strength and unit weight of the samples.

Tensile Strength: The increase in fiber content resulted in positive effects on tensile strength of 1% and 2.5% hemp fiber-supplemented samples, but 5% fiber content decreased tensile strength as compared to the control group. The highest tensile strength was obtained from 1% hemp fiber-supplemented samples. Inclusion of fibers into concrete mixtures facilitated its ductility and prevented load-induced cracks and deformations. Various factors, such as quantities, types, geometries, matrix structure of the mixture and fiber size, influence tensile strength of concrete specimens (Özyurt et al., 2006; Aslan, 2020). Fibers added to concrete suppress microcracks by localizing macrocracks and increase the apparent tensile strength of the matrix (Ganesh-Babu &Pavan-Kumar, 2004).

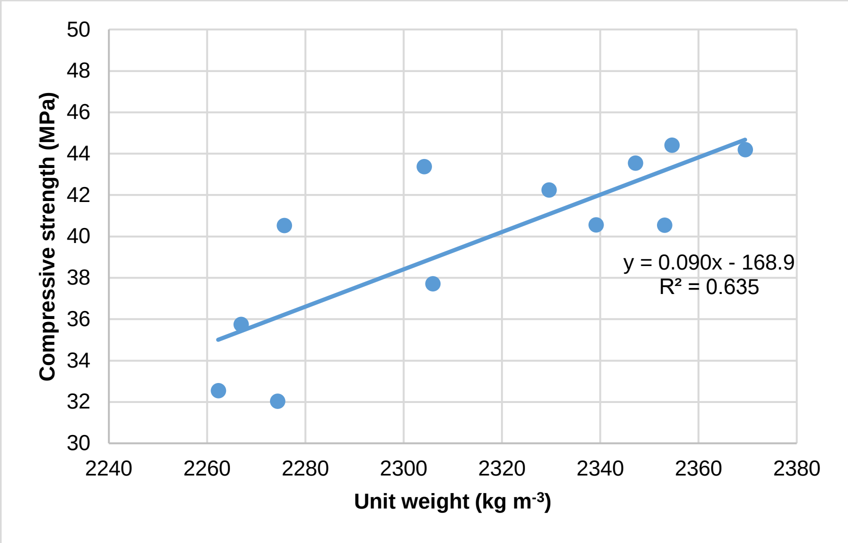

Figure 2. The relationship between compressive strength and unit weight
Şekil 2. Basınç dayanımı ve birim ağırlık ilişkisi

Water Absorption: Water absorption ratios increased with increasing hemp fiber ratios. As compared to control samples, the highest increase in water absorption was determined in 5% fiber-supplemented samples (138.53%). This can be attributed to high water absorption capacity of hemp fibers and the increase in void ratio within the concrete due to fiber-induced clustering. In this sense, a thin plaster should be applied over the hemp fiber-supplemented concrete surface to prevent water from passing through. Because the fibers used as additives absorb excess water, the amount of water used in the concrete mixtures to be prepared must be increased. Furthermore, when preparing mixtures, studies should be conducted to reduce water absorption and minimize voids formed by the use of water-impermeable additives (Figure 3).

Freeze-Thaw Resistance: Concretes produced with different proportions of hemp fibers were subjected to freeze-thaw cycles. Although 28th day compressive strength of hemp fiber-supplemented concretes exposed to freeze-thaw cycles decreased slightly as compared to samples kept under normal curing conditions, but the difference was not significant.

The compressive strength values of hardened concrete samples after freeze-thaw cycles were also compared to compressive strength values of the control samples to determine the reductions in compressive strength. Since the compressive strength variations in all samples were less than 20%, it was determined to be resistant to freeze-thaw cycles (Ekmekyapar & Örüng, 2001; Anonim, 2019e). Weight loss values of the produced concrete samples after freeze-thaw cycles were also determined. It was observed that increase in hemp fiber content led to an increase in weight loss. The highest weight loss was determined in samples with 1% hemp fiber content. The weight loss values determined through weight measurements of hardened concrete samples before and after the freeze-thaw cycles were very small, below 0.3%. Based on minimal weight loss values, it can be concluded that the samples were not significantly affected by freeze-thaw cycles.

Visual examination of hardened concrete samples after freezing-thaw cycles revealed that objectionable deformations such as cracks, dispersion, rupture and fragmentation occurred infrequently, the samples partially maintained surface smoothness and pits and spongy surface structure did not form. It can be stated that hemp fibers added to concrete have no negative effect on freeze-thaw resistance and effects of freeze-thaw cycles on concrete properties were not significant. Hemp fibers in various mixing ratios provided sufficient frost resistance to concrete samples.

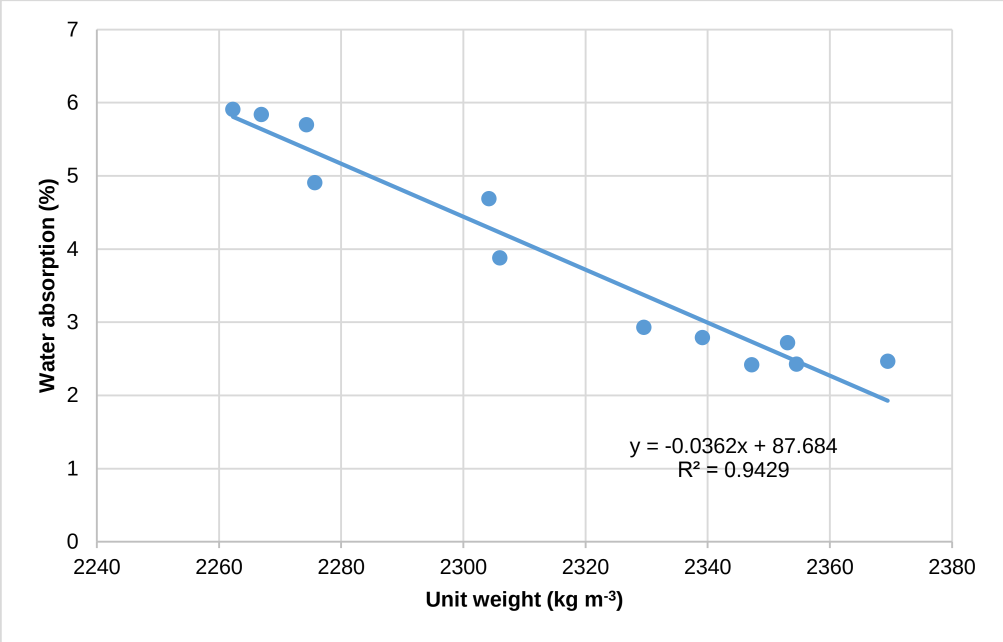

Figure 3. The relationship between water absorption and unit weight
Şekil 3. Su emme ve birim ağırlık ilişkisi

Thermal Conductivity: Thermal conductivity values of the produced concrete samples ranged from 2.0395 to 2.5162 W m^{-1} K^{-1}. Thermal conductivity values decreased with increasing fiber ratios. The highest reduction in thermal conductivity, up to 18.95%, was observed in the samples with 5% fiber content (2.0395 W m^{-1} K^{-1}) as compared to the control samples.

Ultrasonic Pulse Velocity: Ultrasound pulse velocity values of the concrete samples ranged from 4.49 to 4.80 km s^{-1}. Decreasing values were seen with increasing fiber ratios. As compared to control samples, the highest decrease in ultrasound pulse velocity, up to 6.46%, was observed in the samples with 5% fiber content. The voids formed as a result of clustering caused by the increase in fiber content hindered propagation of ultrasound pulses, leading to a decrease in ultra sound pulse velocity.

CONCLUSION

Present findings revealed that increasing hemp fiber ratios resulted in a material with lower unit weight, compressive strength, ultrasound pulse velocity and thermal conductivity coefficients and with a higher tensile strength and water absorption. Use of hemp fibers in concrete production yielded a material with high tensile strength, low thermal conductivity and suitable for cold climate conditions. It was concluded that fiber content could be adjusted to enhance tensile strength (up to 1%). Beyond this ratio, strength properties decreased, but insulation properties were improved. It was suggested that in single-story agricultural structures not subjected to excessive load effects in cold climates, measures could be taken to enhance strength and durability characteristics by incorporating hemp fibers as structural elements. However, excessive fiber content led to increased voids and hindered homogeneous mixing, negatively affecting compaction and compressive strength. Presence of voids also resulted in decreased workability, increased water absorption and lower compressive strength. To prevent fiber agglomeration within the concrete, further research could explore different additives and methods. By adjusting hemp fiber content and testing various thicknesses, desired thermal conductivity coefficients could be achieved, leading to reduced heating costs and decreased use of insulation materials. Further research is recommended on environment-friendly, sustainable and locally available hemp fiber-modified insulation materials that provide high insulation properties and promote healthy living conditions in agricultural structures.

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Contribution of the Authors

Authors declare the contribution of the authors is equal.

Statement of Conflict of Interest

Author has declared no conflict of interest.

REFERENCES

Anonim, (2002). *Isı yalıtımı - Kararlı halde ısıl direncin ve ilgili özelliklerin tayini - Isı akış tayini için metotlar (TS ISO 8301).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2003). *Yapı malzemeleri ve mamullerinin ısıl performansı-Mahfazalı sıcak plaka ve ısı akış sayacı metotlarıyla ısıl direncin tayini-Yüksek ve orta ısıl dirençli mamuller (TS EN 12667).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2009a). *Beton agregaları (TS 706 EN 12620+A1).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2009b). *Yapı malzemeleri ve mamulleri - Isıl direncin, korumalı tablalı ısıtıcı ve ısı akı ölçerin kullanıldığı metotlarla tayini - Isıl direnci orta ve düşük seviyede olan kuru ve rutubetli mamuller (TS EN 12664).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2012a). *Çimento- Bölüm 1: Genel çimentolar-Bileşim, özellikler ve uygunluk kriterleri (TS EN 197-1).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2012b). *Agregaların geometrik özellikleri için deneyler bölüm 1: Tane büyüklüğü dağılımı tayini- Eleme metodu (TS EN 933-1).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2012c). *Beton - Basınç deney numunelerinin hazırlanması, hızlandırılmış küre tabi tutulması ve deneyleri (TS 3323).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2017). *Taşıyıcı hafif betonların karışım hesap esasları (TS 2511).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2018). *Beton yapım, döküm ve bakım kuralları (Normal hava koşullarında) (TS 1247).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2019a). *Beton - Sertleşmiş beton deneyleri - Bölüm 2: Dayanım deneylerinde kullanılacak deney numunelerinin hazırlanması ve küre tabi tutulması (TS EN 12390-2).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2019b). *Beton - Sertleşmiş beton deneyleri - Bölüm 3: Deney numunelerinin basınç dayanımının tayin (TS EN 12390-3).* Türk Standartları Enstitüsü, Ankara

Anonim, (2019c). *Beton - Taze beton deneyleri - Bölüm 2: Çökme (slump) deneyi (TS EN 12350-2).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2019d). *Beton - Taze beton deneyleri - Bölüm 6: Birim hacim kütlesi (TS EN 12350-6).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2019e). *Beton - Sertleşmiş beton deneyleri - Bölüm 7: Sertleşmiş betonun birim hacim kütlesinin tayini (TS EN 12390-7).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2019f). *Beton - Sertleşmiş beton deneyleri - Bölüm 4: Basınç dayanımı - Deney makinelerinin özellikleri (TS EN 12390-4).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2020). *Agregaların mekanik ve fiziksel özellikleri için deneyler bölüm 2: Parçalanma direncinin tayini için metotlar (TS EN 1097-2).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2021). *Yapılarda beton deneyleri - Bölüm 4: Ultrasonik atımlı dalga hızının tayini (TS EN 12504-4).* Türk Standartları Enstitüsü, Ankara.

Anonim, (2022a). http://halityazici-deu.com/dersler/ozel-betonlar/, Yazıcı, H.(Alınma Tarihi: 03.12.2022).

Anonim, (2022b). *Agregaların mekanik ve fiziksel özellikleri için deneyler - Bölüm 6: Tane yoğunluğunun ve su emme oranının tayini (TS EN 1097-6).* Türk Standartları Enstitüsü, Ankara.

Anonymous, (1982). *State-of-the-report on fibre reinforced concrete, (ACI 544.1R-82). Concrete International: Design and Construction. 4 (5)*: 9-30, American Concrete Institute, Detroit, Michigan, USA.

Anonymous, (1986). *Testing Concrete-Part 203: Recommendations for the Measurement of Velocity of Ultrasonic Pulses in Concrete.* British Standards Institution, London.

Anonymous, (1997a). *Standard test method for density, absorption, andvoids in hardened concrete.* American Society for Testing and Materials, USA.

Anonymous, (1997b). *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing.* Annual Book of ASTM Standards, vol. 04.02. West Conshohocken, PA.

Anonymous, (2003). *Standard Test MethodforSteady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus.* American Society for Testing and Materials, Philadelphia, Pa., 15 s.

Anonymous, (2015). *American Society for Testing and Materials. Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.* ASTM C39/C39M-01, Philadelphia.

Anonymous, (2016). *Standard Test Method for Pulse Velocity through Concrete*; American Society for Testing and Materials: West Conshohocken, PA, USA.

Açıkel, H., Altun, F., & Elcuman, H., (2005). Miskantus Bitkisinin Öğütülmüş Halde ve Lif Katkısı Olarak Betonun Mekanik Özelliklerine Etkisinin Deneysel İncelenmesi. Antalya Yöresinin İnşaat Mühendisliği Sorunları Kongresi, Antalya, 23-25 Eylül, 2005, s.244-252.

Ağaoğlu, O. (2018). *Beton Atıklarının Agrega Olarak Kullanılması İle Üretilen Makro Lifli Betonların Mekanik Özelliklerinin İncelenmesi (Tez no 492590).* [Yüksek Lisans Tezi, Konya KTO Karatay Üniversitesi, Fen Bilimleri Enstitüsü, İnşaat Mühendisliği Anabilim Dalı]. Yüksek

Öğretim Kurulu Ulusal Tez Merkezi.

Aslan, S. (2020). *Cam Lif Takviyesinin Beton Üzerindeki Etkilerinin İncelenmesi Tez no 626182.* [Yüksek Lisans Tezi, Avrasya Üniversitesi, Fen Bilimleri Enstitüsü, İnşaat Mühendisliği Anabilim Dalı]. Yüksek Öğretim Kurulu Ulusal Tez Merkezi.

Atashafrazeh, M. (2013). *Polipropilen Lif Takviyeli Betonların Yüksek Sıcaklık Etkilerinden Sonra Basınç Dayanımlarının İncelenmesi Tez no 324740.* [Yüksek Lisans Tezi, Atatürk Üniversitesi, Fen Bilimleri Enstitüsü, İnşaat Mühendisliği Ana Bilim Dalı]. Yüksek Öğretim Kurulu Ulusal Tez Merkezi.

Candoğan, B. N., Yetik, A. K., Sincik, M., Demir, A. O., & Büyükcangaz, H. (2022). Determination of Diurnal Leaf Gas Exchange for Drip-Irrigated Kenaf Plant in Sub-Humid Climatic Conditions. Polish Journal of Environmental Studies, 31(5), 4557-4566

Cengiz, A. (2015). *İnşaat Endüstrisine Yönelik Doğal elyaf Katkılı Kompozit Malzemelerin Hazırlanması Tez no 392759.* [Yüksek Lisans Tezi, Hacettepe Üniversitesi, Fen Bilimleri Enstitüsü, Kimya Anabilim Dalı]. Yüksek Öğretim Kurulu Ulusal Tez Merkezi.

Ekmekyapar, T., & Örüng. (2001). *İnşaat malzeme bilgisi*. Atatürk Üniversitesi Ziraat Fakültesi Ofset Tesisi, Erzurum.

Ganesh-Babu. K., & Pavan-Kumar. D. (2004). Behavior of Glass Fibre Reinforced Cement Composites. ICFRC International Conference on FibreComposites, High Performance *Concretes and Smart Materials*, 8-10 s., Chennai.

Gedik, G., Avinç, O. O., & Yavaş, A. (2010). Kenevir lifinin özellikleri ve tekstil endüstrisinde kullanımıyla sağladığı avantajlar. *Tekstil Teknolojileri Elektronik Dergisi,* 4, (3), s39-48.

Jami, T., Karade, S.R., & Singh, L.P. (2019). A review of the properties of hemp concrete for green building applications. *Journal of Cleaner Production,* 239, 117852

Karaman, S. (2007). Tarımsal yapılarda kullanılan hafif inşaat malzemeleri. *Harran Üniversitesi Ziraat Fakültesi Dergisi, 11* (1),63-69.

Kurt, G. (2006). Lif İçeriği ve Su/Çimento Oranının Fibrobetonun Mekanik Davranışına Etkileri Tez no 223839. [Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, İnşaat Mühendisliği Anabilim Dalı]. Yüksek Öğretim Kurulu Ulusal Tez Merkezi.

Manan, M. A., & Ganapathy, C. (2002). Engineering properties of concrete with oil palm shells as coarse aggregate. *Construction Building Material*, *16*, 1, 29–34.

Mujadidi, M. Y. A. (2020). Cam Lifi Kullanımının Betonun Mekanik Özeliklerine ve Korozyon Dayanıklılığına Etkisi. Kütahya Dumlupınar Üniversitesi Tez no 646884, [Lisansüstü Eğitim Enstitüsü, İnşaat Mühendisliği Anabilim Dalı]. Yüksek Öğretim Kurulu Ulusal Tez Merkezi.

Neville, A.M. (2012). *Properties of concrete, fifth ed.* Pearson Education.

Özyurt, N., Taşdemir, M. A., & Shah, S. P. (2006). Lif Donatılı Çimento Esaslı Kompozitlerde, Lif Dağılımının Elektriksel Bir Yöntem İle Tahribatsız Ölçümü. *İstanbul Teknik Üniversitesi Mühendislik Dergisi, 5,* (4), 119–130.

Shahzad, A. (2011). Hemp Fiber and its Composites – A Review. Journal of Composite Materials 46(8), 973–986.

Şisman, C. B., & Alkaya, S., (2019). Usability of sunflower stems as lightweight aggregate in concrete production, Fresenius Environmental Bulletin 28 (12 A), 9983-9990

Tran Le, A. D., Maalouf, C., Mai, T.H., & Wurtz, E. (2009). Study of the transient behaviour of a hemp concrete buildıng envelope. Building., Simulation. Eleventh International IBPSA Conference, Glasgow, Scotland, July 27-30.

Walker, R., Pavia, S., & Mitchell, R. (2014). Mechanical properties and durability ofhemp-lime concretes. Constr. Build. Mater. 61, 340-348.

Zollo, R. F. (1997). Fiber-reinforced concrete: An Overview after 30 years of Development. *Cement and Concrete Composites, 19*(2), 107-122.