Research Article

ICONARP
International Journal of Architecture and Planning
Received: 19.10.2019 Accepted: 04.12.2020
Volume 9, Issue 1/ Published: 21.06.2021
DOI: 10.15320/ICONARP.2021.153 E- ISSN:2147-380

ICONARP

Hemp as a Potential Material in Architecture: Is it Possible in Turkey?

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Abstract

Purpose

Hemp, also known as cannabis sativa, has long been one of the most important agricultural crops—an essential food for humans and animals since the Neolithic period. It is also one of the most-durable raw materials used in both traditional crafts and many newer industries, such as the marine, clothing, automotive, and architectural industries. However, despite its beneficial health properties and use in making durable products, hemp has been banned in many developed countries largely because it has been labeled an illegal plant due to its psychoactive properties. After the 1980s, industrially cultivated hemp in the form of hempcrete, hemp brick or low or high technology cast in situ wall systems gained recognition in architecture. Since the industry 4.0 industrial revolution in the 2000s, the use of hemp has become increasingly important in medicine and nutrition and in industries such as paper, plastics, architecture and construction. Hemp has been illegal for many years in Turkey. However, in Turkish history, using cannabis, hemp and hashish for food, pleasure, socializing, clothing, rope, paper and mortar has been an accepted sociocultural phenomenon. Therefore, this article seeks to evaluate the possibility of using hemp in architecture by addressing its use in architecture, specifically in Turkey.

Design/Methodology/Approach

This research uses a literature review to explore both the history of hemp in Turkey and its construction applications.

Findings

The results showed that given enough support, the use of such materials could create beneficial effects for the architecture, construction and education sectors in Turkey.

Research Limitations/Implications

In the future, a research with funding and permissions could be conducted to observe of the physical and chemical characteristics of hemp and hemp-based materials, which is lacking in this study.

Social/Practical Implications

Recognizing the benefits of hemp could have positive effects on the economy, health, agriculture and architecture of communities in Turkey. Hemp can replace petroleum-based materials while having the advantages of being cost effective, providing a variety of production possibilities, and needing less water for cultivation.

Originality/Value

This is the first study to address the potential use of industrial hemp in Turkey from an architecture and design perspective.

Keywords: *Hemp architecture, Hempcrete, building material, sustainability*

INTRODUCTION

Although most people have knowledge of hemp, we hesitate to talk about it due to its controversial nature in contemporary societies. This avoidance is mainly due to attitudes in the civilized Western world and comes from a lack of knowledge of it or from the strict policies and regulations that governments and institutions have implemented regarding the use of hemp since the 1950s in Western societies. As a historically and culturally important plant, hemp has been one of the most important and largest agricultural crops in the history of humankind. In addition, hemp has been an essential food and high-protein resource for humans and animals due to its high nutritional properties (Herer, 2010).

Hemp one of the earliest recorded domestically grown plants, having been cultivated since Neolithic times (Stanwix & Sparrow, 2014); it is "the strongest, most-durable, longest-lasting natural soft-fiber" plant and can be grown in any climate or soil condition (Herer, 2010). Hemp, which is also known as cannabis sativa L. or indica L., is a plant that grows naturally in many different geographies (Pecenko et al., 2014)[1]; it is a versatile raw material that has been used in many ways over the past 10,000 years (Deitch, 2003).

The use of industrial hemp is currently spreading throughout many sectors, including architecture and construction. Since its recognition in Europe in the 1980s, hemp has regained its former importance, especially in the medicine and health sector, as well as in biocomposite industries.

Hemp use became widespread in Europe through migration to the shores of the Black Sea and towards India and the Middle East (Bouloc, 2013). The current state of hemp use currently remains ambiguous and contradictory due to research results that emphasize its importance in health and its other benefits.

The barriers and production bans are gradually being abolished by governments and nongovernmental organizations in many countries. Therefore, this article reviews the literature on the use of industrial hemp in architecture, design and construction worldwide, while specifically addressing its production possibilities in Turkey.

THE USE OF HEMP AND CANNABIS THROUGHOUT HISTORY

Hemp appeared in the earliest known woven fabric in 8,000–7,000 BC (Herer, 2010). Hemp emerged in China c. 8000 BC. Pottery has been found that was dated between 6200 and 4000 BC and depicted clothing that, through analysis, was shown to be made from hemp East (Bouloc, 2013). In the Neolithic Çatalhöyük settlement, hemp was found in a well-preserved linen cloth made from flax and placed between the skeletons of persons buried beneath the floors in one of the shelters; similar discoveries have been made in places from the Levant all the way to central Anatolia (Hodder, 2013). Hemp seeds and rope have also been found in graves and tombs in China from 2000 BC East (Bouloc,

[1] Initially studied and classified as two types—as cannabis sativa and indica—by Lamarck in 1785, a third type of hemp, i.e., cannabis ruderalis, was later found by the Russian botanist D. E. Janischevsky in 1924 (Hillig & Mahlberg, 2004).

DOI: 10.15320/ICONARP.2021.153

2013). In addition to having nutritional qualities, hemp leaves and flower tops (marijuana) have been commonly used as medicines for at least 3,000 years (Herer, 2010).

Cannabis was used in Mesopotamia since the time of the Sumerians, and its seeds were used as a medicine. It is estimated that cannabis may have been carried to Europe by the Scythians in the VII century BC. The first information about the use of cannabis as a drug is found in Herodotus's The Histories (5th century BC) (Baytop, 1995). From a sociocultural context, hemp has been smoked in various forms in many cultures. The cannabis indica form of hemp appeared in the 15th-century medieval art miniatures of Mehmed Siyah Kalem (Haydaroğlu, 2004); (Yörükan Karamağaralı, 1982) (Figure 1). In addition, in İslamic art, hemp and hashish motifs have been found in life trees on stone reliefs.

Figure 1. A miniature by Mehmed Siyah Kalem of a man presenting cannabis to another, 15th century (Yörükan Karamağaralı, 1982) Image from (Haydaroğlu, 2004) (The image is from the Topkapı Palace Museum, TSM 2160/10-A.).

The trade of hemp was also been "a fundamental driving force in the early colonization of America" (Deitch, 2003). Throughout history, hemp has been used for basic needs; oil extracted from hemp seeds was used as lamp oil, resin, paint and varnish "to waterproof the hulls of wooden ships [as well as for] fuel, medicines and cosmetics and paper" (Deitch, 2003). Hemp seeds were consumed as porridge, and hemp flour was used in baking. Its strong fibers have been valued for use as cordage, rope, cloth (linen), and sailcloth (Stanwix & Sparrow, 2014); (Deitch, 2003).

In addition to the abovementioned useful properties, hemp has had very important uses in healthcare because it can be used for easing pain, as well as for animal feed or in veterinary medicine (Herer, 2010); (Deitch, 2003). Hemp has been used in Arabia, Persia, Mesopotamia, Egypt, and India (Levey, 1979). Also referred to as *kendir, kenevir*, and *kınnab* in Turkish, hemp (cannabis sativa) was used in Ottoman medicine as a pain killer and by İbn-i Sina (Avicenna) (Kahya, 2017). In Western medicine, hemp was recognized for its health properties between 1850 and 1941. Extremely strong marijuana (known as *cannabis extractums*) and hashish extracts, tinctures and elixirs were previously used as

medicine in the USA (Eddy, 2011); (Herer, 2010). However, the rapid development and popularization of the cotton industry in the late 18th century (Allegret, 2013) caused a sharp decrease in the areas producing hemp over the last 150 years in Europe until the 2000s (Allegret, 2013). However, since anti-hemp propaganda began in the USA in the 1920s, hemp has faced restrictions and bans in many developed countries due to the illegal use and misuse of hemp for its psychoactive effects on humans (because of the THC content). After 1936, the USA "enacted laws to regulate marijuana. Its decline in medicine was hastened by the development of aspirin, morphine, and then other opium-derived drugs, all of which helped to replace marijuana in the treatment of pain and other medical conditions" (Eddy, 2011).

The production of both hemp and flax decreased continuously after World War I. Due to the its medical effects and pharmacological properties, hemp lost its "widespread use as a component fiber in many fabrics", as the chemical company DuPont was developing "synthetic fibers derived from the petrol industry" (Allegret, 2013). The discrimination against hemp due to its psychoactive properties and its misuse because of those properties has resulted in it being banned and poorly recognized today; thus, the value of a raw feedstock such as hemp must be contemplated not only from sociocultural, sustainability and health perspectives but also from the perspective of the monetary policies imposed on it.

Therefore, the story behind hemp helps us understand its importance and potential uses in many sectors, from human and animal health to the conservation of nature. Therefore, this article focuses on the use of hemp in our modern societies and urges us to reconsider its potential use in architecture and construction. Today, cannabinoids (CBD oil), nonpsychoactive compounds derived from the leaves of *cannabis sativa* and medical marijuana plants, have been recognized as having beneficial antitumor effects for some types of cancer (Velasco et al., 2012) and for soothing the symptoms of MS; additionally, they have been found to have beneficial health effects for those with many other chronic diseases.

Other beneficial uses of the hemp plant include its use in "crop rotation", as well as "erosion, pest and weed control", and "any other horticultural or environmental purposes" (Herer, 2010). Since hemp "needs less water and fertilizer than cotton and needs no pesticides" and is "high in cellulose", it has been evaluated as an alternative [out of sources other] to trees for paper making throughout history (Danenberg, 2002) (Figure 2).

DOI: 10.15320/ICONARP.2021.153

Figure 2. A hemp field in China (Hemp Edification, 2016).

INDUSTRIAL HEMP IN ARCHITECTURE, DESIGN AND CONSTRUCTION

Raw materials, including those used in earthen architecture, such as adobe, rammed earth, cob (mud mixed with straw) and straw bale houses, have been used in the making of spaces and in architecture since the beginning of humankind, both traditionally and as a modern design. Earthships are made of recycled materials such as used tires, while cob houses are made of mixtures of soil, sand, and straw. Cob houses do not usually have construction inside; the materials used in cob housing are not dried bricks. However, the houses are formed on site. In straw bale houses, straw bales are used as the loadbearing structural elements, which are plastered with a lime-based, earth or clay mixture. Sometimes the straws are bounded together with string or other support to add rigidity.

Since the 2000s and after the industry 4.0industrial revolution, hemp has gained importance in Europe, and the European Industrial Hemp Association (EIHA) (2005) was established (Ulaş, 2018). Today, as Peev mentions, "hemp production is still facing restrictions in many countries which make its implementation in the building sector difficult" (Peev, 2012). However, since the 1980s, hemp has been evaluated for its use in architecture, since it is a "renewable and low energy material" (Danenberg, 2002).

From a global perspective, between 1961-2000, Asia had the largest hempseed production, i.e., 56.8%, while Europe produced 41.1% and 2.1% of hemp was produced in the Americas; however, this shifted to 75.4% in Europe, 23.2% in Asia and 1.4% in the Americas between 2000 and 2018 (FAOSTAT, 2020a); (FAOSTAT, 2020b).

Plants such as flax, straw, hemp, reed, and those with starch-based fibers, such as banana, pineapple, coconut, bamboo and China-grass, have been used to make biocomposites (Gruber, 2011). In terms of agricultural livestock husbandry materials, products such as "straw, flax, sugar cane bagasse, corn, hemp, rice husk, groundnut shells, kenaf,

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sheep wool, casein and polylactic acid (PLA)" have been used as raw materials in buildings (Suttie *et al*., 2017).

In terms of hemp, the fibrous bark and hemp hurds (shiv), as the softer parts of the plant, make good building and construction materials. Hemp seeds can be used as "a raw material for biologically derived plastics, resins, paints, varnishes and shellacs" (Danenberg, 2002). Both the stalks and the fibers of hemp are processed for and used as construction materials (Réh & Barbu, 2017). Hemp has been used as a traditional building material for centuries. The use of hemp in the history of architecture and construction goes back to the 6th century (between 500 and 751 AD), when hemp was used as a mortar in "bridge abutments" in Merovingian bridges in France (Hemp Edification, 2015). A stone bridge built with hemp mortar in Saint Céneri le Gérei in this period still stands. The mortar consists of more than 10% hemp, which allows the mortar to "absorb moisture, allowing the mortar to take in and release the excess water when conditions allow" (Cannalore, 2018) (Figure 3).

Figure 3. Hemp mortar stone Merovingian bridge, Sarthe River Bridge in Saint Céneri le Gérei, France (Cannalore, 2018).

As Réh and Barbu explain, "hemp fiber, as with many other natural fibers, is undergoing a renaissance within the construction sector" today. Hemp has gained importance due to its natural properties and "the environmental benefits in terms of energy saving during construction phases" (Réh & Barbu, 2017). Hemp fibers have been described as a material that is "cost effective", has "high tensile strength and stiffness", is "ideally suited for needle-punched nonwoven products", is an "effective replacement for glass fiber", "reduces molding time", "can be customized to meet a variety of specifications and different manufacturing systems", and in which a "consistent quality and availability of supply is possible" (Réh & Barbu, 2017) (Figure 4).

DOI: 10.15320/ICONARP.2021.153

Figure 4. Hemp/Flax Plant Straw (Hemp Straw Pellet Mill, n.d.).

Hemp a more sustainable raw material than other materials currently used, and the final product is also carbon negative. This means that hemp has the ability to absorb more greenhouse gases over its lifetime than are emitted during its production process (Réh & Barbu, 2017). According to the European Industrial Hemp Association (EIHA), which supports "the cultivation, processing and use of industrial hemp", within the confines of EU law, "hemp will and is playing an important role in the production of innovative biobased products like natural fiber reinforced plastics, insulation and construction materials" (EIHA (The European Industrial Hemp Association), 2009). Some other hemp associations include the Indian Industrial Hemp Association (founded 2011), the Hemp Industries Association, USA (1994), the Canadian Hemp Trade Alliance (2003). The top hemp-growing countries are China, Canada, the USA, France, Chile, and North Korea (James, 2019). Following hemp's growing popularity, "the International Hemp Building Association" (IHBA) was founded in Ireland in 2009 (The International Hemp Building Association (IHBA), 2019). This association, along with similar organizations, promote the use of hemp and its applications and practices using handmade and industrial techniques. In architecture, the IHBA and HempBuilding, which is directed by Steve Allin and is located in Ireland, aim to build a hemp community and develop and support the production and use of all hemp-based construction materials and their byproducts (The International Hemp Building Association (IHBA), 2020).

Hemp has been used in numerous products and industries for many years in Asia and Europe; however, as Gołębiewski mentions, because hemp crops were considered illegal, the hempcrete technology that emerged at the end of the twentieth century was prohibited (Gołębiewski, 2017). Despite these legislation barriers in many countries, the spread of industrial cannabis as an economic and sustainable raw material is increasing. Many governmental and nongovernmental organizations are making arrangements to overcome the obstacles to the use of hemp in many sectors, from healthcare to construction materials. Industrial hemp is receiving recognition in countries such as Ireland, Australia, Great Britain and France and is mostly used in single-family homes, multifamily and public buildings,

warehouses, and other structures. The current studies indicate that the long-term performance of this material is promising, and the legislation regarding hemp production is beginning to change; thus, it is likely that hemp will be used and produced in many countries in the near future (Gołębiewski, 2017).

Hemp composite building materials are "inexpensive, fire-resistant construction materials, with excellent thermal and sound-insulating qualities"; they are produced by "heating and compressing plant fibers to create strong construction paneling, replacing dry wall and plywood" (Herer, 2010) (Figure 5).

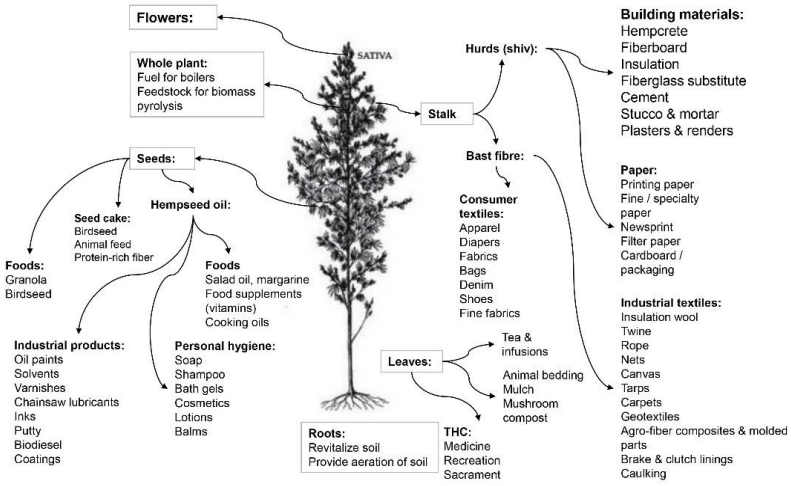

Figure 5. Commercial uses of hemp today (Data derived from (Stanwix & Sparrow, 2014); (Yörükan Karamağaralı, 1982); Image derived from (Leafscience, 2017).

In the Great Seljuq, Anatolian Seljuk and Ottoman periods, the hemp motif was used on tiles, ceramics, tombstones, carpets and miniatures (Yörükan Karamağaralı, 1982). There is also evidence that in Ottoman architecture, hemp and linen fibers mixed with porous and soft Horasan mortar were used as one of the three types of mortars in a number of mosques, such as the soft texture mortar used in the dome of the Rustem Pasha Mosque (1555-1561), which was built by an architect named Sinan, and the dome of the Sultan Ahmed Mosque, which used a harder texture mortar. "The hardness of this material, which is a good sound absorber at low and medium frequencies, can be controlled according to need" (Kayılı, 1988) (Figure 6). Additionally, in the Selimiye Mosque, the interior walls have a hemp motif.

Figure 6. Sultanahmet Mosque, 1603-1617, İstanbul, built by architect Sedefkar Mehmed Aga (Sultanahmetcamii, 2019).

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In Turkey, adobe architecture was prevalent in Anatolia throughout history, mainly in the Mesopotamian region. After the World War II, many countries developed contemporary earthen architecture. Having significant ecological and economic advantages, including being energy efficient, modern works on earthen architecture started in the 1950s in Turkey and were given the name *alker* in the early 1980s. *Alker* (adobe mixed with lime, gypsum and water) construction was developed by Ruhi Kafesçioğlu. Many *alker* construction buildings have been built, mainly in rural areas of Turkey (Kafesçioğlu, 2017). Another historic hemp house was built in Nagano, Japan, in 1698. Hemp stalks, also known as *asagara*, were used in the interior walls and under the roof (Figures 7, 8).

Figure 7. The Nakamura Family Residence, Miasa Mura, 1698, Japan (Miasa village, 2019).

Figure 8. The Nakamura Family Residence: *Asagara* (hemp stalks) used under a *Kaya* (Eulalia) roof; *asagara* used as an interior wall; hemp stalks at the base of thatched roof beams; and roof tied with hemp ropes (Miasa village, 2019) (from left to right)

HEMP USES IN ARCHITECTURE

Hempcrete (hemp-lime composite)

After the 1980s, hemp's use as an industrial raw material was rediscovered and redeveloped in France in the form of "hempcrete" (hemp-lime composite) in the construction industry (Herer, 2010). Hempcrete is "created by wet-mixing the chopped woody stem of the hemp plant (hemp shiv) with a lime-based binder (natural hydraulic lime) to create a material that can be cast into molds" (Allin, 2005); (Stanwix & Sparrow, 2014). Hemp shivs are byproducts of hemp fiber

harvesting and the trash burned in the field (Réh & Barbu, 2017). This mixture is a non-loadbearing, sustainable, "breathable" (vapor permeable) and insulating material that can be used to form walls, floor slabs, ceilings and roof insulation in both new build and restoration projects (Allin, 2005); (Stanwix & Sparrow, 2014). Other binders for hempcrete include cement clinker, pozzolanic ash, natural cement, clay, and gypsum (Maher, 2014) (Figures 9, 10).

Figure 9. A Hempcrete mixture (Allin, 2005); (Stanwix & Sparrow, 2014); Images derived from (Limetec, 2019); (Plainshemp, 2019).

Figure 10. a) The first Hempcrete use in the renovation of Nogent-sur-Seine, France; b) Maison d'Adam, Angers, France, renovated in 1994 (Chevreuil, 1966); (Google Map, 2019); (Gołębiewski, 2017).

Hemp fibers have been produced with the same technique and reintroduced in a material named Isochanvre in France. Isochanvre is "made from hemp hurds mixed with lime" (Herer, 2010). It can be used in drywall construction between form work or as interior or exterior insulation; it can also be poured as a floor or as an addition to an existing slab to raise the level of a floor. In Europe today, France is "the biggest producer of hemp, but only about 5% of hurds are used in the building sector" (Hemp Edification, 2015); (Danenberg, 2002). Hempcrete can be manually applied or sprayed, and it can be used in industrial buildings attached to steel frames with timber panels.

Since hempcrete has "low mechanical strength" (Gołębiewski, 2017), it does not have high strength or loadbearing characteristics; instead, it can be "used for walls, roofs and floor" as well as "wall insulation" on the "outer side of an existing home". Other properties of hempcrete include "low thermal conductivity", "high vapor permeability", and being "very water absorbent". Hempcrete is "fire resistant" and "resistant to biological" and "chemical corrosion" and has good "acoustic properties" (Gołębiewski, 2017). In addition, hempcrete "is very fire resistant, is an extremely efficient insulator, can be grown with very little water, and is

DOI: 10.15320/ICONARP.2021.153

virtually impermeable to termites. The lime content in the hemp blocks sucks in large quantities carbon dioxide—up to 12 tons, according to the company's own estimates—which it needs to harden, meaning that the wall continuously becomes more solid and that the structure, over time, becomes carbon negative" (Cannabric, 2012). Hempcrete can also be constructed in circular shapes (Hemptechglobal, 2019).

Hemp Technologies in the USA and Cannabric, designed by the German architect Monika Brümmer, are two of the main hemp companies engaged in hemp building projects. Cannabric has been successfully used in ecological and bioclimatic architecture, the restoration of historic buildings and the rehabilitation of traditional cave dwellings (Cannabric, 2019a). As a material similar to a concrete mixture, hempcrete is made of wood chips (hemp shivs) derived from hemp (cannabis sativa), a lime-based binder and water (Cannabric, 2012). This mixture is realized by using a mechanical mixer; the mixture is placed or sprayed onto surfaces; it can be poured into slabs or shaped with formwork (Stanwix & Sparrow, 2014); (Cannabric, 2012)[2]. It can be "built with prefab pressed bricks" and "the outer walls can then be finished with a coated wooden cover or with a plaster mix of lime and sand" (Réh & Barbu, 2017) (Figures 11, 12, 13, 14, 15).

[2] According to Stanwix and Sparrow, the mixture is applied rather than poured, since it does not have a liquid consistency (Stanwix & Sparrow, 2014).

Figure 11. Process of hempcrete: mixing; cast in situ hand-placed hempcrete around a softwood timber structural frame; spray-applying the mixture; and sprayed hemp is projected against a permanent shuttering board (Stanwix & Sparrow, 2014)

Figure 12. Hempbrick by Cannabric, compressed earth brick with hemp for insulating, loadbearing inside- and outside walls (Cannabric, 2019b).

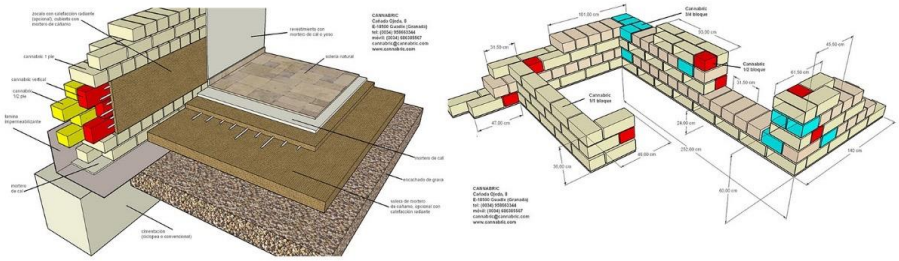

Figure 13. a) Hempbrick by Cannabric, with insulation and b) loadbearing properties (Cannabric, 2019b).

Figure 14. A Hempcrete residential building constructed in Asheville, North Carolina, by Hemptech Global (Hemptechglobal, 2019).

Figure 15. Hempcrete house in Marfa, Texas Hemptech Global (Hemptechglobal, 2019).

Hempcrete can be produced in both block form and panel form. “Hempcrete blocks are usually laid by wetting on the surface and bedded using a thin mortar of hydraulic lime and sand” (Stanwix & Sparrow, 2014). During application, hempcrete can be “cast in situ” or “precast”. In a cast in situ application, it takes weeks for the material to dry, and the process is affected by the environmental conditions, such as “temperature, exposure, humidity and effective management of drying”, but there are reduced labor costs in this type of application. However, in the precast method, the blocks have a time advantage because the material has dried prior to the application (Stanwix & Sparrow, 2014).

Another material produced from hemp fibers is hemp and flax wool, which was developed in 1998. Hemp wool is composed of hemp fibers “using heat-fusible fibers, generally of polyester” (Arnaud *et al.*, 2013). Housing insulation made from hemp is quickly becoming a popular eco-friendly alternative to traditional insulation materials, such as mineral wool. As a low energy, natural material, hemp can take its place among materials such as “biologically derived plastics, resins, paints, varnishes and shellacs” (Danenberg, 2002).

DOI: 10.15320/ICONARP.2021.153

Hemp Uses in Industrial Design

Hemp also contributes to strengthening bioplastics as raw feedstock. Whether or not it is biodegradable, natural or petroleum-based plastic can be made from natural fibers, such as those of "animal origin (wool, silk…) or of plant origin (cotton, flax, hemp, jute, sisal, kenaf, cocoa, abaca and wood)". Plant-based fibers are commonly used in plastics. In Europe, wood, flax and hemp are three of the most commonly used fibers (Mougin, 2013).

Hemp fibers have also been used in durable bioplastics to improve their quality (EIHA (The European Industrial Hemp Association), 2009); additionally, due to "their high strength and rigidity, these plastics are currently used in the construction of cars, boats, and even musical instruments" (O'Connell, 2017). "Some of the earliest plastics were made from cellulose fibers" that came from "nonpetroleum-based sources" (O'Connell, 2017). In the 1940s, Henry Ford designed a car with panels made of hemp fibers (Deitch, 2003) and other agricultural feedstock. Today, hemp is used in a variety of applications in industrial design ranging from everyday objects to the automotive industry and its components, such as car doors, as seen in the panels of some of BMW, Mercedes and Bugatti cars. A hemp plant contains "65-70% cellulose", making it a good source of cellulose (wood contains approximately 40%, flax 65-75%, and cotton up to 90%). Hemp can be added to conventional, petroleum-based plastics or, alternatively, can be used on its own. However, 100% hemp-based plastic is rarely produced because "composite bioplastics", which are a mixture of hemp and other plant-based sources, are on the market (O'Connell, 2017). As a low-cost, sustainable material with a low environmental impact, hemp bioplastics "reduce…CO2 emissions" (EIHA (The European Industrial Hemp Association), 2009); (O'Connell, 2017) (Figure 16).

Figure 16. Industrial products with hemp: 1) A hemp motorcycle; 2) a sports car, the Lotus Eco Elise, made from different natural fiber compounds using hand lay-up, vacuum bagging and RTM (UK), Lotus Cars; 3) BMW 5 Series car door, a case with natural fiber and polypropylene made using compression molding (Hempro International, Winter & Linotech); an urn made from hemp fiber and bioplastics using compression molding or injection molding; a scale; and a case made of natural fiber and polypropylene using compression molding (Germany), Hempro International, Winter & Linotech (EIHA (The European Industrial Hemp Association), 2009); (EIHA (The European Industrial Hemp Association), 2010); (Carus, 2013) (from left to right in order).

Hemp has attracted growing interest from designers, mainly in the furniture field, and it is used for a variety of products, from everyday objects such as water- and humidity-resistant plant containers, e.g., such as "Agri-Hemp" by Michele Armellini and Marco Grimandi; to water skateboards, e.g., the "Delta-9" by Gabriele Basei. One example is a stackable hemp chair designed by architect and designer Werner Aisslinger. To make the chair, hemp fibers are molded under heat. The design features "soft curves, along with a horizontal and vertical ring structure, [which] is a new approach to this complex seating typology" (Anon, 2016). Another experimental project called Fabric-Action explores the use of hemp in other everyday objects, such as skateboards,

swings, and even air purifiers. The forms can be shaped using techniques such as 3D-printing, CNC technology and laser-cutting (Novozhilova, 2017) (Figures 17, 18, 19).

Figure 17. Hemp chair by Werner Aisslinger, 2016 (Anon, 2016); chair and house made of hemp and kenaf, compressed with a water-based thermoset binder (Studioaisslinger, 2016).

Figure 18. Triangular modules made from recycled triangular hemp pieces made from recycled materials, Benjamin Hubert, 2015 (Layer, 2015).

Figure 19. Kinesis, by Ekaterina Shchetina and Libero Rutilo, is a swing made out of three different types of hemp; Agri-Hemp by Michele Armellini and Marco Grimandi is made with thermoformable woven hemp; "Delta-9", designed by Gabriele Basei, and is made with waterproof hemp (From left to right) (Novozhilova, 2017).

HEMP AS A POTENTIAL CONSTRUCTION MATERIAL IN TURKEY: ITS HISTORY

Although the laws regarding the control and production of industrial hemp in Turkey are quite new, the use of hemp and hashish is quite old. Hemp, also referred to as "kenevir/kendir" (esrar) or "çedene" in some districts of Turkey, is known as "beng/benc" in Iran; "banga, ganja" in India; "haşiş" in Iraq, Syria, and Egypt; "kif" in North Africa and marijuana in the Americas (Baytop, 1995). During the Great Seljuk, Anatolian Seljuk and Ottoman Empires, hashish and Indian hemp were used in handicrafts, such as tiles, ceramics, carpets, gravestones and miniatures (Yörükan Karamağaralı, 1982). According to the writings in the Sultanahmet Camii construction book, in the Ottoman period, "keteni sıva", "keteni rah-ı ab", and "keten-i kenevir" linen fibers were utilized in plaster construction and waterway insulation (Sultanahmet Cami, 2018).

In Turkish history, as mentioned in Mongeri's narrative, cannabis was used because of its psychoactive properties during the Ottoman Empire

DOI: 10.15320/ICONARP.2021.153

and was consumed in spaces known as “esrarkeş kahveleri” (coffee shops for cannabis) (Baytop, 1999)[3]. Although its use was occasionally prohibited, the use of cannabis was never fully prevented (Baytop, 1999); “In the early days, hemp leaves were burned to remove the smoke, or pills and pastes prepared from the leaves were swallowed to obtain a drug effect. After the widespread use of tobacco, the cannabis leaves were mixed with the tömbeki (a type of tobacco) and started being drunk in hookah…Although it has been banned from time to time and various fatwas have been made for the execution of the users, it has never been completely prevented from being obtained and used. There was a class called “esnâf-ı bengciyân” in Istanbul. They used to prepare mixtures containing syrup, paste, and cannabis-like products in their shops at the Tiryakiler Bazaar in the Süleymaniye District. Evliya Çelebi notes that there were sixteen shops of such tradesmen, and sixty people were employed in this line of business”. After 1864, “only pharmacies began selling cannabis in exchange for a prescription” (Baytop, 1995).

Cannabis was cultivated in many regions of the Ottoman Empire, and Izmit, Bursa and Mosul were the leading regions in terms of abundance and quality: “After explaining that marijuana is one of the causes of mental illnesses seen in the East (Istanbul) in 1860, Mongeri gives detailed information about cannabis cultivation, marijuana production and drinking in the Ottoman Empire... In 1860, more than half of the hashish was exported to Syria and Egypt... In Istanbul, hashish was mainly used for syrup for sherbet or plaque of tobacco” (Baytop, 1995).

In this context, in the Istanbul Encyclopedia, Reşat Ekrem Koçu provides detailed information and accounts of cannabis use, including in *esrarkeş dervish*, or coffee shops, for madrasah and cannabis in the Ottoman period. He mentions that Turkey, specifically Istanbul, is one of the places where marijuana is easiest to obtain and is most abundantly supplied (Koçu, 1971a). He later mentions tourists and travelers who used cannabis and participated in the Beatnik culture in İstanbul and caused the moral corruption of the young generation, supporting these stories with news articles published in periodicals (Koçu, 1971b). Although the use of cannabis and hashish has a place in Turkish society socially, as far as it is known, its use in the field of construction was not mentioned in the sources until the 1900s, from its use in the Ottoman period.

Until the middle of the 18th and 19th centuries, 80% of the textile fibers produced in the world consisted of flax and hemp, while this number lessened starting in the 1930s. It is estimated that the “cannabis policies of international policy makers [had] an important role in this” (Kılıç, 2017). After the Republic, early studies on hemp use in Turkey were conducted by agricultural engineers in Turkey. Hemp was grown in Kastamonu in 1938. Early research after the Republic was conducted by the agricultural engineer Fethi İncekara, who wrote his thesis on the morphology of hemp in the 1950s.

[3] Originally from L. Mongeri, “Etudes sur l’aliénation mentale en Orient: Causes de la folie - l’Esrar”, Gazette Medicale d’Orient, p. 8, İstanbul 1864, p. 69, 102).

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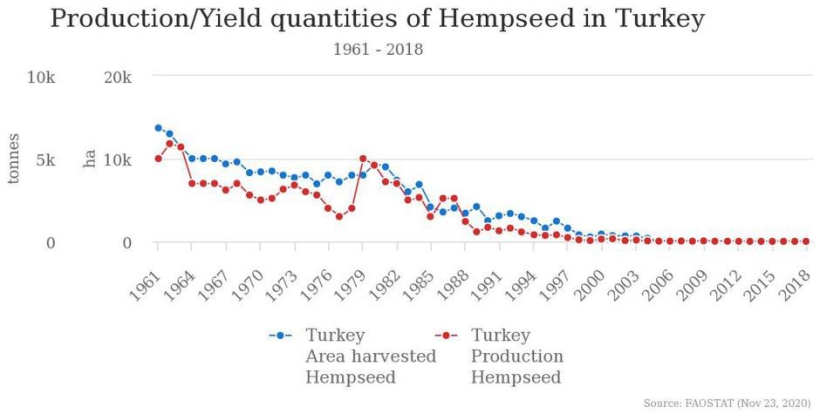

Figure 20. Production/Yield quantities of hempseed in Turkey, between 1961-2018 (FAOSTAT, 2020d).

The first production of hemp was in the Taşköprü (Kastamonu) Hemp Factory (Taşköprü Kendir Fabrikası), which was founded in 1946 by Sümerbank and was a hemp pooling and peeling facility; it closed due to its loss in 1951 (Ulaş, 2018). The second attempt was the Hemp Industry Establishment (Kendir Sanayii Müessesesi) established in Kastamonu in 1949 for the production of twine and canvas from hemp fiber. The factory, "which meets the sack needs of the Turkish Grain Board" (Toprak Mahsülleri Ofisi, 1938), started to import jute, which is used as the equivalent of hemp and is much cheaper in India, after 1953, due to the low yield and profitability of using hemp as a raw material. This had negative effects on the production of hemp, and later, SEKA used hemp for paper production. With the foundation of a factory in Taşköprü, which was established in 1984 and privatized, hemp was later imported due to its economic reasons, which nearly put an end to hemp production in Turkey (TMMOB Ziraat Mühendisleri Odası., 2019).

In Turkey, hemp is used in the production of medicine, paper, biofuel, fabric, textile, and automotive industry applications, in all areas where oil and petrochemicals are used, cosmetics, soaps, electricity, construction sector, feed industry, oil making, as well as in asphalt and road construction (Ulaş, 2018).

In 1964, the area harvested for hempseed in Turkey was 10,000 hectares with 3,500 tonnes; this rate dropped dramatically to 6 hectares and a total of 3 tonnes in 2018. The harvested area for hempseed is 32,140 ha and 142,883 tonnes worldwide (FAOSTAT, 2020c) (Figure 20).

A regulation numbered 29842 and known as "Kenevir Yetiştiriciliği ve Kontrolü Hakkinda Yönetmelik" (Hemp Cultivation and Control of Regulations, published in 2016) aims at determining "the procedures and principles regarding permissible cannabis cultivation and unauthorized cannabis cultivation in order to prevent the production of cannabis-related drugs". There are a total of 19 cities and districts in Turkey that are allowed to grow cannabis[4] (Kenevir Yetiştiriciliği ve Kontrolü Hakkında Yönetmelik (Hemp Cultivation and Control of Regulations, 2016).

[4] The first regulation for cannabis/hemp was put in place in 1930. Regulation 1609 generalizes about marihuana preparations sold in pharmacies and pharmaceutical warehouses (Tamim (Circular), 1930). Regulation 4895, which passed in 1943, defined the exchange of cannabis quotas between Turkey and Germany (Kanunlar (Laws), 1943). In regulation 20672, which passed in 1990, there is clarification that hemp cultivation for fiber, seed or both purposes is permitted in a total of 18 provinces and districts in Turkey. Apart from these provinces and districts, cannabis cultivation for whatever purpose is prohibited (Kenevir Ekimi ve Kontrolü Hakkında Yönetmelik (Regulation on Hemp Cultivation and Control), 1990).
Cannabis is cultivated in the following cities and their all districts: Amasya, Antalya, Bartın, Burdur, Çorum, İzmir (Tire–Ödemiş), Karabük, Kastamonu (Taşköprü), Kayseri, Kütahya, Malatya, Ordu (Fatsa-Ünye), Rize, Samsun, Sinop, Tokat, Uşak, Yozgat ve Zonguldak (Kenevir Yetiştiriciliği ve Kontrolü Hakkında Yönetmelik (Hemp Cultivation and Control of Regulations, 2016)

DOI: 10.15320/ICONARP.2021.153

In the Black Sea region, fiber plants (flax, hemp, and nettle) have been cultivated for many years; however, such cultivation is relatively small compared to the widespread production of cotton in other parts of Turkey[5]. Weaving is a traditional and widespread handicraft in the eastern Black Sea region. One unique fabric in the region, which is mainly used in clothing, is called feretiko (Rize fabric), which is a kind of cloth made of hemp and cotton grown in the Black Sea and woven on hand looms in the Trabzon and Rize regions (Usta, 2017).

In Turkey, raw materials that can be evaluated in architectural construction include, in addition to hemp, everything from straw to sunflowers and canola stalks to corn, and the options depend on their geographical distribution. Turkey has a suitable climate and soil structure for industrial hemp cultivation, and the Black Sea is a very suitable breeding area, especially in terms of climate and soil demand (Gül, 2008). After 2016, hemp was produced on a total of only 70 decares of land with the permission of the Ministry of Food, Agriculture and Livestock in the Black Sea region (Tarım, 2018). Within these constraints, the ASAM Kendir Institute (ASAM Cannabis Institute), which was founded in 2018, functions as an organization within the Eurasian Center for Strategic Studies under the Eurasia Foundation (Avrasya Stratejik Araştırmalar Merkezi). The Institute aims to cultivate, produce, and commercialize hemp in Anatolia for medicinal and scientific research purposes, such as in agriculture, food, textiles, pharmaceuticals, paper, cardboard, automobiles, natural and oil-free plastic materials, construction materials, biodiesel, biomass energy, and cosmetics. It is estimated that THC-free and CBD-rich, dust-free hemp plants, which can be easily grown, will make a major contribution to the soil and development of Turkey. Today, in addition to other industries, hemp is evaluated in Turkey in terms of the building and construction industry, such as its applications in roofs, floors, insulation materials, frames, pipes, mortar additives, and wood-plastic composites (Ulaş, 2018).

[5] Hemp is used in ropemaking in Kastamonu and in thread and cloth in Rize; however, feretiko production is not suitable for rapid or substantial production in the textile industry.

HEMP FOR A SUSTAINABLE WORLD

Since the processing of hemp is not complicated and has the advantages of low labor costs and low energy consumption, “hemp can play a central role in the transition from a hydrocarbon-based economy to an ecologically sustainable carbohydrate-based economy” (Danenberg, 2002). On the other hand, although hemp is also a renewable agricultural feedstock, its use in architecture may also shift to an intense material advertisement. This case would be similar to the commercialization of bioplastics in the middle of the nineteenth century, as Smith mentions (Smith, 2009).

The fact that hemp does not require any pesticides makes it a suitable plant for permaculture. Hemp can be used to purify water in a sustainable system (Tallarico, n.d.). Hemp can help us achieve more sustainable building practices that are cost effective. Hemp and

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environmentally friendly binders can replace wood panels to a certain extent (Réh & Barbu, 2017). However, the testing, evaluation and analysis of the long-term sustainability and characteristics of hemp products in the construction industry are very new (Danenberg, 2002). In addition to life cycle assessment (LCA), the land use and environmental impacts need to be observed (Suttie *et al*., 2017).

When we consider hemp production as a tool for our endless consumption practices, nature is seen as a raw material that is used for human consumption and needs and is ready to be engineered, as we have seen with green plastics or bioplastics. Similarly, the emergence of bioplastics derived from natural raw agricultural waste has led to the mass production of bioplastics instead of serving niche markets; this has, in turn, meant that the cost of analyzing and testing bioplastics for their mass production instead of serving the niche market is challenging.

The fact that adobe, a material made from soil, is similar to other derivative building materials that have been used in various societies and especially in rural areas throughout the existence of humankind, has not received as much attention as "contemporary hemp" is another thought-provoking point. Time will show how strong the effects of hemp will be on architecture. Another point of discussion is the evaluation of these natural plants being produced as ecological materials in Turkey.

CONCLUSIONS AND RECOMMENDATIONS

As a sustainable raw material, hemp very gradually increased in the construction sector in Turkey due to it being perceived as a new material. Another fact is that with the recent lifting of the bans, the potential for the use of hemp in the field of protection will be discovered in the near future.

Regarding public policies on the use of hemp, the growing interest and its economic and commercial impacts need to be evaluated in Turkey by the construction sector. With the current partial lifting of the ban on industrial hemp production, which came to a standstill in the 2010s, hemp is attracting more interest as an economic raw material the construction industry.

With the help of the research on hemp architecture, this paper will be able to pave the way for a series of studies on its use both in traditional production forms and as industrial architectural materials, thanks to the necessary permissions. Following this, the acquisition of the necessary production permits in Turkey's industrial hemp recently started to be addressed in architecture and industrial design also.

To increase the interest in sustainable materials in architecture, design and engineering education, the exploration of hemp and the materials derived from it and implementation of practical practices will gain importance for the future of energy efficient buildings. Hemp production can be carried out with low and high technology. Considering the possibilities of hemp materials in terms of the handmade process,

DOI: 10.15320/ICONARP.2021.153

applied workshops, mock-up models, prototype buildings and applications from cultivated raw hemp obtained from local agriculture can be applied in architecture, design and civil engineering education. Because permaculture is gaining more importance in Turkey, the education of hemp construction and educational facilities can be implemented in already existing permaculture and areas.

ACKNOWLEDGEMENTS/NOTES
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

FINANCIAL DISCLOSURE
The authors declared that this study has received no financial support.

ETHICS COMMITTEE APPROVAL
Ethics committee approval was not required for this article.

LEGAL PUBLIC/PRIVATE PERMISSIONS
In this research, the necessary permissions were obtained from the relevant participants (individuals, institutions and organizations) during the survey, in-depth interview, focus group interview, observation or experiment.

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Resume

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DOI: 10.15320/ICONARP.2021.153