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Literature Review on Fiber Reinforced Adobe Materials


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ABSTRACT

The use of adobe, a traditional building material, dates back about ten thousand years from today. Mudbrick material is an ecological building material that showing natural and sustainable properties. These environmentally friendly and sustainable features provide a variety of advantages versus contemporary building materials. This material is not harmful for the environment and it is also completely recyclable. It has superior properties such as low energy usage and low emission rate of harmful gases such as CO_2. On the other hand, adobe has a negative sides compared to modern materials. It shows low resistance to water and low compressive strength. Due to these reasons, differences has started in material usage lately.

With the development of the materials industry, adobe ceased to be used in the city, but still used in rural areas due to its economic reasons. Modern materials have produced a unfavorable impact on environmental conditions. The negative effects of these materials on the environment are not only limited to the production process, but also continued during the usage and consumption period. In this perspective, it is possible to consider the use of traditional materials instead of contemporary materials.

Nowadays, researches are being conducted in the ''manufacturing and construction sector for materials and technologies'' that expend energy saver and pollution preventer. There is a tendency towards research that combines the positive sides of traditional and contemporary materials. The researchers interest has turned to traditional materials such as local plant fibers and soil composites. Therefore, efforts should be made to improve the physical properties of adobe materials during the production process. In this study, national and international studies aimed at ''improving the mechanical and physical properties of adobe'' have been investigated. Physical and mechanical differences between traditional adobe and reinforced adobe have been revealed. It is stated that other additives such as lime, gypsum, cement, puzolan and fiber involved in the mudbrick mixture increases the strength values. Chemical additives, on the other hand, can have both positive and negative effects on the material. Natural fibers were considered for this investigation because they are recyclable and have no negative effects on the material structure. With the use of local plant fibers, the development and dissemination of the use of adobe material, which is a sustainable construction material, may be considered.

KEY WORDS : Earthen construction materials, adobe reinforced with fiber, comparative review

1 INTRODUCTION

Today, when the building and construction industry is one of the most critical concerns of our century, with global energy usage responsible for 36% of carbon emissions and energy efficiency accounting for 40% of that, global warming is a severe concern [1]. Furthermore, development and demolition operations disrupt the natural equilibrium of the environment. The need for sustainable, reusable construction materials is increasing in order to reduce the environmental effect of buildings. Earth might be considered a building material in this context.

For ages, adobe has been used as a wall element in various constructions such as homes, barns, and coops. It is an eco friendly and long-lasting construction material. Moreover, adobe is a waste-free and 100% recyclable material. It provides various advantages, including being healthy and cost-effective, being easily produced using local facilities and basic equipment, requiring little energy to create, and releasing no hazardous gases into the atmosphere, like as CO2. Adobe, although being a superior material with several qualities, has a low water and pressure resistance. Because of their low compressive strength and vulnerability to water, traditional bricks have lost its appeal in preference of contemporary construction materials. Despite this, because of its low cost, it is still widely utilized in rural regions.

Currently, research is being performed on sustainable materials and technologies that consume very little energy and emit fewer pollutants when used in the production and building industries. Traditional materials used in pre-industrial times have attracted the researchers' interest, including local vegetable fibers and earth composites. These composites can be produced using locally available fibers or with chemical stabilizers. In this context, research has been carried and is still being done to improve the physical properties of the adobe material used in the manufacturing process. These can be gypsum [2], cement [3], lime [4], fly ash [5], and other chemical stabilizers. Because of the high energy manufacturing process, cement, for example, increases the embodied energy of the building element. It also has a negative impact on recyclability due to the chemical reactions it generates [6]. Thermal properties can also change with lime and cement-based stabilization, according to certain research. The utilization of these stabilizers can cause the structural element's vapor permeability and moisture balance to be disrupted [7]. Chemical additives can have both positive and negative impacts on the material. Soil composites made from vegetable fibers will be investigated in this study since they are recyclable material that do not react chemically with the soil. The research focuses on alternative additives to chemicals in general. Research was conducted on relevant publications in the Science Direct, Researchgate, and Web of Science databases for this purpose. The researchers looked at 20 studies that were take apart from soil-fiber composites created between 2008 and 2022.

2 LITERATURE REVIEWS OF SCIENTIFIC STUDIES

Plant or animal origin fibers can be used to stabilize the soil, although plant origin fibers are preferred since they are more accessible. Because of their inexpensive cost, these fibers are being used more often to produce material composites with improved properties. Additionally, the utilisation of plant fibers results in less contamination of the environment. It's also environmentally friendly and ecology because it's recyclable [8]. The materials produced by this stabilization procedure are also beneficial to human health, and the constructions built from these blocks are likewise comfortable. Researchers have recently focused their attention on fiber-soil composites due to these advantages. Fibers are commonly used in research aimed at improving soil properties: hemp straw [11], fonio straw [12], jute fiber [13], doom fibers [14] red millet, [15], wheat straw [16], kenaf [17] and specific vegetable fibers [18], etc.

Vegetable fiber has been adapted to the soil since ancient times to strengthen its durability and prevent cracking. In the adobe, with organic fiber plant additives, homogeneous and balanced drying takes place. Fractures and shrinkage decreases appear as the stabilizing process progresses.

Tensile-stressed fibers prevent drying fractures while simultaneously increasing material cohesiveness (Cohesion / Adhesion). As a result, the material's scructure system is reinforced. Together with the vegetable fibers utilized, the main features that have a substantial impact on the physical, mechanical, and durability behavior of soil composites are: the type, tensile strength, and durability of the fibers, as well as their length and volume percentage in the composite mixture [10]. The soil-fiber cohesiveness is weakened by water absorption in the adobe.

Table 1. Natural additives and fibers added to soil material are classified according to their qualities. Waste substances (W), by-products (BY), including two states (W/BY), not stated in the article as a source of additives (-). mechanical characteristics (M), durability (D), hygroscopic (H), and thermal properties (T).

Fiber Type	Fiber Source (W/BY)	Conducted Studıes	Year	Location of Study	Ref
wheat stalk	W/BY	M D	2008	Turkey	[16]
coconut	W	M	2008	India	[19]
straw	W/BY	M D	2010	Italy	[20]
pineapple leaves	W	M D	2011	Malaysia	[21]
oil palm fruit	W/BY	M D	2011	Malaysia	[21]
hibuscus cannabinus	-	M T D	2014	France	[22]
coconot husk Bassage oil palm fruit	W	M D	2014	Ghana	[23]
kenaf	-	M T D	2015	Burkina	[17]
banana fibers	W	M	2016	Egypt	[24]
oat fibers	W/BY	M T H	2016	Portugal	[25]
oat fibers	-	M T	2017	Portugal	[26]
rice husk	W	M D	2017	Iran	[27]
pine needles	-	M	2018	Spain	[28]
wheat straw	W/BY	M T D	2018	Italy	[29]
lavender straw barley straw	W/BY	M T D	2019	France	[30]
fonio	BY	M T D H	2019	France	[12]
red millet	W	M T D	2020	Cameroon	[15]
Straw	-	M	2021	Iraq	[31]
Doum fiber	-	M D H	2022	Morocco	[32]

Table 2. Physical properties of fibers and methods of producing samples

Fiber Type	Sample Dimensions (mm)	Fibers (%)	Fiber Length(mm)	Ref
wheat stalk	100x100x100	0.5	50	[16]
coconut	38 dia & 76 high	2.0-2.50	10-30	[19]
straw	310x460x130	0.00-0.75	2.0-8.0	[20]
pineapple leaves	100x100x100	0.25-0.75	10	[21]
oil palm fruit	100x100x100	0.25-0.75	10	[21]
hibuscus cannabinus	295x140x200	0.2-0.8	30-60	[22]
coconot husk	295x140x100	0.2-0.6	50	[23]
Bassage	295x140x100	0.2-0.6	38	[23]
oil palm fruit	295x140x100	0.2-0.6	80	[23]
kenaf	295x140x100	0.2–0.8	30	[17]
banana fibers	240x120x90	0.35	50–60 70–80 90–100	[24]
oat fibers	40x40x160	1.0	10-20	[26]
rice husk	22x22x7 22x11x7	0.3-0.9	-	[28]
pine needles	290x140x100	25	1.42-4.46	[29]
wheat straw	150x150x150	3	-	[30]
lavender straw barley straw	15x15x15 50 mm dia & 50 mm high	3.0-6.0	-	[31]
Fonio	40x40x160	0.2-1.0	20-100	[12]
red millet	100x100x30 40x40x160	0.0-4.0	2.0-5.0	[15]
Straw	240x110x75	2.5-5.0	20-60	[32]
Doum fiber	40x40x50	0.0-2.0	35-40	[33]

3 REVIEW AND ANALYSIS

Compressive strengths were investigated using fibers in different combinations with variable straw content and soil from five distinct sources in a study done by Şükrü Yetgin et al (2008). As a result, the effects of varying quantities of fiber (straw) on compressive stress and strength were investigated. Comparisons were also conducted with fiber-free samples, with the findings evaluated against the materials physical qualities. The water content, specific gravity, and tensile ratio of fibrous and non-fibrous adobe samples were evaluated in the context of pressure behavior and strength in the tests. Tensile experiments were also included in these researches. As a result, an attempt was made to formulate a conclusion on the materials' workability and applicability.

The studies revealed that when the adobe content of the fiber increases, so does the tensile, but the compressive strength decreases. The obtained compression test results demonstrate three common features for fibrous specimens:

- ✓ Because fibers absorb water, the water content should be raised as the fiber content increases for processability.
- ✓ The weight of the sample and hence its strength decreases as the water content rises.
- ✓ Plastic tendencies increase as clay content rises. However, because to an increase in fiber content, an early fracture is detected. The material that dries quickly is more brittle.

The following are the findings of compression tests and tensile tests performed on various adobe samples with and without fiber:

- ✓ As the fiber content increases, the compressive strength reduces.
- ✓ During stress, fibers (straw) having a circular cross section and a hollow structure demonstrated flexibility.
- ✓ Fiber level in normal adobe mixes should be managed at around 0.5 percent by weight.
- ✓ The rate of shrinkage diminishes as the amount of clay and water in the mixture increases.
- ✓ The shrinking rate reduces as the fiber content increases.
- ✓ By increasing the fiber content, tensile strength decreases while compressive strength and unit length increase [16].

According to Millogo et al. (2015), kenaf fibers were utilised in the soil stabilization in their investigation. Fibers 30 mm long were prepared and put to the soil mixture at a rate of 0.2-0.8 percent. The prepared soil mixture produced samples sized 29.5x14x10 cm. The mechanical properties of adobe blocks made from a mix of soil and fiber have been examined. The samples compressive strength values range from 0.5 to 3.7 MPa. In blocks with additional fiber at a rate of 0.4 wt%, the compressive strength was obtained to be optimal. The compressive strength increases by 16 percent at this optimal value. Fibers are added to the soil for two main reasons: to prevent fractures during the drying process and to boost the flexural strength of the blocks produced. As a result, flexural and tensile tests should be carried out. The samples flexural strength was measured to be in the range of 0.9-1.9 Mpa. It was revealed that it improves the flexural strength of the fibers as a result of the tests conducted. However, adding more than 0.8 weight percent fiber to the soil can weaken the soil-fiber matrix, resulting in a reduction in strength. Soil blocks that haven't been reinforced with fibers are brittle, but those that have been reinforced with fibers are ductile. The soil's ductile behaviour results in a rigid state in the event of an earthquake, as well as limiting fracture formation. As a result, the fibers retaining the fractures are linked to the increased ductility of the reinforced samples [17].

Ouedraogo et al. (2019) conducted research on the physical, mechanical, thermal, and water impact properties of fonio fiber and soil composites. The by-product foino fiber was added to the soil mixture with a length of no more than 1 cm and a ratio of 0.2-1.0 wt percent. The samples were prepare 4x4x16 cm blocks and dried for 21 days. Compressive strength values of 2.3-2.6 Mpa were obtained as a consequence of the tests performed on the samples. The sample series with the greatest strength had a fiber contribution of 0.4 wt percent and a value of 2.6 Mpa. After this ratio, the compressive strength of a series of samples was shown to diminish. In the situation of flexural testing, the strength ranges from 0.3 to 1.3 Mpa. In the series when 0.2 percent wt percent was added, the maximum strength was attained. The flexural strength began to decline once the optimal value was reached. The porosity increased in samples with an excess of fonio fiber input, according to microscopic investigations. The hydrophilic characteristics of the cellulose in the fiber boosted capillary water absorption by up to 0.4 weight percent. The soil-fiber cohesiveness is weakened by water absorption in the adobe. Swelling and curing of the fibers causes pores in the material. The thermal conductivity was observed to decrease with the addition of fiber as a result of the experiments. This is owing to cellulose's insulating properties [12].

In research, Chan (2011) researched at the physical and mechanical qualities of adobe bricks. Two local fibers were added to the soil and water combination in a ratio of 0.25-0.75 percent as additives. The fibers were obtained from pineapple leaves and palm fruit bunches. In addition, a soil of 5-15 percent cement was utilized. Baked and uncooked adobe blocks are among the samples. Experiments were conducted to see how additives affected the physical and biological qualities of adobe blocks. Experiments were used to assess the compressive strength, water absorption amounts, and biological features of the produced samples. Due to the fibers' ability to absorb water, samples with a higher fiber content tended to dry faster. According to the outcomes of the investigations, the best value for cement compressive strength is 0-5 wt percent. The samples exposed to temperature had the maximum compressive strength, whereas the compressive strength of the cement-containing samples declined as the temperature increased [21].

Table 3. Physical properties of fibers, strength values of the produced samples and water absorption

Fiber Type	**Fiber Properties**			**Compressive strength (Mpa)**	**Flexural strength (Mpa)**	**Absorption %**	**Ref**
	Length (mm)	**Diameter (mm)**	**Content (wt%)**				
wheat straw	50	3	0.72-3.84	0.5-3.7	0.15-0.7		[16]
Kenaf	30	0.13	0.2-0.8	2.3-2.8	0.9-1.9	307	[17]
Fonio	100	0.15	0.2-1.0	2.3-2.6	0.3-1.3		[12]
Pineapple leaves	10		0.25-0.75	2.0-6.0	1.9-3.5		[21]
Palm fruit bunch	10		0.25-0.75	3.0-9.0	2.55-4.6		[21]

4 RESULTS AND DISCUSSION

The purpose of this study is to investigate at the studies that have been conducted on using vegetable fibers to improve soil parameters. Vegetable fibers are added to the material in varied amounts and with varying qualities in the research analyzed. Many of the researches that have been conducted with these fiber additions have focused on the soil' mechanical and thermal qualities. When mechanical characteristics are evaluated, it is observed that the pressure and flexural strength increase to an optimum value with the addition of fiber, but that once this value is reached, the strength data begins to decline. The basic reason for this is that the higher fiber content causes faster water absorption in the material and faster drying of the sample. In the research [21], cement additive was also combined with pineapple leaves and palm fruit bunch fibers. When compared to using only fiber, this has resulted in better results in strengthening the soil' strength qualities. The soil, however, disturbs the moisture balance following the loss of energy in the cement manufacturing process and the contact it makes with the material, which has negative consequences in terms of recyclability and sustainability. While increasing the strength values, it may cause certain drawbacks. Although the use of vegetable fiber in the production of soil dates back to ancient times, scientific research on the subject is relatively new. Work to improve and increase the usage of adobe material that can provide users with comfortable conditions on its own is still being performed and should be conducted. The importance of adobe, which is a cost-effective and ecologically friendly construction material, should be recognized, and its usage should be promoted.

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