STABILIZATION OF COMPRESSED ADOBE WITH POLYPROPHYLENE STAPLES

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CHAPTER 1 PROJECT TITLE

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SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13 ✓	Climate Change
SDG 6 ✓	Clean Water and Sanitation	SDG 14 ✓	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15 ✓	Life on Land
SDG 8 ✓	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
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STABILIZATION OF COMPRESSED ADOBE WITH POLYPROPHYLENE STAPLES

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In

Civil Engineering

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This is to certify that the project/research work presented in this thesis, entitled "Stabilization of Compressed Adobe with Polypropylene Staples" was supervised by Dr. Saeedullah Jan Mandokhail (Faculty of Engineering and Architecture), No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Department of Civil Engineering, FOE&A, BUITEMS, in partial fulfillment of the requirements for the degree of BS Civil Engineering.

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LIST OF ABBREVIATIONS

OMC	Optimum moisture content
MDD	Maximum dry density
Dr	Relative density
PP	Polypropylene

ABSTRACT

Housing is a basic need for human to live a safe and healthy life and is very crucial in the socio economic development of any country. Soil is one of the oldest building material that is used by mankind since Mesopotamian civilization period. Currently most of the population in rural areas are living in mud houses. Adobe has been used for constructing houses due to its numerous advantages. Adobe are sustainable, environment friendly, eco-friendly and having excellent thermal properties. Which can result in energy savings and increased comfort in both hot and cold climates. They are resistant to fire, pests, and rot, making them a reliable choice for long-lasting structures. Furthermore adobe is very economical as compared to other construction material. However, there are some disadvantages of adobe. It has been found highly brittle, absorbing large amount of water, and low flexural strength. The adobe are generally stabilized by mixing cementitious material and fibers with the soil. Various stabilization methods have been adopted through the years. Some of the reinforcement technique have appeared be expensive and/or ineffective. Therefore, new soil stabilization techniques are still being researched to improve the geotechnical properties of soil. These days, the environmental and economic concerns have attracted the attention of geotechnical engineers to produce alternative methods which can fulfill the design and environmental requirements. Recently soil stabilization by insertion of randomly distributed fiber have attracted the attention of geotechnical engineers. If burned bricks is used in the building they are costly and even a middle class family cannot afford the cost of the buildings and it is not environmental friendly. Natural and synthetic fibers have been used for the stability of the adobe which are not usable by everyone especially poor people because of its cost is high. The objective of this study is to stabilize compressed earth blocks with polypropylene (PP) staples. PP staples are extracted form PP woven bags used for faking purposes in the market which however are wasted after its primary use. In this study the PP staples were used in various lengths of 2cm, 4cm, and 6cm in different percentages (0%, 0.1%, 0.2% and 0.3%). The results show that the pre crack flexural strength of reinforced sample was slightly decreases with PP staples. The post crack flexural strength was significantly increased with increasing length and percentage of PP staples. The PP staple with 6cm length and 0.3% produce maximum post crack flexural strength. The post crack flexural strength was increased from zero to 3.3kpa for zero % PP and 0.3% with 6cm length respectively.

Keywords: Adobe, Brittle, Shear Strength, polypropylene staples, Economic.

CHAPTER 2 INTRODUCTION

2.1 Background

As a construction material, raw earth material is one of the oldest and very first building material that is used by mankind (Bouillon 2012). Although new building materials with far higher performance have mostly replaced earth building construction, in many countries where modern techniques are too expensive to execute, earth building construction is still a significant building construction activity (Savary et al. 2020).

Housing is a basic need for human to live a safe and healthy life and is very crucial in the socio economic development of any country. Thought the technology is developed and socioeconomic advancements have been made all over the world, still it is continuously difficult for both governments and individuals to meet the requirement of suitable housing all over the world in general and developing countries in particular (Bouillon 2012; Mukhtar et al. 2016) The developing countries are the mostly affected by the housing issues with rapid housing shortage in the recent years. The affordable housing has always been a demand of the society as well the government(Mukhtar et al. 2016).The use of locally available construction material is always a cheaper, lower embodied energy level and environment friendly.

Masonry constructions were introduced during the Mesopotamian civilization period (ca. 5000-3500 BCE). At that time, bricks and alluvial deposits were used for construction purposes due to easily available in large amount everywhere in the globe.

Adobe structure existed in every parts of the world in rural and urban regions. It is estimated that one third of the worlds and half of developed countries population lived in mud house (Avrami et al. 2008; Delgado and Guerrero 2006; Houben et al. 1994) (Sharma et al. 2016). Mud houses are having several advantages such as low construction cost, thermal conductivity, easy availability of construction material, environment friendly, and requires less energy for construction as compare to concrete houses and low maintenance cost (Mesbah et al. 2004; Walker 1999; Walker 2004). The motivation toward mud houses in development country is to build ecological environment (Minke 2000). Another reason of mud structure construction in developed countries is not due to low cost but also for culture tradition and uniqueness is attached with them (Zami and Lee 2010).

The construction material such as burned bricks(Islam and Iwashita 2010), cement and other product used in modern structure consumes excessive energy during manufacturing and release toxic and harmful gases in environment (Nagaraj et al. 2014). Furthermore, the transporting truck transfer the materials from one site to another, generally more than 100 miles away from construction site can cause uneconomical and emit toxic gasses in atmosphere (Saleh 2004; Sharma et al. 2015; Shukla et al. 2009; Tiwari et al. 1996; Turanli and Saritas 2011) In this regards, earth is easily available material in rural area of Asia, South America and Africa. Moreover, it does not require skillful labor and modern machinery for the construction of adobe structure (Binici et al. 2009; Revuelta-Acosta et al. 2010; Turanli and Erdogan 1996).

More than 70 % of Baluchistan population is living in rural areas and with more than 85 per cent of its rural population living below the poverty line .Most of the people are living in mud houses in rural areas either due to cultural tradition or poverty.

The reality of the Sustainable Development Goals (SDGs) 11, which aims to make cities and human settlements inclusive, safe and sustainable, requires low-income countries to provide adequate shelter to reduce housing shortages, this can be achieved by using clay bricks as a building material that can be produced inexpensively (Danso and Manu 2020; Danso et al. 2015; Ige and Danso 2022).

The vital issue of the adobe housing is low durability, low tensile strength, high compressibility, swell and shrinkage due to moisture variation (Stavridakis 2006). These weaknesses can restrict the strong, durable and sustainable structure (Danso 2018)Studies have also stated that the mud structures are less resistant to earthquake forces due to its brittle behavior and low tensile strength (Islam and Iwashita 2010; Oskouei et al. 2017; Turanli and Saritas 2011).

However, the adobe structures can be stabilized by improving the properties of adobe. Mechanical compaction, chemical stabilization with cement, lime and bitumen, and fiber inclusions have been used to improve the properties (Islam and Iwashita 2010).

2.2 Problem statement

Adobe are weak in flexure strength, compressive strength, and less resistance to rain deterioration. Polypropylene staples are used to enhance the properties of earth bricks. Polypropylene staples extracted from packing woven bags, and have not been used to reinforce the compressed adobes. Polypropylene woven bags mostly become waste after their primary use and are easily and widely available in houses as well as in the market.

2.3 Aim and Objective

The aim of the study is to stabilize the compressed adobes with Polypropylene staples. The aim of the study will be achieved through the following objectives;

- To study the effect of length of PP staples on the flexural strength of compressed adobes.

- To study the effect of percent of PP staples on the flexural strength of compressed adobes.

2.4 Report Organization

Chapter 1 consist of the introduction of the study followed by Chapter 2 in which literature review is explained, and Chapter 3 explains the methodology which is followed by us for this study. Chapter 4 explain and discusses the results obtained in this study. Chapter 5 explain the key outcomes of the study and recommendations for the future studies.

CHAPTER 3 LITERATURE REVIEW

3.1 Introduction

Adobe is a building material made from earth and organic materials. Earthen construction is an alternative construction method that allows for the reduction of the embodied energy of building materials and the increment in sustainability in the construction. As a construction material, raw earth material is one of the oldest and very first building material that is used by mankind (Savary et al. 2020).

These days Considerable attention has been given on the importance of providing low-cost housing for low income populations. More recently the social and cultural aspects of design and construction techniques have also got attention. The focused has been given to use the locally available material for construction purposes to produce economical and sustainable houses. Soil has been used as a construction material to build houses since years. (Eko et al. 2012)has stated that about 50 % of the world's population is still living in mud houses. Most of the population living in the rural areas of Pakistan and particularly of Baluchistan are also living in mud houses either due to cultural tradition or poverty.

Due to a lot of people living without homes in different developing countries the development of affordable housing is necessary (Mostafa and Uddin 2016b). Currently rammed earth is used as a construction material in many developed countries of the world. Since now the construction is converted to a new building materials like concrete, rebar, cement etc, but these materials are costly and it is not affordable by everyone. It is estimated that one third of the world population is living in buildings made of earth materials(Sharma et al. 2016). There are about 500000 buildings in UK made of earth, mostly constructed before the 20th century is still present. IN India the walls of 55% of homes are still constructed from raw earth (Barbero-Barrera et al. 2020).

According to the recent research's that 62.56% population of Pakistan is living in rural areas, and in rural areas there is almost 98% of buildings are made of earth materials(Saleem et al. 2016). The earth materials like earth bricks are strong when they are dry, but become endurable when exposed to moisture content and it became fail also the compressive strength of adobe bricks is less then fired bricks. Adobe bricks also fails in tension, in order to increase the compressive strength of the adobe brick, the brick is compressed by compressor which will increase the compressive strength of the brick, also increases the resistance against deterioration (Rafi et al. 2012). In order to increase the flexural strength of the brick, people reinforced it by synthetic fiber.

There are various methods of constructing the houses from mud/soil. Mostly the poured earth, adobe (mud bricks), rammed earth (pise) or compressed adobes. In this Chapter we will focus on the compressed adobe (Mud Bricks) and the methods or techniques used in stabilizing/strengthening the adobe.

3.2 Adobe structure/Bricks

Adobe is among the earliest building materials, and is used throughout the world since years. The remains of the walls of the Temple Oval at Khafajah, exposed during the excavation in the 1930's was built with adobe bricks about 2500 B.C (Ngowi 1997).

There are a limited mud brick complete structures which have survived through regular maintenance. The oldest existing unprotected earth structure is the Pueblo at Taos, in New Mexico, which is reportedly over 900 years old shown in Figure 3.1. In the east, China has a long history of mud brick construction, and sections of the Great Wall (begun in 214 A.D.) are made of earth. In the USA adobe construction has been popular for centuries. The Traditional mud brick construction is still widespread in Australia and New Zealand.

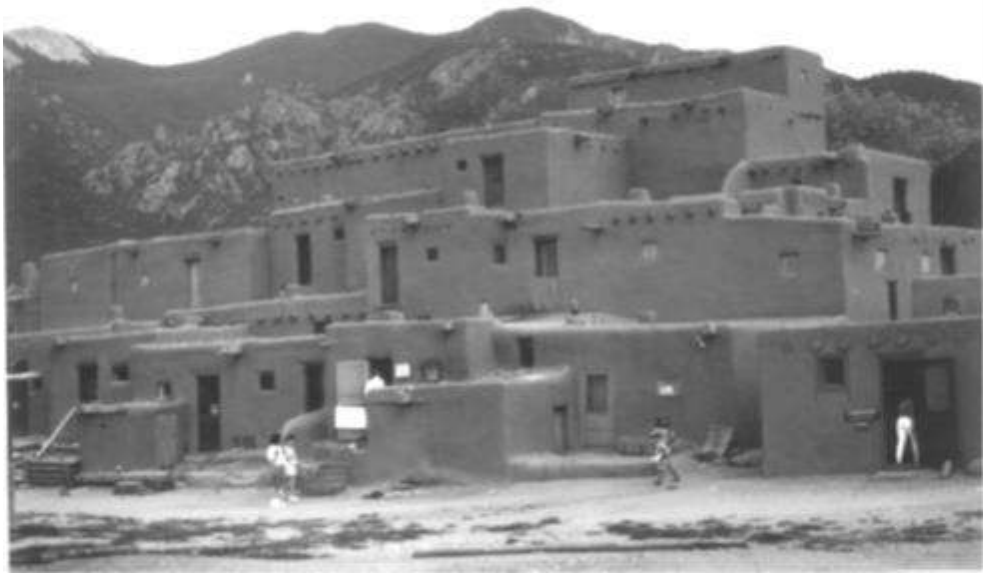

Figure 3.1 Adobe Pueblo at Taos (Kumar et al. 2006) PhD Thesis .

The external walls are mostly covered with mud plaster to protect them from erosion. The internal walls are also plastered to give a smooth finishing.

Most parts of the world have abundant soil resources that are simple for low-income groups to access. In some places, the only material that can be used to build with is soil, and producing building materials from it requires just basic, inexpensive machinery. These important benefits are not significantly diminished by the inclusion of stabilizers, and adobe bricks are appropriate as a building material for the vast majority of popular architectural designs. To sum up, adobe bricks highly competitive against their more conventional alternatives in their fire resistance and are virtually non-combustible (Araya-Letelier et al. 2021).

Due to these issues, earth is not institutionally accepted as a building material in the majority of nations, and as a result, building codes and performance standards have not been fully developed despite their many positive attributes and the potential they hold for technological advancement through stabilization methods and increased construction (Babé et al. 2020).

3.2.1 Earth quake and adobe structure

The adobe brick structures are also less earth quick resistant structures and more prone to collapse during the earthquake Figure 3.2.and Figure 3.3 shows the collapsed buildings made of mud bricks during 2021 earthquake in Harnai and Ziarat, respectively. Adobe structure show brittle failure during earth quick unfortunately which cause high casualty rate.

Figure 3.2 Failure of adobe structure after earth quake in Harnai in 2021

Figure 3.3 Failure of adobe structure after earth quake in Ziarat in 2021

3.3 Issues with Adobe

Various researchers have discussed the appropriateness and durability of adobe structures is in details (Salih et al. 2020). However, adobe structures have some major issues which make them prone to failure. These issues are their brittle behavior, low compressive strength, low tensile strength, low durability, high compressibility, swelling and shrinkage due to moisture variation (Islam et al. 2019; Stavridakis 2006). These weaknesses of the adobe can restrict the strong, durable and sustainable structure (Danso 2018).

Another major challenge of the adobe structure is its poor response to earthquake loading. Various studies have been conducted to assess the response of adobe structure to ground shaking. Various researchers have found that the adobe structures are less resistant to earthquake shaking due to their low tensile strength and brittle behavior (Islam and Iwashita 2010; Oskouei et al. 2017; Turanli and Saritas 2011).

The weak response of adobe structure to earthquake forces have also been seen in Awaran, and Harnai during the earthquake of magnitude 7.7 in 2013 and an earthquake of magnitude 5.9 in 2021, respectively. The destroyed adobe/clay houses during the 2013 and 2021 earthquake are shown in Figure 3.4 and Figure 3.5 respectively.

It is needed to mitigate such problems of adobe structure and enhance the poor properties of soil to produce durable structures (Ige and Danso 2022; Islam et al. 2019).

Figure 3.4 Aftermath of Awaran Earthquake 2013

Figure 3.5 Aftermath of Harnai Earthquake 2021

3.4 Adobe Reinforcement

The poor properties of adobe structure needs to be enhanced to materialize a sustainable, durable and strong structure (Islam et al. 2019). Such deficiencies may be overcome by reinforcing the soil mixture with additives or stabilizers (Ige and Danso 2022). Various methods of reinforcing the adobe structure have been in practice e.g. the use of cementitious material which include cement, lime and fly ash, blast furnace slag, fibers which include natural and synthetic fibers, and mechanical stabilization.

Various research studies have been conducted on reinforcing the adobe with natural fiber (Millogo et al. 2014; Mostafa and Uddin 2016b; Ramakrishnan et al. 2021). Scientists are concentrating on environmentally friendly and sustainable inventions because global warming poses a serious threat to all living things, impacting climate change, sea level, etc. In light of the increasing awareness of environmental issues and sustainable building practices. The research of eco-friendly materials places Adobe blocks at the top due to its many advantages, including maintaining indoor air quality, maintaining indoor temperature, and having little environmental effects. Despite the blocks' long history of use in rural areas of poor nations, recent years have seen a boom in study in this area due to some of their shortcomings in terms of strength and durability. In this review, plant fiber fused blocks are investigated in order to comprehend how the fibers affect the characteristics of adobe blocks. This review article is based on twenty-five significant investigations, including the characterization of natural fiber and their cellulose content, material composition tables, mechanical, hydrothermal, and durability performance of earth matrix. Developing adobe blocks will benefit the environment in many ways, particularly with regard to global warming and climate change, and can also help in achieving minimal energy and resource consumption. The study also highlighted the importance of analyzing the properties of the fiber to be fused and reported the lack of testing in durability criteria like abrasion, life expectancy, fire resistance, etc. (Ramakrishnan et al. 2021).

Adobe is also reinforced by the bio aggregate such as animal straw sheep wool and wood aggregate a great effect was produced on the adobe brick such as the shrinkage is decreased because particle opposed the deformation. The addition of the bio aggregate also decreases the water absorption of the adobe brick (Laborel-Préneron et al. 2016).

(Ramakrishnan et al. 2021) has well documented the adobe reinforced with natural fibers. In the study it is stated that jute fiber, banana fiber, millet and barley fiber can be widely used in enhancing the mechanical properties such as compressive and flexural strength, and durability in term of erosion and abrasion. The use of such fiber as reinforcing material also reduces the amount of waste generated.

3.4.1 Fibers

The term "natural fibers" is used in this review since it describes the majority of the materials that are readily and naturally available at the research site. Banana, hibiscus cannabin’s, seagrass, barley, lavender, folio, pine needle, millet, date palm, palm kernel, jute, bagasse, coconut, and other fibers are among those that are covered in this essay(Sharma et al. 2016). The general information about the fibers’ characteristics and place of origin is discussed.

The fibers were genuine, indigenous fibers from Grewia Optiva and Pinus Roxburghii (Chir Pine & Beul). Since both are locally accessible natural vernacular materials, both offer disposal issues, and both require an alternative use, only natural vernacular fibers were chosen on the basis of their simplicity and quantity. Additionally, a preliminary pilot survey and case study of traditional homes were undertaken as part of the research, and they highlighted the issue of adobe walls needing frequent maintenance and repair due to surface erosion brought on by low durability. This created a need for sustainable natural fibers that are both affordable and practical for rural residents to get and use. When combined with soil matrix, this fibrous substance would improve adobe's capacity to weather. For usage as reinforcement in soil matrix, fibers from Pinus Roxburghii and Grewia Optiva were chosen (Sharma et al. 2016).

Banana as a fiber has a great impact on the strength of the adobe blocks. The experiment has done on the adobe brick without banana fiber and banana fiber it was observed that the almost 71% greater stress was required for reinforced with fiber with fiber blocks as compared to unreinforced with fiber blocks. It was also observed that the failure mode of reinforced block was conical break failure mode which contributes to the consistency of the compressed earth blocks (Mostafa and Uddin 2016a; Mostafa and Uddin 2016b).

3.4.2 Cement

Cement is a binding material that hardens when it dries and reacts with carbon dioxide in the air. Its strength is inversely related to its quality and can stabilize soil independently. Cement primarily interacts with water and doesn't depend on soil minerals, making it widely used for soil stabilization. Various types of cement are available, chosen based on the desired strength and soil type. Cement reacts with water during hydration, resulting in hardening. It encapsulates soil without altering its structure, as the hydration process occurs slowly from the surface of cement granules. (Bharath et al. 2014).

For better performance and longevity of the block, Ordinary Portland Cement (Type II) (Moderate Sulfate Resistance) was utilized in all mixtures. Construction exposed to sulfate-ion-containing soil or water typically uses this type (Mostafa and Uddin 2016b).

For the greater durability of the adobe bricks cement was added with the soil as a stabilizing agent. The commonly used mixing proportion used is 6-10% of the soil, and in this study 45.35kg of soil and 3.17kg of cement was used. the factory produced bricks, was used as a benchmark registered the highest value at 9653 kpa while the result obtained from the compressive strength of the soil cement brick was 7584 kpa which is closer to the burned brick (Obonyo et al. 2010).

3.4.3 Cement and lime both

Adobe can be stabilized with the combination of cement and lime (Nagaraj et al. 2014). used lime in combination of cement and concluded that lime with cement is improving the long-term build-up of strength better than using cement alone (Malkanthi et al. 2020) studied that Lime-stabilized blocks can be used for single-story buildings, while the combination of lime and cement stabilizers helped to obtain higher compressive strengths than that of lime alone. (Ngowi 1997) examines the methods of improving earth construction in two major villages in Botswana as a case study. Tests with different stabilizers showed that only certain proportions were effective and it was concluded that the traditional earth construction may be improved by using certain ratios of cement and lime as stabilizers.

For the durability of the adobe bricks cement and lime both are used with the soil to compare the test result with the factory produced brick(Obonyo et al. 2010), after the testing of both bricks the factory produced bricks compressive strength was 9,653kpa while the compressive strength of the mixture of the cement and lime both with the soil of proportion 45.35 kg of soil,2.27kg of cement,3.17 of lime, was 8,274kpa which is so close with the burned brick compressive strength (Obonyo et al. 2010).

3.4.4 Use of fiber and cementitious material

Adobe was also reinforced through fibers with the combination of cementitious material. Ige and Danso (2022) used 0.25%–1% rice husk waste, and 10% lime to carry out a comprehensive assessment of the composite material. The study recorded 62% and 95% improvement, respectively, for compressive and tensile strengths at 28 days of rice husk waste and lime stabilized abode bricks over the un-stabilized adobe bricks at 0.75% rice husk content. The addition of lime significantly improved the performance of the bricks against the action of erosion. Akinwumi et al. (2019) determined that highest compressive strength was obtained for the CEB containing 1% waste plastic of size <6.3mm and its compressive strength amounted to a 244.4% increase. Of the CEB samples stabilized with shredded waste plastic, the sample containing 1% waste plastic of sizes < 6.3mm also had the least erosion rate.

For the durability of the adobe brick soil is mixed with fiber and cementitious material to determine the compressive strength of the adobe brick. The fiber and cementitious materials are used in the proportion of the 45.35 kg of soil, 2.27 kg of cement.0.45 kg of fiber the compressive strength was observed 7,929 kpa, while the factory produced brick was made for the comparison which was tested and the compressive strength was observed 9,653kpa (Obonyo et al. 2010).

3.4.5 Stabilized by chemicals

Properties of adobe can be improved using different chemicals like calcined clay-based alkali-activated binder (Idriss et al. 2022), they worked on stabilization of compressed earth blocks (CEB) with a calcined clay-based alkali-activated binder. (Dass and Malhotra 1990) they worked on red mud to produced RED MUD BRICKS. From their study they obtained maximum wet compressive strength of 3.75 MN m-2 with 5 % lime and 4.22 MN m -2 with 8% lime after28 days of casting and humid curing in the month of August. (Idriss et al. 2022), they worked on stabilization of compressed earth blocks (CEB) with a calcined clay-based alkali-activated binder.

3.4.6 Stabilizing through Natural fibers and natural binder

Some researcher used natural binder like Alginate with natural fiber to improve its properties. (Galán-Marín et al. 2010), they used natural polymers and fibers to stabilized soil. Alginate (a natural polymer from the cell walls of brown algae) has been used as bonding in the composite. Sheep’s wool was used as reinforcement. Tests done showed that the addition of alginate separately increases compression strength from 2.23 to 3.77 MPa and the addition of wool fiber increases compression strength a 37%.

In this research, we aim to enhance the flexural properties of adobe bricks by incorporating recycled polypropylene (PP) staples. These staples will be sourced from used polypropylene bags after its first use, that typically store items like flour, rice, and sugar. We will experiment compressed adobes with various staple lengths (2cm, 4cm, and 6cm) and by different staples weights (0.1g, 0.2g, and 0.3g) in combination with soil proportions (50% sand, 50%clay).water is used as a lubricant. Through a series of flexure tests, we intend to determine the optimal staple length and staples weight required to achieve optimum compressed adobe performance.

CHAPTER 4 RESEARCH METHODOLOGY

4.1 Introduction

This chapter describes the materials and the methods used in this research. The necessary tests including sieve analysis (Dry and wet), hydrometer analysis, and Atterberg's limits test, proctor tests (standard and modified) were performed on four different soil samples of (Kuchlak, Saranan, BUITEMS, and Airport Road) areas. The suitable soil for this research is selected on the bases of above test results which was Saranan area soil. Materials, their properties and equipment used to conduct this research study is presented in this chapter. The materials used in this study are, clay as main matrix, sand and polypropylene staples as fibrous materials.

4.2 Materials

4.2.1 Clayey soil

Four soil samples were selected for basic tests to select appropriate sample having adequate amount of clay to prepare adobe. The samples were collected from Saranan, Kuchlak, Buitems and Airport chock Quetta, as shown in Figure 4.1. Hydrometer tests and plasticity tests were performed to select suitable soil for adobe preparation.

Figure 4.1 Collection of soil samples

4.2.2 Hydrometer test

The sieve analysis by wash method and hydrometer test were performed on soil samples in accordance with (ASTM-D6913/D6913M-17 2017)and (ASTM-D7928-21 2021) respectively, as shown in Figure 4.2 and Figure 4.3. The hydrometer analysis results are shown in Figure 4.4. The content of sand, silt and clay computed from wash sieve analysis and hydrometer tests are presented in Table 4.3.

Figure 4.2 Sieve analysis (wash method) performed on soil

Figure 4.3 Hydrometer tests performed on soil

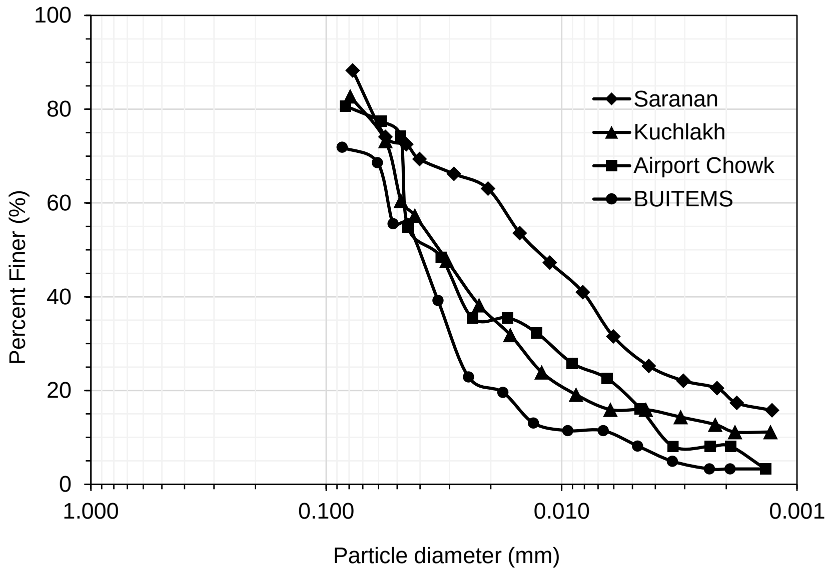

Figure 4.4 Grain size distribution curve of soil samples

4.2.3 Plasticity tests

The Atterberg's limit test (liquid limit test and plastic limit) were performed according to (ASTM-D4318-17e1 2017), as shown in Figure 4.5. The results of the plastic limit and liquid limit tests are presented in Table 4.1, and Table 4.2. The liquid limit tests results are also shown in Figure 4.6, and Figure 4.7.

Figure 4.5 Liquid limit and plastic limit tests performed on soil

Table 4.1 Plastic limit test of soil sample collected from Kuchlak

	Liquid Limit			Plastic Limit		
No. of Blows	16	21	33	-	-	-
Wt. of container (gm)	11.43	11.34	12.12	6.7	7.48	-
Wt. of Container + wt. of wet Soil (gm)	24.9	29.42	26.3	11.8	11.34	-
Wt. of Container + wt. of Dry Soil (gm)	21.3	24.98	24.2	10.9	10.69	-
Wt. Of Dry Soil (gm)	9.87	13.64	12.08	4.2	3.21	-
Wt. Of water (gm)	3.6	4.44	2.1	0.9	0.65	-
Moisture Content (%)	36.5	32.6	17.4	21.4	20.2	-
	19.5			**17.64**		
Plasticity Index (PI)	**1.9**					

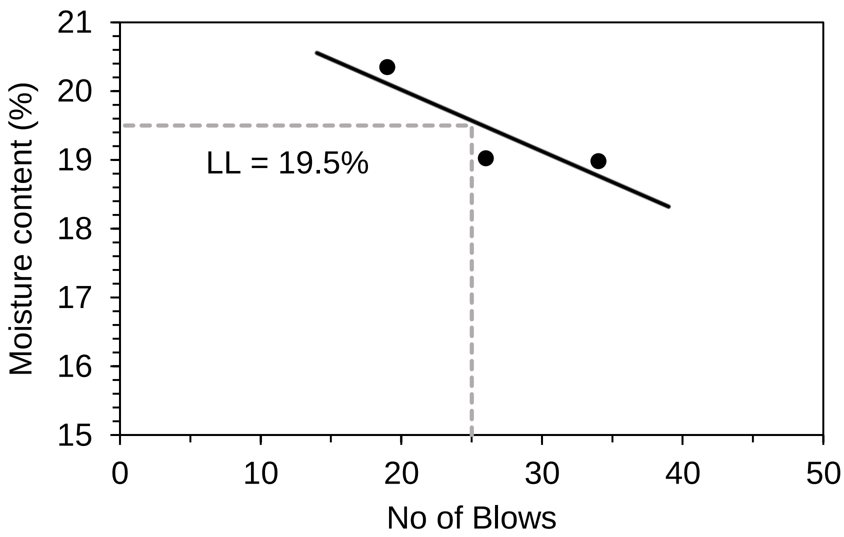

Figure 4.6 Liquid limit of soil collected from Kuchlak

Table 4.2 Plastic limit test of soil sample collected from Saranan

	Liquid Limit			**Plastic Limit**		
No. of Blows	19	26	34	-	-	
Wt. of container (gm)	17	25	33	5.34	7.6	5.13
Wt. of Container + wt. of wet Soil (gm)	11.79	13	11.5	8.2	9.97	7.91
Wt. of Container + wt. of Dry Soil (gm)	23.72	24.89	20.92	7.72	9.56	7.38
Wt. Of Dry Soil (gm)	21.37	22.54	19.21	2.38	1.96	2.25
Wt. Of water (gm)	9.58	9.54	7.71	0.48	0.41	0.53
Moisture Content (%)	2.35	2.35	1.71	20.16	20.91	23.5
	24			**20.5**		
Plasticity Index (PI)	**3.5**					

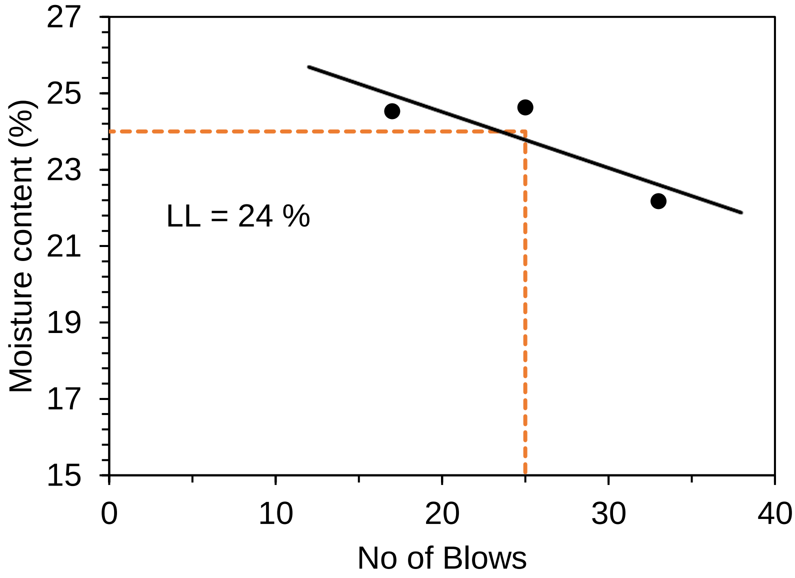

Figure 4.7 Liquid limit of soil collected from Saranan

4.2.4 Specific gravity tests

The Specific gravity (G_s) of soil is always needed in phase relationship of soils, such as void ratio and density of soil solids. It is defined as the ratio of density of soil solid (ρ_s) and density of water at 20°*C*. The density of water (ρ_w) at 20°C is 0.99821 g/cm^3 or 1.0 Mg/m^3. Specific gravity tests were performed on the clay soil as shown in Figure 4.8. The tests were performed according to, standard test method for specific gravity of all soil. The specific gravity by definition is,

Figure 4.8 specific gravity test conducted on clay in laboratory

Table 4.3 presents the summary of physical properties of soil samples selected from various locations. According to results of soil tests, the soil sample from Saranan is selected for Adobe casting, which have 20% clay, 78.32% silt and 2.1% sand.

Table 4.3 Physical properties of clay

Tests	**Samples Location**			
	Saranan	**Kuchlak**	**Buitems**	**Saranan**
Plastic limit	21.52% (highly plastic >17)	Nil	Nil	17.64% (highly plastic >17)
Liquid limit	23.8	25.5	Not possible	19.5
Wet Sieve analysis	2.10% retained s#200 97.90% passed s#200	6.22% retained s#200 93.78% passed s#200	3.4% retained s#200 96.6% passed s#200	3.9% retained s#200 96.1% passed s#200
Hydrometer analysis	20%Clay, 78.32%Silt, sand2.1%	10%Clay, 90%Silt	3%Clay, 97%Silt	4%Clay, 96%Silt
Specific Gravity	2.735	2.688	2.577	2.63

4.2.5 Sand

The Sand was collected from the airport road Quetta. The sieve analysis was performed according to ASTM C136, as shown in Figure 4.9. The grain size distribution curve of sand is presented in Figure 4.10. The physical properties of sand are given in Table 4.4. The results show that the sand is fine sand.

Figure 4.9 Sieve analysis tests of sand

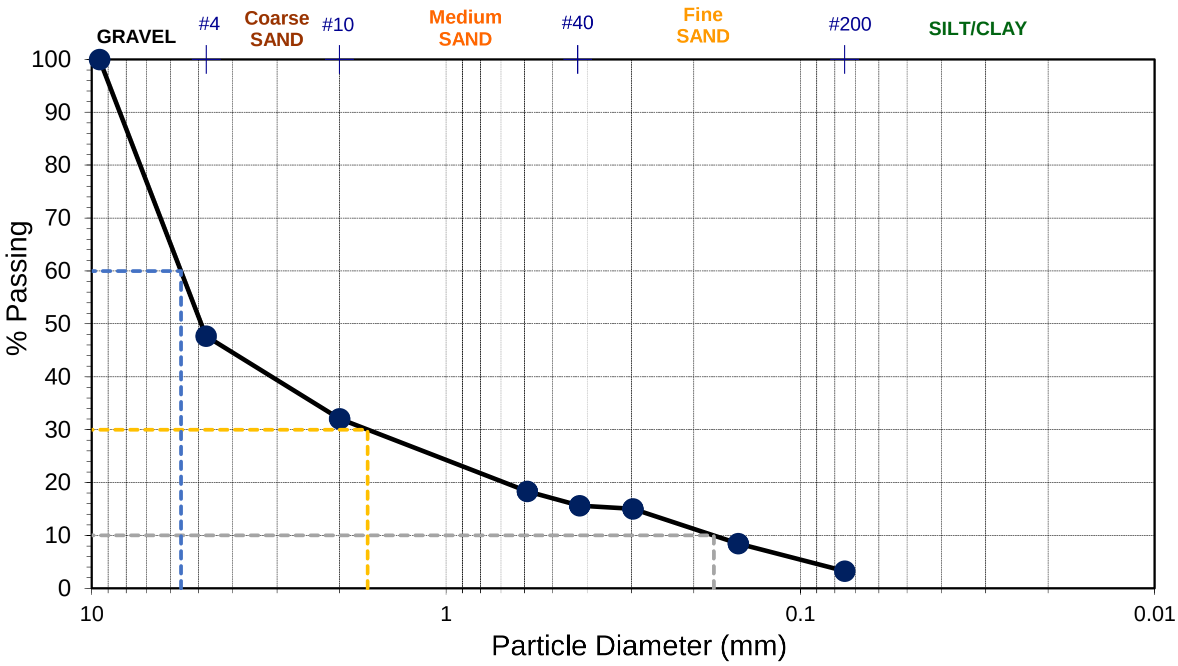

Figure 4.10 Grain size distribution curve of sand

Table 4.4 Physical properties of sand

Physical properties	Value
D10	0.18
D30	1.67
D60	5.60
Cc	31.94
Cu	2.83

4.2.6 Polypropylene staples

The polypropylene bags which is also called china bags. We have purchased it from the local market. It is also available in every home and local community after their first use like when it is free from sugar, rice, flour etc. We will cut the staples fiber in width and length (in grid pattern) of and 20, 40 and 60 mm respectively. We will make pp-staples from it as shown in Figure 4.11, by cutting it in 20, 40, and 60 mm and the tensile strength of the yarn is determined by Engr. Ghuffran in his MS thesis by computerized tensile strength which is 5.5 N. The properties of the pp staples are presented in Table 4.5.

Table 4.5 Physical property of polypropylene

PP Staples	**Property**
Material	POLYPROPYLENE
Type	STAPLE
Width (mm)	3
Length (mm)	20, 40, 60
Tensile load (N)	5.5
Softening temperature	85 C
Specific gravity	0.92
Moisture absorption	< 0.1%

Figure 4.11 Preparation of polypropylene staples

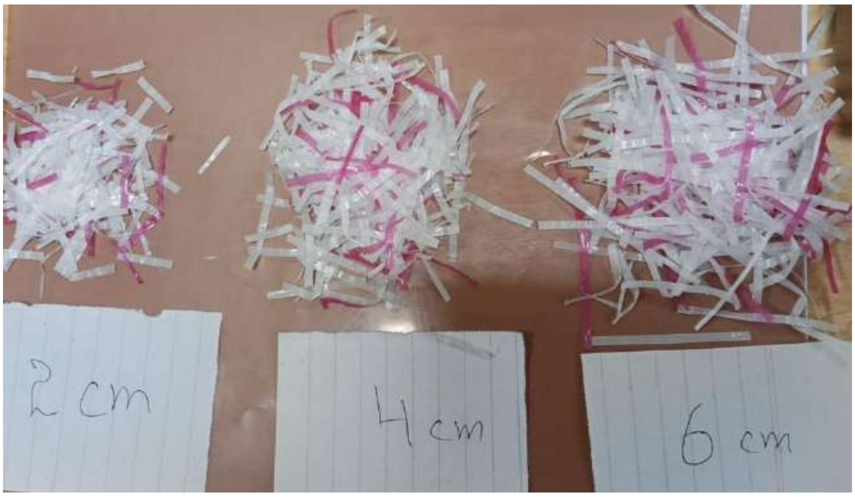

Figure 4.12 Poly propylene staples of 2cm, 4cm, and 6cm

4.3 Proctor tests

Modified Proctor tests were performed on samples of clay mixed with 0%, 30%, 50%, and 70% of sand according to ASTM D1547, as shown in Figure 4.13. Maximum dry density and optimum moisture contents were determined for clay and sand mixtures.

Figure 4.13 Modified Proctor tests were performed on sample in laboratory

4.4 Sample preparation

Making adobe is a traditional method of creating building materials from natural resources, such as clay, sand, water, and organic materials like lime. Adobe bricks have been used for centuries in various cultures to construct homes and other structures. Below is a general outline of the process of making adobe bricks.

4.4.1 Soil Preparation

The first step is to gather the raw materials and remove any debris, rocks, or organic matter from the clay and sand mixture. The lumps in soil is broken down into finer particles to ensure uniformity. We have taken 6kg soil (3kg sand, 3kg clay) to prepare one adobe sample as shown in. Staples is added in various lengths (2cm, 4cm, and 6cm) and various weight (0.1%, 0.2% and 0.3%), as shown in Figure 4.14 below.

Figure 4.14 Soil preparation

4.4.2 Mixing

Once the soil is prepared, it's mixed thoroughly with water to create a workable and homogenous clayey mixture. It's important to achieve the right consistency to ensure the bricks hold their shape during the molding process as shown in Figure 4.15.

Figure 4.15 Mixing of material

4.4.3 Adding Stabilizers

Polypropylene staples has been added as a reinforcement in different ratios for the stabilizing of the adobe. These additives enhance the brick's ability to withstand cracking and shrinkage.

4.4.4 Molding

The clayey mixture is poured into rectangular molds, made of metal as shown in Figure 4.16. These molds determine the size and shape of the bricks. The molds are then placed on a flat surface and left to dry for a short time.

Figure 4.16 Molding process and apparatus

4.4.5 Compression

When the soil sample is kept in the mold then it compressed with a compressor machine in order to gain dense and compressed sample as shown in Figure 4.17.

Figure 4.17 Compressing the sample batch to get compressed adobe

4.4.6 Demolding

After the bricks have partially dried and held their shape after compression, they are carefully removed from the molds and set on a flat, level surface to continue the drying process as shown in Figure 4.18.

Figure 4.18 Demolding process of adobe from compression machine

4.4.7 Drying

The freshly molded bricks are left to dry for curing for 28 days. During this time, they lose moisture and harden. It's essential to protect the bricks from rain or excessive moisture during the drying as shown in Figure 4.19.

Figure 4.19 Drying of sample for 28 days

4.5 Flexural test

Center--point flexural tests were performed as per (ASTM-C293/C293M-16 2016) on the reinforced and unreinforced adobe samples. Schematic of a Suitable Apparatus for Flexure Test of by Center-Point Loading Method as shown in Figure 4.20.

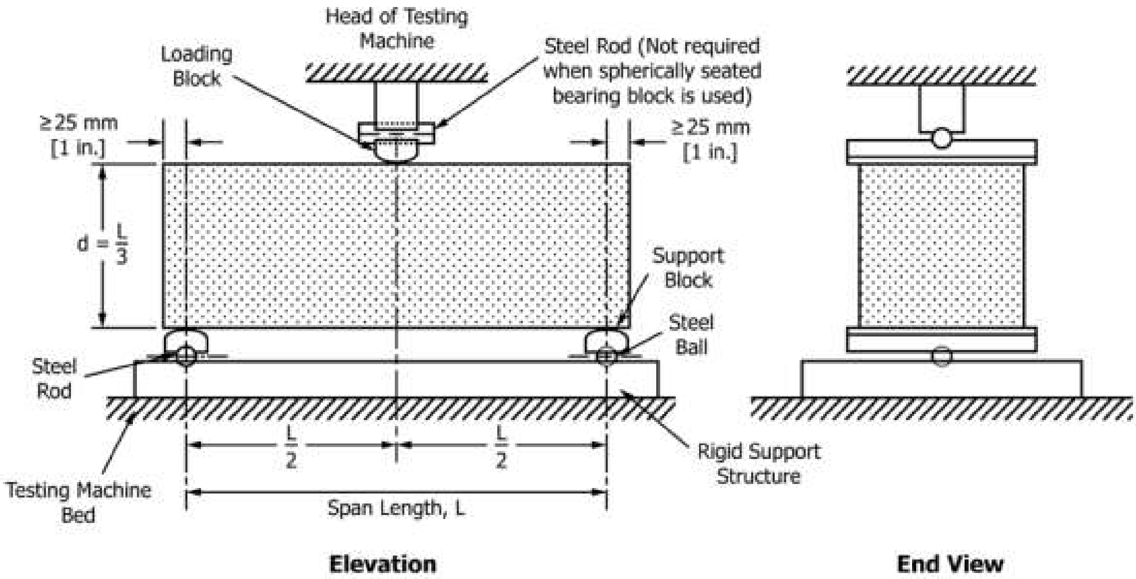

Figure 4.20 Schematic of center point loading flexural test (ASTM C293/C293M – 16)

CHAPTER 5 RESULTS AND DISCUSSION

5.1 Introduction

This chapter presents the results of proctor test performed on mixture of clayey soil mixed with various amount of sand. The chapter also presents the results of flexural test performed on unreinforced and reinforced adobe samples.

5.2 Proctor tests results

The results of the modified proctor test performed on clay mixed with 0, 30, 50 and 70% sand are shown in Figure 5.1. The effect of sand content on maximum dry density (MDD) and optimum moisture content (OMC) is shown in Figure 5.2. The OMC is decreases with increasing sand amount, while the MDD increases with increasing sand contents.

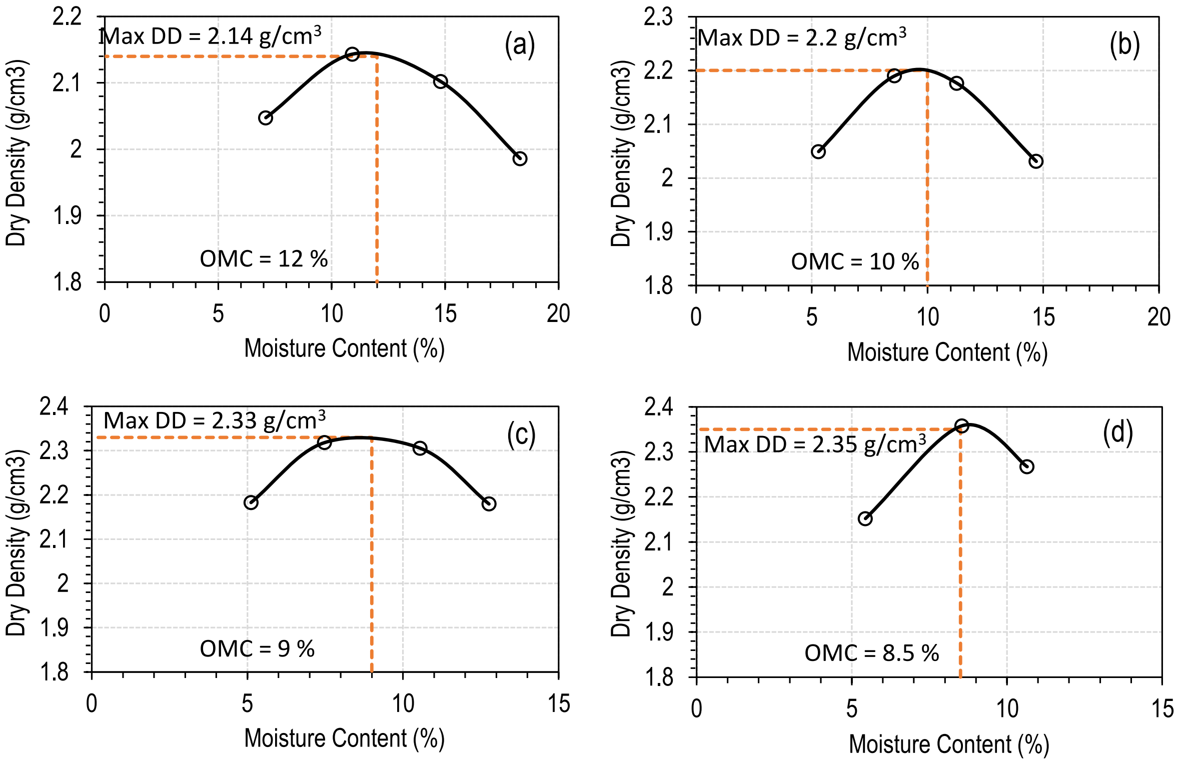

Figure 5.1 Modified proctor test performed on clay with sand

(a) 0% sand, (b) 30% sand, (c) 50% sand, (d) 70% sand

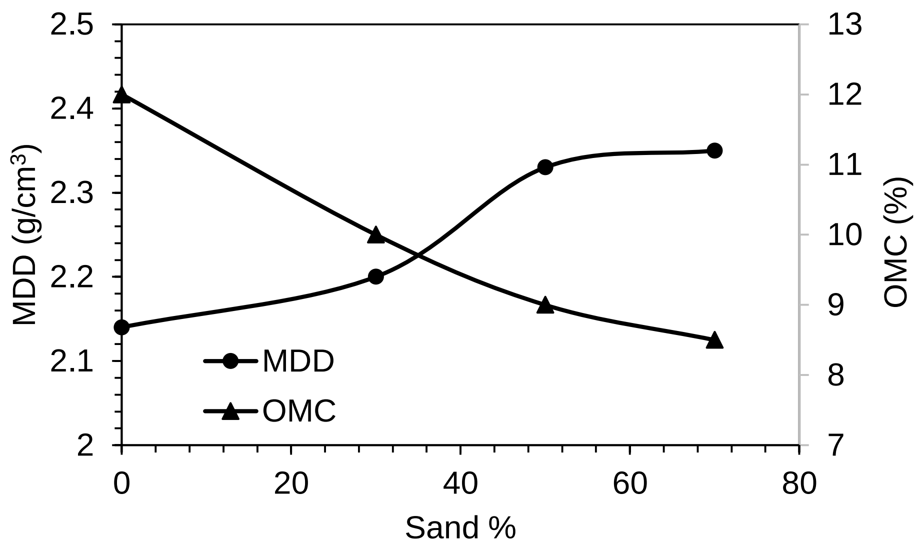

Figure 5.2 Effect of sand content on MDD and OMC

5.3 Effect of Polypropylene Staples on Flexural Strength of Adobe

Polypropylene (PP) Staples of various lengths were added to adobe to study its effect on the flexural strength. The PP staples of 2cm, 4cm and 6cm in length were added in different percentages (0%, 0.1%, 0.2% and 0.3%) with the combination of (50%sand, 50%clay) is used in adobe. As Figure 5.6 shows that the pre crack flexural strength of reinforced sample was slightly decreases with PP staples however the post crack flexural strength was significantly increased with increasing length and percentage of PP staples as shown in Figure 5.7. The PP staple with 6cm length and 0.3% produce maximum post crack flexural strength Figure. The post crack flexural strength was increased from zero to 3.3kpa for zero % PP and 0.3% with 6cm length respectively as shown in Figure. The tests results show that the unreinforced adobe fails suddenly after the flexural load is reached the maximum as shown in Figure 5.3 (a). While, in the PP staples reinforced adobe the crack gradually widens with increasing mid-span displacement as shown in Figure 5.3(b, c & d).The Figure 5.4,Figure 5.5 show the results of flexural tests conducted on the adobe reinforced with PP staples length of 2cm, 4cm and 6cm of various percentages(0%,0.1%,0.2% and0.3%) by weight. The results shows increase in the flexural strength. The post failure strength is also improved with increasing amount of PP staples of 4cm and 6cm, while 2cm staples slips due to low embedded length, so due to slipping phenomena the post peak flexure strength of 2cm were low. Similarly with 2cm of PP staples the post failure flexural strength is gradually decreased and tends to zero at large displacements. While the 4cm and 6cm length of PP staples show that the post failure strength is slightly decreased at large displacement. Figure 5.6 shows the peak flexural strength of total samples. The post peak flexural strength of adobe increases with the increase in staples length and staples percentage as shown in Figure 5.7.

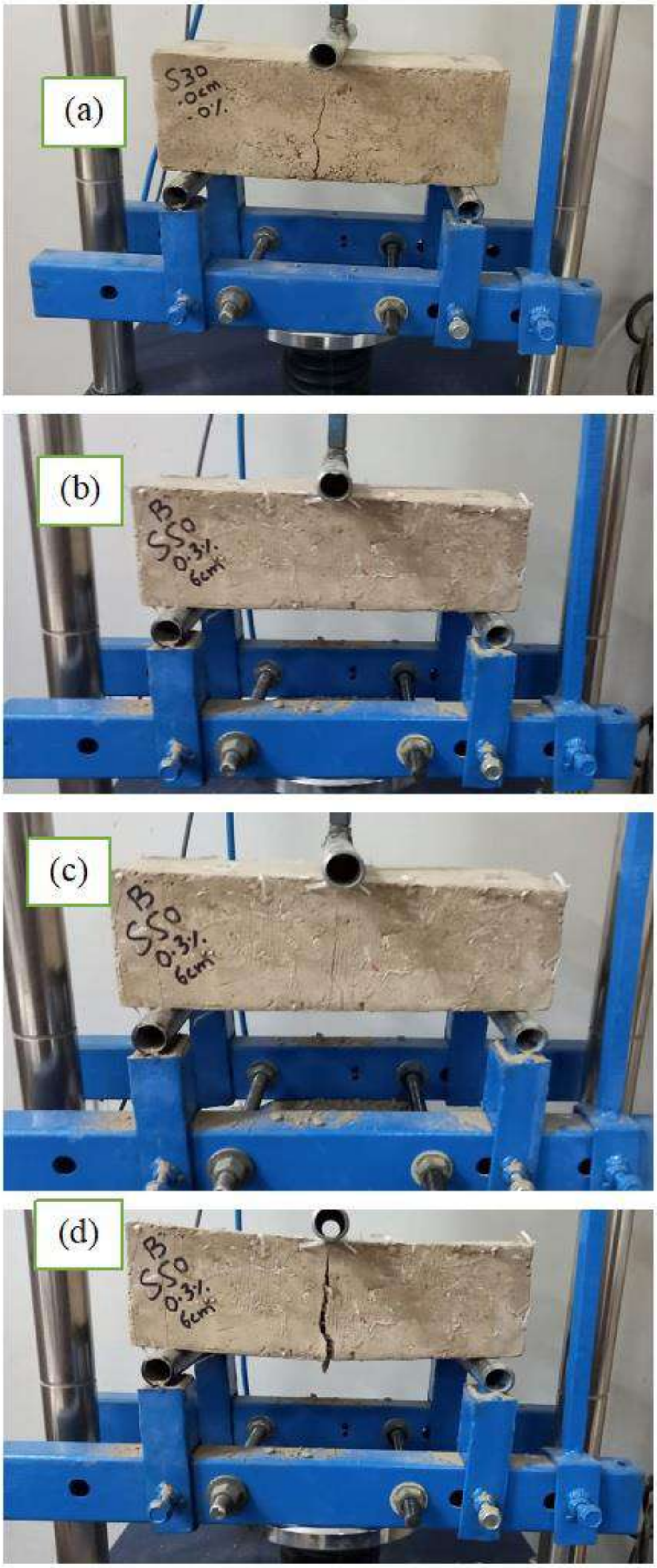

Figure 5.3 (a) Unreinforced Adobe (b, c, d) PP staples reinforced Adobe

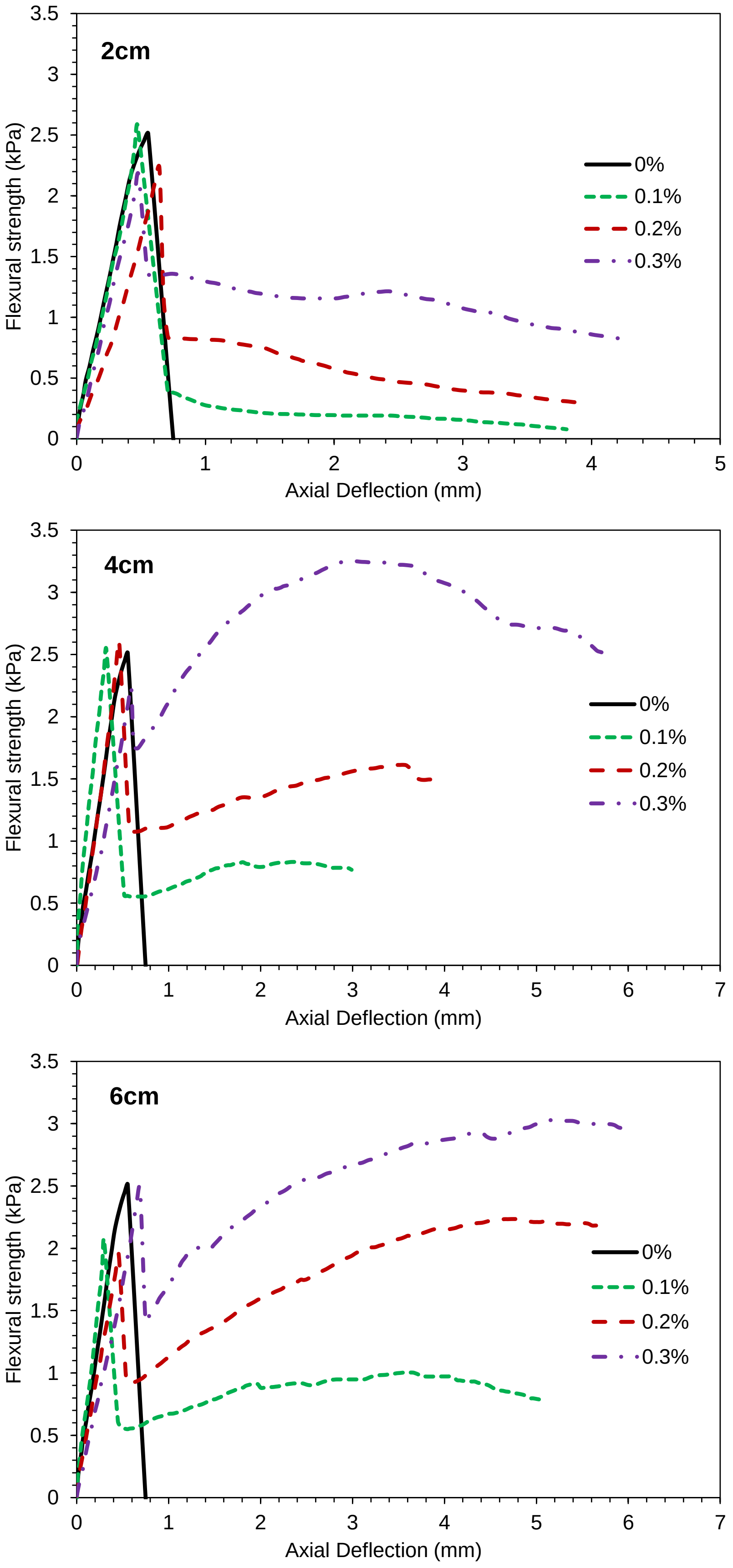

Figure 5.4 Effect of Polypropylene Staples (2cm, 4cm, and 6cm) on Flexural Strength and axial deflection of adobe at various staples percentages (0%, 0.1%, 0.2%, and 0.3%)

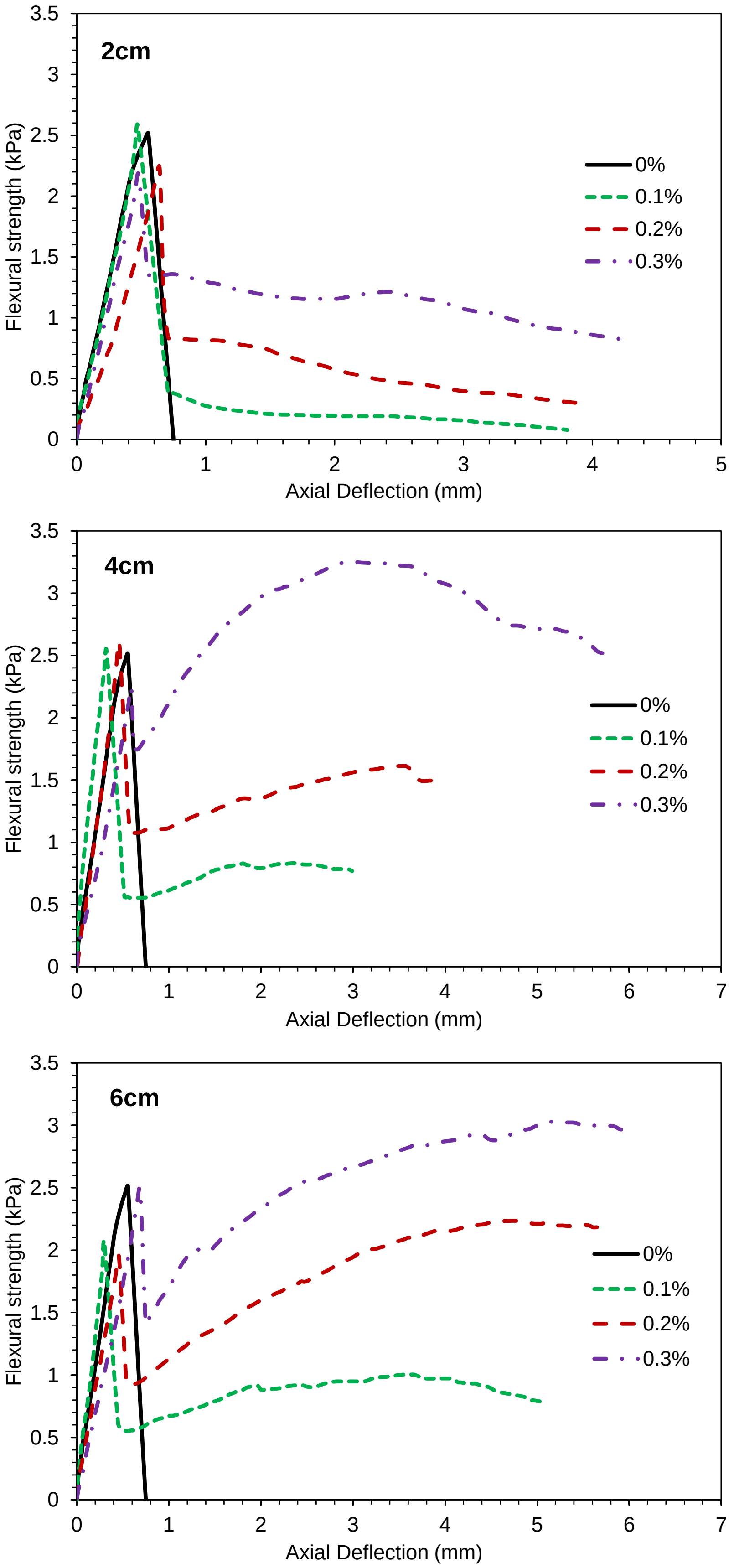

Figure 5.5 Effect of Polypropylene Staples of various percentages (0.1%, 0.2%, and 0.3%) on Flexural Strength of adobe at different staples length (2cm, 4cm, and 6cm)

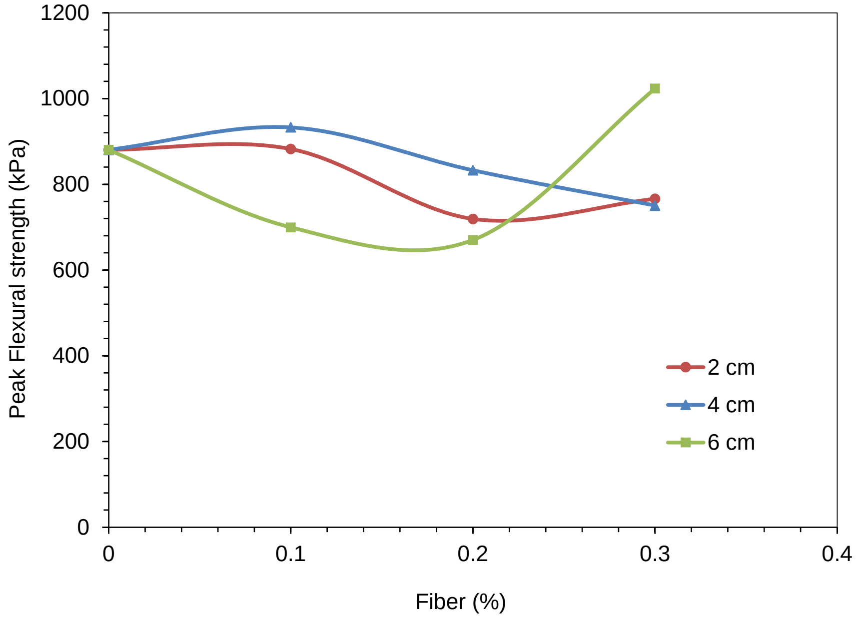

Figure 5.6 Effect of Polypropylene Staples (2cm, 4cm, and 6cm) on peak flexural Strength of adobe of various percentages (0%, 0.1%, 0.2%, and 0.3%)

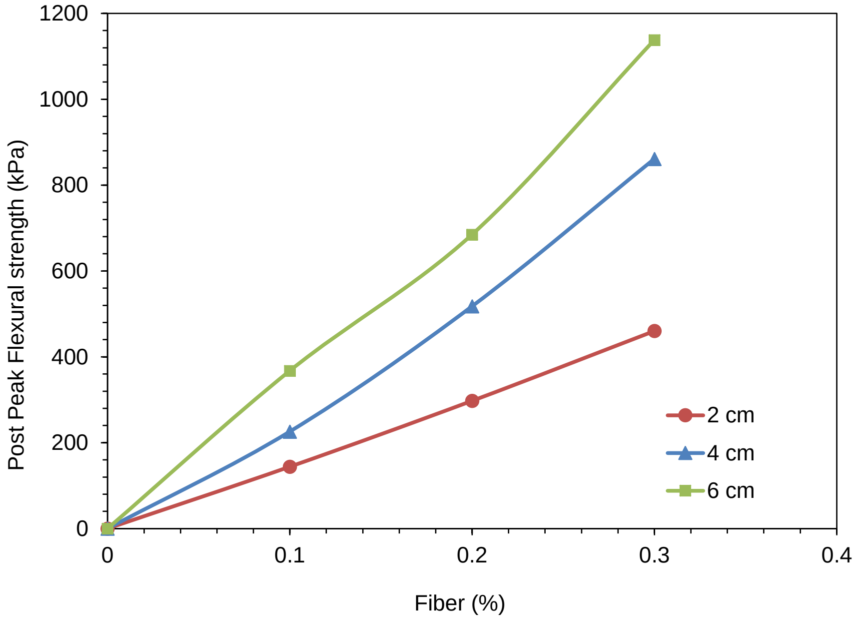

Figure 5.7 Effect of Polypropylene Staples (2cm, 4cm, and 6cm) on Post peak flexural Strength of adobe of various percentages (0%, 0.1%, 0.2%, and 0.3%)

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6.1 Introduction

This chapter presents the summary of the key out comes of the study. In the study the compressed earth blocks were reinforced with PP staples extracted from PP woven packing bags. The PP staples were cute in different length of 2cm, 4cm and 6cm, and mixed in different percentages of 0, 0.1, 0.2 and .3%. Center point flexure tests were performed on unreinforced and reinforced samples.

6.2 Conclusion

The main conclusion of the research are as follows;

1. The addition of sand to clay enhances the compaction characteristics of the mixture. The increased density resulting from higher sand content improves the stability and resistance to deformation of the clay-sand mixture. Moreover, the decrease in optimum moisture content indicates that the mixture becomes easier to compact and requires less water for achieving maximum compaction. This information is valuable for engineers and construction professionals involved in soil stabilization and compaction projects, as it assists in determining the ideal sand content and moisture content for achieving optimal compaction and stability.
2. The 2cm polypropylene staples do not provide enough reinforcement to enhance the peak flexural strength significantly, due to slipping phenomena. However, as the length of the staples increases to 4cm and 6cm, the embedded length in the adobe increases, reducing the likelihood of slipping and improving the overall peak flexural strength of the compressed adobe samples.
3. Based on the results, it can be concluded that the flexural strength of adobe increases as the percentage of pp staples increases from 0.% to 0.2% and 0.3%.It is suggested that the addition of pp staples has a positive impact on the flexural strength of adobe.

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