REPUBLIC OF RWANDA

ULK POLYTECHNIC INSTITUTE

P.O BOX 2280 Kigali

Website: //www.ulkpolytechnic.ac.rw

E-mail: polytechnic.institute@ulk.ac.rw

ACADEMIC YEAR 2023/2024

DEPARTMENT OF CIVIL ENGINEERING

OPTION OF CONSTRUCTION TECHNOLOGY

COMPARATIVE STUDY OF DIFFERENT BETWEEN BURNT BRICKS AND SAND CEMENT BRICKS ON AFFORDABLE HOUSES IN RWANDA

Submitted in partial fulfillment of the requirements for the award of an advanced diploma in Construction Technology

Presented by: NDAYISENGA Samuel

Roll number: 202150282

Under guidance of: Eng. Eric NGORORANO

Kigali, October, 2024

DECLARATION

I, NDAYISENGA Samuel (202150282), hereby declare that this report of “Comparative study of different between burnt bricks and sand cement bricks on affordable houses in Rwanda” project, done and checked under the supervision of **Eng. Eric NGORORANO**, is my original work and has never been submitted anywhere for any academic qualifications.

Signature………………

NDAYISENGA Samuel

Roll number: 202150282

Date…/…/……

CERTIFICATION

This is to certify that this dissertation work entitled ""Comparative study of different between burnt bricks and sand cement bricks on affordable houses in Rwanda"" is an original study conducted by NDAYISENGA Samuel (202150282) under my supervision under guidance.

Supervisor: Eng. Eric NGORORANO

Date: …../……/…….

Signature………………

Head of department

Eng.Bonaventure NKIRANUYE

Date: …../……/…….

Signature………………

DEDICATION

I dedicate this final project report to the Almighty God, for the guidance, strength, power of the mind, protection, and skills and for giving us a healthy life, to my parents struggle from my childhood until now, to my siblings, to my classmates and colleagues for their help in my academic daily life.

ACKNOWLEDGEMENT

First of all, I thank the ULK Polytechnic Institute for providing with me the knowledge through all these years. I also thank them for the workshops and field visit trips that were provided to us for further understanding of the learnt modules practically.

My deepest acknowledgement goes to my supervisor, **Eng. Eric NGORORANO,** despite his multiple responsibilities, he accepted to supervise me during the period of this work. His helpful interventions, assistance and encouragements provided me to do well this work.

Also, I am highly grateful to my Lecturers, to the college and classmates for their great support. Their knowledge and wisdom have supported and enlightened me throughout the process of my studies.

ABSTRACT

This project focuses on a comparative study of burnt clay bricks and sand-cement bricks for affordable housing in Rwanda. The study seeks to address the problem of environmental degradation caused by the use of burnt bricks, which contribute to deforestation, loss of fertile topsoil, and construction inefficiencies due to their low strength and susceptibility to damage. The main objective is to assess the compressive strength, cost-effectiveness, and overall practicality of sand-cement bricks compared to burnt bricks.

The methodology involved laboratory tests on both sand-cement and burnt bricks. Compressive strength tests were conducted on brick samples, with sand-cement bricks showing superior performance. The average compressive strength of sand-cement bricks was 10.5 MPa, compared to burnt clay bricks at 6.0 MPa, indicating that sand-cement bricks are more durable and better suited for load-bearing construction. Additionally, a compressive test was performed on unburnt clay bricks, yielding an average compressive strength of 3.5 MPa, further highlighting the structural advantage of sand-cement bricks.

Cost analysis for constructing a 20m × 3m wall showed that using clay bricks would require approximately 8,170 bricks, with a total material and transport cost of 434,000 Frw. For sand-cement bricks, 8,577 bricks were needed, with a higher total cost of 720,000 Frw due to the more expensive materials and additional transportation requirements. Despite this, sand-cement bricks offer long-term savings due to their higher durability and reduced maintenance.

The study concludes that sand-cement bricks, although more expensive, provide better strength, durability, and construction efficiency. Burnt clay bricks, while cheaper, are less resistant to environmental wear and lead to environmental harm during production. Based on these findings, it is recommended that construction companies adopt sand-cement bricks for affordable housing projects to ensure stronger, more sustainable, and cost-effective building practices. Additionally, clients should consider the environmental and long-term benefits of using sand-cement bricks over burnt clay bricks.

Keywords: sand-cement bricks, burnt bricks, compressive strength, cost analysis, affordable housing,

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1. GENERAL INTRODUCTION

1.1. Background information

For a better performance of work in the area of building construction, significant knowledge of the materials that are about to be used is required as long as the country is growing so fast in development as much as their population needs so much improvement that can help them to keep moving forward in the country's vision of development (KI Gartoumi, 2022)

In building construction, it is needed to change and bring in new ideas and this is the reason why it is needed to make it a part of the project to keep up to date with information about the new and existing materials and methods of fixing.

Bricks are among the oldest building materials that are widely used as a construction material because of its high durability, strength, uniform shape and size, easily handling and available. This project will mainly base on the comparative study on the use of burnt and sand-cement bricks for the affordable house in Rwanda (Zhang et al. 2018)

All about the clay burnt bricks will be clearly explained, the ways of manufacturing, their uses, properties, advantages and disadvantages and for sand cement bricks, mix is moulded under a great pressure to produce the required brick shapes (Zhang et al. 2018)

1.2. Problem statement

In planning of this research, it is very important for us to study how you can use the sand-cement bricks instead of using the burnt bricks. Due to many inconvenient or disadvantages that burnt bricks show, for example using burnt bricks will lead to extensive loss of fertile top soil that could be disturbing environment hazards. In addition as it has been observed every year, a vast area of forest is destroyed in search of soil for bricks manufacturing, this could show down the rate of deforestation (KI Gartoumi, 2022)

Also burnt bricks show more wastage from its manufacturing till after construction and also even after they are constructed on the building, they are damaged easily by rain and as it is clearly seen that they do not show a good appearance on the building without other finishing work.

For referring to the standard bricks requirements, it is easy and necessary to avoid those defaults by using sand-cement bricks to achieve the required strength, reasonable cost and good quality of bricks This is an eye-opener kind of post which describes the disadvantages of continuity of using burnt bricks for the affordable house.

1.3. Objectives of the project

1.3.1 Main objective

This project has the main objective of comparing the burnt bricks and sand cement bricks in terms of strength and cost.

1.3.2. Specific objectives

The following specific objectives will be pursued in order to achieve the main objective stated:

- To identify the kind and quality of bricks that might be used in building construction.
- To build the skills and knowledge in bricks materials
- To identify the good quality of clay burnt bricks and sand-cement bricks.
- To describe the variation of the compressive strength due to the clay burnt brick and sand-cement bricks.
- To determine the quantity and quality for each of the kind.

1.4. Scope and limitation of the Research

This research dealt only with comparative study of different burnt bricks and sand cement, it will be undertaken to show how safe economical, durability, good quality, appropriate strength and cost of these materials The study dealt with the comparative study on the use of clay burnt and sand-cement bricks for the affordable house in Rwanda.

- Those all bricks are rectangular shape were used and they were all solids.
- The study was based on sand-cement bricks which are manufactured both mechanically and manually.
- The study mostly dealt with compressive strength and cost of burnt bricks and sand-cement bricks as oldest building materials used in building construction.
- The study didn’t dealt with water absorption test
- The study didn’t dealt with cement test
- The study didn’t dealt with sand equivalent test

1.5. Significance of the study

This study has important of teaching and learning process in sense that it will improve and make the broad understanding about impact of practices in improving student’s achievement in practical subjects especially construction technology, also it will help in students subjected to construction learning theory-based practices instruction exhibit higher achievement as the practices are regarded as an indispensable element in student’s achievement.

When this research will be performed:

- It will be shared to everyone who will use those bricks.
- It will become a good performance according to the use of sand-cement brick without any wastage.
- It will be easy to know clearly the best brick which has a good quality and compressive strength required for good brick.
- For the other students, it will be helpful to refer to the study so that they can develop their own research referring to what we did.
- This study will help Rwanda community to select the construction brick with a good quality, convenient strength and affordable cost.
- It will help to understand the behavior of burnt brick compared to sand-cement bricks due to applied load
- It will show each materials advantages and disadvantages for each.

1.6. Structure of the Research

This research will be divided into five main chapters in order to provide clarity and coherence on the discussions of all investigations carried out on comparative study on different burnt bricks and sand cement bricks.

CHAPTER ONE : General introduction which deals with Introduction, problem statement, research objectives, benefits of the research, scope of the research, research hypothesis, materials and methods and finally structure of the research.

CHAPTER TWO: Related literature review to give all the details and theories concerning the on the different clay burnt bricks and sand cement bricks

CHAPTER THREE: Methodology which deals with the methods, procedures, the definitions of the instruments that will be used for the investigations and, the methods and techniques used to collect all the data required.

CHAPTER FOUR: Data analysis and interpretation which deals with the presentation, analysis and interpretation of the findings. Here the research will be able to show if sand cement bricks is a more durable and a more economical solution than the clay burnt bricks.

CHAPTER FIVE: Conclusions and recommendations which is the last, presents conclusions, recommendation to state the output of the research**.**

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

A brick is a building material used to make walls, pavements and other elements in masonry construction. Traditionally, the term brick referred to a unit composed of clay, but it is now used to denote any rectangular units lay in mortar. A brick can be composed of clay-bearing soil, sand and lime, or concrete materials. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities. Two basic categories of bricks are fired and non-fired bricks (De Carvalho et al, 2016)

Block is a similar term referring to a rectangular building unit composed of similar materials, but is usually larger than a brick. Lightweight bricks (also called "lightweight blocks") are made from expanded clay aggregate.

Fired bricks are one of the longest-lasting and strongest building materials, sometimes referred to as artificial stone, and have been used since circa 5000 BC. Air-dried bricks, also known as mud bricks, have a history older than fired bricks, and have an additional ingredient of a mechanical binder such as straw.

Bricks are laid in courses and numerous patterns known as bonds, collectively known as brickwork, and may be laid in various kinds of mortar to hold the bricks together to make a durable structure.

The only artificial building material that can attest to its use since the dawn of human civilization is brick. Bricks are used extensively in construction and civil engineering projects because of their remarkable qualities, which include great compressive strength and durability, exceptional fire and weather resistance, and strong thermal and sound insulation.

2.2. Classification of bricks

2.2.1. Common bricks

Bricks made of clay can be categorized based on their types, attributes, and groups.
Common burnt clay bricks are acknowledged for use in bricklaying applications and have no particular aesthetic value. Plastering or rendering is necessary for walls constructed with regular bricks. (R. S. Burn (Ed.) 2015)

2.2.2. Facing bricks

Quality burnt clay bricks, which give attractive appearance in their colour and texture. It is used without rendering, plastering, or other surface treatments (Burn, R. S. (Ed.) 2015)

2.2.3. Load bearing bricks

Load bearing bricks, which can be either common or facing bricks, conform to specified average compressive strength limits depending on their classes as given in table below.

Table 2.1: Average compressive strength and their classes

Class	**Average compressive strength**	
	N/mm^2	**P.S.I.**
1	7	1,000
2	14	2,000
3	20.5	3,000
4	27.5	4,000
5	34.5	5,000
7	48.5	7,000
10	6	10,000
15	103.5	15,000
***Based on British Standard 3921:1965**		

2.2.4. Engineering bricks

Burned bricks at extremely high temperatures are known as engineering bricks. They meet established standards for strength and water absorption and have a robust, semi-vitreous body. The main applications for them are in civil engineering projects that call for strong damp resistance, chemical resistance, and high load bearing capability. (Oti and colleagues, 2019)

Table 2.2: Average compressive strength with average water absorption

Engineering	**Average Compressive Strength, (No less than) N/mm² U.S.A.**	**Average Water Absorption, % (No greater than)**
A	69.0 (10,000psi)	4.5
B	48.5 (7,000psi)	7
***Based on British Standard 3921:1965**		

2.2.5. Damp proof course

Clay bricks of specified low water absorption used at the base of a wall (minimum two courses) to resist the upward movement of ground water. Their use is recommended for free standing wall where otherwise a sheet of DPC material would create a plane of weakness causing the wall to be vulnerable to lateral forces (D'Orazio et al, 2014)

2.3. Properties and functional performances of brick

Clay is burned at high temperatures to make bricks. Heat-induced sintering results in the fusion of clay particles and the development of incredibly strong ceramic connections in the burnt clay bodies. These kinds of relationships are very stable. Bricks are hence resistant to extreme

weathering processes and virtually all common chemical attacks. (R. S. Burn (Ed.) 2015)
2.3.1. Strength
Bricks have a strong compressive strength that is widely recognized. Their size and shape, the production process, and the raw materials utilized all affect their compressive strength.
When fired at a high enough temperature and using a de-aerated extruder, bricks may easily survive compressive pressures more than 28 N/mm2 (4,000 psi).

2.3.2 Aesthetic appeal

Clay is burned at high temperatures to make bricks. Heat-induced sintering results in the fusion of clay particles and the development of incredibly strong ceramic connections in the burnt clay bodies. These kinds of relationships are very stable. Bricks are hence resistant to extreme weathering processes and virtually all common chemical attacks. (R. S. Burn (Ed.) 2015)

2.3.1.Strength

Bricks have a strong compressive strength that is widely recognized. Their size and shape, the production process, and the raw materials utilized all affect their compressive strength. When fired at a high enough temperature and using a de-aerated extruder, bricks may easily survive compressive pressures more than 28 N/mm2 (4,000 psi) in view of the high cost to maintain the appearance of a building, the unique features of brick become an unparalleled advantage to housing design.

2.3.3. Porosity

One crucial aspect of brick is its porosity. Brick is said to be more porous than other pre-cast or molded building materials because of its tiny capillaries. The rate of moisture transmission in brick is ten times faster than in other construction materials because of the capillary effect. During the day, moisture is released, and at night, it is reabsorbed. One of the best qualities of brick that helps control the temperature and humidity of the atmosphere in a home is its capacity to release and re-absorb moisture through the capillary effect. Brick is a great building material because of this unique quality, which makes it especially appropriate for homes in tropical climates.
However, all materials that are porous are vulnerable to chemical attacks and can get contaminated by weathering agents such as rain, running water, and air pollution. When it comes to a building material's performance and uses, porosity is a crucial consideration.

According to the results of the experiment, bricks with an 8% water absorption rate are ten times more resilient to salt assault than bricks with a 20% water absorption rate. Compared to concrete blocks and cement mortar, which have standard water absorption rates above 15%, well-burned brick has a rate of less than 10%. This explains why, over time, brick walls require relatively little upkeep (Cultrone, 2013).

In order to minimize the negative consequences while preserving the benefits linked with porosity, it is ideal to keep the rate of water absorption of face bricks in masonry brickwork at or near 10%. Brick's initial rate of absorption is a little-known characteristic (IRA). In actuality, during bricklaying, the early rate of absorption has a significant impact on the strength of connection between the bricks and mortar. A high IRA value tends to quickly remove too much water from the mortar, which prevents the cement from properly hydrating. Research indicates that a 50% decrease in brickwork strength occurs when the IRA is increased from 2 kg/m2/min to 4 kg/m2/min.

Generally, bricks with IRA exceeding 2 $kg/m^2/min$ will gives rise to difficulties in lying using common cement mortars. Modern brick extruder with de-airing action produces denser brick with lower IRA.

2.3.4. Fire resistance

Brick naturally has a high fire resistance. For non-load bearing uses, 200 mm of unplastered brickwork will provide a maximum rating of 6 hours of fire resistance, whereas 100 mm of brickwork with 12.5 mm of regular plastering will provide a fire resistance of 2 hours. Brick can withstand loads up to 1000°C, but concrete walls can only withstand temperatures of up to 450°C due to the loss of moisture.

It is a known fact that brick's non-combustibility encourages its use in fire-resistant construction. There are several cases from the past where people decided to build their homes out of brick following a disastrous fire that destroyed the entire city.

Perhaps the most famous instance is the great London Fire in 1666, after which the rebuilding was largely done if not entirely in brick (Khaliq, 2016)

2.3.5. Sound insulation

Brick walls have excellent insulating qualities because of their solid construction. For the frequency range of 200 to 2,000 Hz, brickwork's sound insulation is typically 45 dB for a 4-1/2-inch thickness and 50 dB for a 9-inch thickness (Khaliq, 2016).

2.3.6. Thermal insulation

When it comes to thermal insulation, brick often performs better than other construction materials like concrete. Bricks' capacity for thermal insulation can be somewhat increased via perforation. In addition, the mass and moisture content of bricks contribute to a reasonably consistent interior temperature. To put it another way, bricks gradually absorb and release heat, keeping the house warm at night and cool during the day.
It is amazing how much energy a brick house can save.

. A study commissioned by the Brick Institute of America had demonstrated that a brick house can save energy up to 30% when compared to that built of wood (Khaliq, 2016)

Table 2.3: A comparison of the thermal conductivities of various materials

Typical Thermal Conductivities of Various Building Materials		
Material	**Btu/(sq.ft.-hr-F/in.)**	**W/mK**
Sand and gravel aggregate (dry)	9	1.3
Cement Mortar	5	0.7
Concrete (1:4)		0.77
Concrete block (1:5) (four Oval-core)	5.2	0.75
Concrete Block (1:10) (four Oval-core)	6.6	0.95
Solid Brick (density: 1925kg/m^3)	5	0.72
Perforated Brick (25% perforation density: 1400kg/m^3)	4	0.58

2.3.7. Wear resistance

Particulate bonding determine a substance's resistance to wear. Because of the incredibly strong ceramic connections that are created by heat at high temperatures, bricks have a high level of wear resistance (Ahmed, A. M., & Rashi, 2019).

2.3.8. Efflorescence

The condition known as efflorescence occurs when soluble slats that have been dissolved in water are moved, deposited, and eventually build up to produce an unattractive scum on brick surfaces. It's possible that the soluble salts came from brick raw materials. However, salts from outside sources, such as contaminated air, ground water, mortar ingredients, and other elements in touch with the bricks, are typically the cause of efflorescence (Ahmed, A. M., & Rashi, 2019).

2.3.9. Flexibility in application

Brick is utilized in a very broad variety of construction and engineering projects for a very broad range of purposes. It can be applied, in particular, to load-bearing structures, which substantially simplify the construction process and save labor, materials, and time. In addition, brick can be formed into practical sizes and shapes to make construction easier. It is highly adaptable and useful in practically any situation (Ahmed, A. M., & Rashi, 2019).

2.3.10. Durability

Brick is possibly the most resilient structural building material created by humans to date because of its exceptional durability. Numerous historic brick buildings that have stood the test of time are examples of how durable burnt-clay brick can be (Ahmed, A. M., & Rashi, 2019).

2.4. Types of bricks

There are different types of bricks available on the market used for various kind of building purpose.

These bricks can be categorized under various headings and subheadings on different bricks.

The various classifications of bricks types are briefly discussed below:

2.4. 1.Classification based on method of manufacturing

Bricks can broadly be categorized into two categories as follows on the manufacturing method which are:

- Unburnt bricks or sun-dried bricks.
- Burnt bricks.

2.4. 1.1. Unburnt bricks

Unburnt bricks or sun-dried are those types of bricks which are dried with the help of heat received from sun after the process of moulding.

These bricks are only used in the construction of temporary and cheap structures. Such bricks should not be used at place where exposed to heavy rain (Oti et al.2019).

Figure 2.1: Unburnt bricks

2.4. 1.2. Burnt bricks

Burnt bricks are prepared by burning the brick-mould in the kiln inside the factory.

These are the most commonly used bricks for construction works. They can further classified into following four categories (Oti et al.2019)

- These bricks are table-moulded and of standard shape and they are burnt in kilns. The surfaces and the edges of the bricks are sharp, square, smooth and straight, they comply with all the qualities of good bricks. These bricks are used for superior work permanent nature.
- These bricks are ground moulded and they are burnt in kilns. The surfaces of these bricks are somewhat rough and shapes are also slightly irregular. These bricks may have hair cracks and their edges may not be sharp and uniform. These bricks are commonly used at place where brickwork is to be provided with a cost of plaster.
- These bricks are ground-moulded and they are burnt in kilns. These are not hard and they have rough surfaces with irregular and distorted edges. These bricks give dull sound when struck together. They are used for unimportant and temporary structures and at places where rainfall is not heavy.
- These are over-burnt type of brick with irregular shape and dark color. These are used as aggregate for concrete in foundation, floor, roads etc. Because of the fact that the over-burnt bricks have a compact structure and hence they are sometimes found to be stronger than even the first class bricks (Oti et al.2019)

2.4. 2.Classification based on shape

The ordinary bricks are rectangular solids. But sometimes bricks are given in different shapes to make them suitable for particular type of construction.

Here we have enlisted different types of bricks available with various shapes.

i. **Bull nose bricks:** a brick moulded with a rounded angle in terms of a bull nose. This type of brick is used for a rounded quoin. A connect which is formed when a wall takes a turn is known as **quoin.** The Centre of the curved position is situation on the long center-line of brick.

ii. **Channel bricks:** these types of bricks are moulded to the shapes of a gutter or a channel and they are often glazed. These bricks are used to function as drains.

iii. **Coping bricks:** these types of bricks are made to suit the thickness of walls on which coping is to be provided. Such bricks take various forms such as chamfered, half round or saddle-back.

iv. **Cow nose bricks:** a brick moulded with a double bull nose on the end is known as a **cow nose.**

v. **Curved sector bricks:** these bricks are in the form of curved sector and they are used in the construction of circular brick masonry pillar, brick chimneys, etc.

vi. **Hollow bricks:** these are also known as the cellular or cavity bricks. Such bricks have wall thickness of about 20mm to 25mm. they are prepared from special homogenous clay. They are light in weight about one-third the weight of the ordinary brick of the same size. These type of can be laid almost about four times as fast as the ordinary bricks and thus the use of such bricks leads to speedy construction. They also reduce the transmission of heat, sound and damp. They are used in the construction of partitioning.

vii. **Paving bricks:** these bricks are prepared from clay containing a higher percentage of iron. The excess iron verified the bricks at a low temperature. Such bricks resist better the abrasive action of traffic. The paving bricks may be plain or chequeled. These bricks are extensively used for garden Wales, streets movements, stables floors, etc.

viii. **Perforated bricks:** these bricks contain cylindrical holes throughout their thickness. These bricks are light in weight and require less quantity of clays for their preparation. The drying and burning of these bricks are also easy. If perforated bricks of large size are used, it will result in the increase of output of mason. The perforated bricks are used in the construction of panels for light weight structure and multi-storey framed structures. They may be circular, square or rectangular shape in cross-section. The distance between the side of and edge of perforation should not be less than 15mm. the distance between the edges of successive perforations should preferably be not less than 10mm. the water absorption after immersion for 24 hours in water should not exceed 15% by weight. The compressive strength of perforated bricks should not be less than 7 N/mm^2 on gross area.

ix. **Purpose-made bricks:** in order to achieve certain purpose these types of bricks are made. The splay or cant bricks are made for jambs of door and windows. The arch bricks are made of wedge shape to keep mortar joint uniform thickness. The ornamental bricks are prepared for corbels, cornices, etc.

Similarly, engineering bricks are prepared for constructions where high durability, compression strength and adequate resistance to sudden shocks are required. These types of bricks are usually more costly than the ordinary bricks but they grant safe, clean and quick construction. Since their cost is justified by their excellent performance in situation for which they are purposely prepared.

2.5. Use of bricks

Bricks plays very important role in the field of civil engineering construction. Bricks are used as alternative of stones in construction purpose. Here some main uses of construction bricks are given below.

- Construction of wall of any size.
- Construction of floors.
- Construction of arches and cornices.
- Construction of bricks retaining wall.
- Making khoa (broken bricks of required size) to use as an aggregate in concrete.
- Manufacture of surki (powdered bricks) to be used in lime concrete.

AlsoBricks can be used for different purposes such

- As structural unit
- As an aesthetic
- As a fire resistant

2.5.1. As a structural unit

Since the clay bricks or burnt bricks are strong, hard, durable, resistive to abrasion and fire, therefore, they are used as a structural materials in different structures

- Building
    - Bridges
    - Foundation
    - Arches
    - Pavement (Foot, Path, Streets)

2.5.2. As an Aesthetic (Unit /Surfaces finish)

Bricks can be used in different colors, size and orientations to get different surfaces designs

As an aesthetic material, bricks can be used

- In pavements
- As facing brick

- For architectural purpose

2.6. Advantages and disadvantages

2.6.1. Advantages of bricks

- Economical (Row material is easily available)
- Hard and durable.
- Compressive strength is good enough for ordinary construction.
- Different orientations and sizes give different surfaces textures.
- Very low maintenance cost is required.
- Demolishing of bricks structure is very easy, less time consuming and hence economics.
- Reusable and recyclable.
- Highly fire resistance.
- Procedures less environmental pollution during manufacturing process (Kostadinova,2019)

2.6.2. Disadvantages of Bricks

- Time consuming construction.
- Cannot be used in high seismic zones.
- Since bricks absorb water easily, therefore, it causes fluorescence when not exposed to air.
- Very less tensile strength.
- Rough surfaces of bricks may cause mould growth if not properly cleaned.
- Cleaning bricks surfaces is a hard job.
- Color of low quality bricks changes when exposed to sun for a long period of time (Kostadinova,2019)

2.7. Reasons to avoid burnt clay bricks

• Compared to sand cement bricks, the construction industry's continued usage of clay bricks will result in a significant loss of fertile top soil. This might be a dangerous environmental hazard.
• The price of clay bricks would increase due to high demand. We should choose alternative building materials like fly ash bricks and hollow or solid blocks in order to maintain the cost of building materials within a realistic level.
• Reducing the rate of deforestation by using fly ash bricks or other substitute building materials. • Burnt clay bricks are made with antiquated technology and lack quality testing facilities at the manufacturing site; an enormous tract of forest is burned annually in search of soil for brick production.

- Most bricks which are manufactured using outdated technology are inferior in quality with low compressive strength. They are not suitable for multi-storey buildings.

- Modern fly ash bricks are manufactured using high end pre-programmed hydraulic machines. Bricks from those machines are egested for its quality and durability.

Compressive strength of fly ash bricks is high and uniform whereas compressive strength of clay bricks is low and uneven (Kostadinova, 2019)

2.8. Steps of brick manufacturing process

2.8.1. Steps Involved in Brick Manufacturing

Manufacturing of bricks consists of the following 4 operations or steps.

i. Preparation of brick clay or brick earth
ii. Moulding of bricks
iii. Air drying of bricks
iv. Burning of bricks

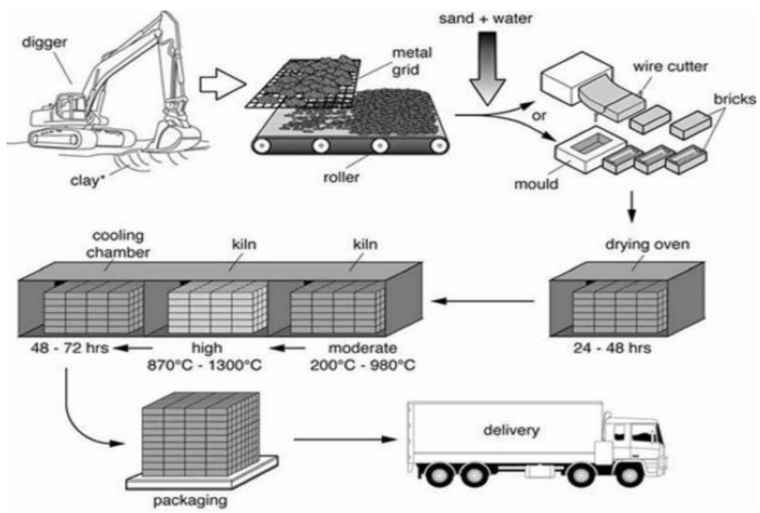

Figure 2.2: The process of brick making

Figure 2.3: clay bricks manufacturing

i. Preparation of brick clay or brick earth

Step-by-step excavation of the soil is followed by its placement on level ground in this step. Next, the dirt is cleared of contaminants like leaves, rocks, and other debris. After contaminants are removed, it is left outside for a few months. We refer to this as the weathering process. To create high-quality brick earth, the soil is mixed with other materials once the weathering process is complete. Next, the blended dirt is softened by being well-broken, hydrated, and worked. Pug mills are typically used for tempering (Babu, 2018).

ii.Moulding of Bricks

Bricks are moulded in many ways depending on the quality of the product to be made. Generally the moulding is done in the following two ways

- Hand moulding
- Machine moulding

Figure 2.4: Hand moulding of clay bricks

For hand moulding the tempered clay is forced in the mould in such a way that it fills all the corners of the mould. Extra clay is removed either by wooden strike or frame with wire. Mould is then lifted up and raw brick is left on ground (Babu, 2018)

Machine moulding is used where large numbers of bricks are to be made. Machines used for moulding is generally of two types.

- Plastic clay machines
- Dry clay machines

In plastic clay machine the clay in plastic state is forced to rectangular openings of a size equal to the length and breadth of the bricks and is then cut into strips of thickness of the brick with wires in frames.

In dry clay machines, dry clay is reduced to powder, filled dry into mould by the machine and then are subjected to high pressure to form hard and well-shaped bricks (Babu, 2018)

ii. Drying of Bricks

Drying is usually done by placing the bricks in sheds with open sides so as to ensure free circulation of air and protection from bad weather and rains. The bricks are allowed to dry till they are left with 5 to 7% moisture content. The moulded bricks are dried because of the following reasons.

- If damp bricks or green bricks are directly taken to burning then, they are likely to be cracked and distorted
- To remove maximum moisture from the brick so as to save time and fuel during burning
- To increase the strength of raw bricks so that they can be handled and stacked in greater heights in the kiln for burning without damage.

Figure 2.5: drying of clay bricks on the sun

iii. Burning of the Bricks

It is the very important step in manufacture of bricks. Bricks may be burnt by two distinct methods given below.

- Burning in a clamp or Pazawah known as clamp burning
- Burning in a flame kiln or Bhatta known as kiln burning

In clamps, one batch of green bricks is heaped along with firewood, coal etc. and sealed with clay. It is then fired slowly to intense heat which may take many days. Modern kilns, however, permanent structures consisting of many chambers. There are intermittent and continuous kilns. Moulded clay is stacked in the chambers. They are then slowly dried and burned to high temperature and cooled. One cycle of loading, drying, burning, cooling and emptying may take as much as two weeks. These processes are carried out intermittently in intermittent kilns and in cyclic order in continuous kilns.

Figure 2.6: burning of the clay bricks

2.9. Common defects in brickwork noticed at site

- The following are a few typical brickwork flaws that are discovered on building sites.
  • The bricks utilized were not up to the quality requirements outlined in the contract.
  • No tests were performed to determine the bricks' water absorption capacity and efflorescence level.
  • The bricks were not adequately submerged in water. A thin layer of water was applied to the brick pile. Inside, the bricks were dry.
  • The brick masonry's joints were thicker than what the contract specification called for.
  • Brickwork below ground level joints were not finished correctly because the contractor believed the joints would be hidden after the earth was filled back in.
- Brick bats were used as fillers and closers.
- Mortar was not mixed properly on a platform or in a machine.
- The brick layers were uneven and not truly horizontal.
- The brick work was not in plumb.
- The brick work was done in weaker mortar and not as per structural requirement.
- The brick courses on edge were not done where needed.
- Gaps existed between door frames/window frames and masonry.
- Heavy efflorescence was observed in the brickwork.
- The brick masonry in long partition walls was not done without reinforcement.
- The holes in the brick work which were left for supporting scaffolding were filled with dry bricks without proper mortar around it and superficially plastered which later became the source of dampness in the building (Collinson, J. 2013).

Figure 2.7: wastage of clay burnt bricks after burning them in clamp

2.10. Characteristics of Good Bricks

The qualities of good bricks are described below, which will assist you in determining whether the bricks are indeed of high quality.

• Color, size, and shape of the bricks should all match.

• When two sturdy bricks collide, a metal sound will be produced.

• If a good brick is dropped from a height of around one meter, it will not break.

Bricks should be submerged in water for a minimum of 12 hours, and their upper surface should be smooth and free of cracks (Collinson, J. 2013).

2.11. Cement

2.11.1. Cement history

Cementing materials have been an important part of history and were frequently employed in antiquity. The Greeks and Romans utilized lime manufactured by heating limestone and adding sand to make mortar, with coarser stones for concrete. The Egyptians used calcined gypsum as cement. When the Romans discovered that cement could be made to set underwater, they exploited this knowledge to build harbors. The settlement of Pozzuoli, next to Vesuvius, inspired the name "pozzolanic" cement, which was created by combining crushed volcanic ash with lime. Crushed brick or tile was employed in places like Britain where volcanic ash was hard to come by. The Romans were therefore probably the first to manipulate systematically the properties of cementitious materials for specific applications and situations (Elsen, R. 2010).

2.11.2. Properties of good cement

It is always desirable to use the best cement in construction. Therefore the properties of good cement must be investigated. Although desirable cement properties may depend on the type of construction generally good cement possess following properties [which depend up on it chemical thoroughness of burning and fineness of grinding].

- Provides strength to masonry.
- Stiffness or hardness early.
- Possesses good plasticity.
- An excellent building material.
- Easy workable.
- Good moisture resistant.

Proper field tests and laboratory test should be done to ensure the qualities of the cement.

2.11.3. Field test of cement

It is necessary to check the quality of cement on site at the time of preliminary inspection. It is not possible to check all the engineering qualities of cement on site but there exist some field test which gives us a rough idea of quality of cement. These field tests are as follows:

- **Date of manufacturing**: as the strength of cement reduces with ages, the date of manufacturing of cement bags should be checked.
- **Cement color**: the color of cement should be uniform. it should be typical cement color i.e. grey color with a light greenish shade.
- **Whether hard lumps are formed**: cement should be free from hard lumps are formed by the absorption of moisture from the atmosphere.
- **Temperature inside cement bag**: if the hand is plunged into a bag of cement, it should be cool, inside the cement bag. If hydration reaction takes place inside the bag, it will become warm.
- **Smoothness test**: when cement is touched or rubbed in between fingers, it should give smooth feeling. If it felt rough, it indicates adulteration with sand.
- **Water sinking test**: if a small quantity of cement is thrown to the water, it should float sometimes before finally sinking.
- **Smell of cement paste**: A thin paste of cement with water should feel sticky between the

fingers. If the cement contains too much pounded clay and silt as an adulterant. The paste will give an earthy smell.

- **Glass plate test**: a thick paste of cement with water is made on a piece of glass plate and it kept under water for 24 hours. It should set and not crack (Elsen, R. 2010)

2.11.4. Types of cement, its composition and use

The following are the types of cement that are in practice.

- Rapid hardening cement.
- Quick setting cement.
- Low heat cement.
- Sulfate resisting cement.
- Blast furnace slag cement.
- High alumina cement.
- White cement.
- Colored cement.
- Pozzolanic cement.
- Air entraining cement.
- Hydrographic cement.

Table 2.4: Different types of cement, their composition and use

Types of cement	**Composition**	**Purpose**
Rapid hardening	Increased lime content	Strength in early days it is used in concrete where formwork are removed at early stage
Quick setting cement	Small percentage of aluminiumsulphate as an acceleration and reducing percentage of gypsum with fine grinding	Used in world is to be completed in very short period and concreting in static and running water
Low heating cement	Manufactured by reducing tri-calcium aluminate	It is used in massive construction like gravity dams
Sulphate resisting cement	It is prepared by maintaining the percentage of tricalcium	It is used in construction exposed to severe sulphate

	aluminate below 6% which increase power against sulphate	action by water and sand in place like canals lining culvert, retaining walls, siphoetc.
Blast furnace slag cement	It is obtained by grinding the clinkers with about 60% slag and resembles more or less in properties of Portland cement	It can use for work economic consideration is predominant
High alumina cement	It is obtained by melting mixture of bauxite and lime and grinding with the clinker it is rapid hardening cement with initial and final setting time of about 3.5 and 5 hours respectively.	It is used in work when concrete is subject to high temperature, frost and acidication.
White cement	It is prepared from raw materials free from Iron oxide	It is more costly and is used for architectural purposes such as pre-cast curtain wall and facing panels, terrazzo surface etc…
Colored cement	It is produced by mixing mineral pigments with ordinary cement.	They are widely used for decoration works in floor.
Pozzolanic cement	It is prepared by grinding pozzolanic clinker with Portland cement.	It is used in marine structures, sewage works, sewage works and for laying concrete under water such as bridges, piers, dams etc…
Air entraining cement	It is produced by adding indigenous air entraining agents such as resins, glues, sodium, salt of sulfate etc… during the grinding of clinkers	These types of cement are especially suited to improve the workability with smaller water cement ratio and to

		improve from resistance of concrete.
Hydrographic cement	It is prepared by mixing water repelling chemical.	This cement has high workability and strength.

2.12. Sand

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size being finer than gravel and coarse than silt. Sand can also refer to as textural class of soil or soil types, i.e. a soil containing more than 85% sand size.

The composition of sand varies depending on the local rock sources and conditions, but the most common constituent of sand is in land continental settings and non-tropical coastal settings is silica (silicon dioxide or SiO_2) usually in the form of quartz (Koirala, M. P., & Joshi, E. B. R. 2017).

The second most common type of sand is Calcium Carbonate, for example aragonite, which has mostly been created over the past half billion years. By various form of life like coral and shell fish. It is for example; the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years like the Caribbean (Elsen, R. 2010)

Sand is an extremely needful material for the construction but this important material must be purchased with all care and vigilance. Sand which is used in the construction purpose must be clean, free from waste stones and impurities. It is important to know what type of sand is beneficial for construction purpose as sand is also classified into three different forms that make it suitable for specific type of construction.

Sand is classified as: Fine Sand (0.075 to 0.425 mm), Medium Sand (0.425 to 2 mm) and Coarse Sand (2.0 to4.75 mm). However this classification of sand is further has types of sand in particular and on that basis only they are being incorporated in the construction. Read out the detailing of the types of sand:

2.12.1. Pit sand

Pit sand is classified under coarse sand which is also called badarpur in common language. This type of coarse sand is procured from deep pits of abundant supply and it is generally in red-orange color. The coarse grain is sharp, angular and certainly free from salts etc. which is mostly employed in concreting (Koirala, M. P., & Joshi, E. B. R. 2017).

2.12.2. River sand

River sand is procured from river streams and banks and is fine in quality unlike pit sand. This type of sand has rounded grains generally in white-grey color. River sand has many uses in the construction purpose such as plastering.

2.12.3. Sea sand

As the name suggest, sea sand is taken from seas shores and it is generally in distinct brown color with fine circular grains. Sea sand is avoided for the purpose construction of concrete structure and in engineering techniques because it contains salt which tends to absorb moisture from atmosphere and brings dampness. Eventually cement also loses its action when mixed with sea sand that is why it is only used for the local purpose instead of structural construction.

There are different standards for the construction purpose which must be checked and considered for the better construction. The requirement according to which sand is chosen should be like:

- For plastering purpose, the overall fine sand used must not be less than 1.5 while silt is preferred to not less than 4 percent.
- For brick work fine sand used must not be less than 1.2 to 1.5 and silt is preferred is 4 percent generally.
- Concreting work require coarse sand in modulus of 2.5 to 3.5 with not less than 4 percent silt content (Koirala, M. P., & Joshi, E. B. R. 2017).

2.12. 4.Uses of sand

•**Agriculture**: sandy soils are ideal for crops such as water melons, peaches and peanuts and their excellent drainage characteristics make them suitable for intensive dairy farming.

•**Aquaria**: sand makes low cost aquarium base materials which some believe is better than gravel for home use. it is also a necessity for salt water reef tanks which emulate environments composed largely of aragonite sand broken down from coral and shell fish

•**Beach nourishment**: Governments move sand to beaches where tides, storms or deliberate changes to the shoreline erode the original sand.

•**Brick**: manufacturing plants add sand to a mixture of clay and other materials for manufacturing bricks.

•**Cob**: coarse sand makes up as much as 75% of cob.

•**Concrete**: sand is often a principal component of this critical construction material.

•**Glass**: sand is the principal component in common glass

•**Hydraulic fracturing**: a drilling technique for natural gas which uses rounded silica sand as a propant, a material to hold open cracks that are caused by the hydraulic fracturing process.

•**Landscaping**: sand makes small hills and slopes (golf courses would be an example).

•**Mortar**: sand is mixed with masonry cement or Portland cement and lime to be used in masonry construction.

•**Paint**: mixing sand with paint procedures a textured finish for walls and ceilings or non-slip floor surfaces.

•**Rail road's**: engine drivers and rail transit operators use sand to improve the traction of wheels on the rails.

•**Recreation**: playing with sand is a favorite beach time activity. One of the most beloved uses of sand to makes sometimes simple structures known as sand castles. Such structures are well known for their impermanence. Sand is also used in children's play. Especial play areas enclosing a significant area of sand, known as sandboxes, are common on many public playgrounds and even at some single family homes.

•**Roads**: sand improves traction (and thus traffic safety) in snowy conditions.

•**Sand animation**: performances artists draw images in sand. Makers of animated files use the same term to describe their use of sand on front lit or backlit glass (Koirala, M. P., & Joshi, E. B. R. 2017).

•**Sand casting**: casters moisten or oil molding sand also known as foundry sand then shapes it molds into which they pour molten material. This type of sand must be able to withstand high temperatures and pressure, allow gases to escape, have a uniform, small grain size and be non- reactive with metals.

•**Sand bags**: these protect against floods and gunfire. The inexpensive bags are easy to transport when empty and unskilled volunteers can quickly fill them with local sand in emergencies.

•**Sand blasting**: graded sand serves as an abrasive in cleaning, preparing and polishing.

•**Thermal weapon**: while not in widespread use anymore, sand used to be heated and poured on invading troops in the classical and medieval time periods (Koirala, M. P., & Joshi, E. B. R. 2017).

•**Water filtration**: media filters use sand for filtering water**.**

2.12.5. How to check quality of sand in field

There are some field tests that can be carried out in the field in order to check the quality of sand used for construction. Following tests may be carried out to ascertain the properties of sand:

2.12. 6.Field Test on Sand

- Take a glass of water and add some quantity of sand in it. Then shake it vigorously and allow it to settle. If clay is present in sand, it will form a distinct layer at the top of sand.

- In order to detect presence of organic impurities in sand, add sand to the solution of sodium hydroxide or caustic soda and then stir it. If colour of solution changes to brown, it indicates the presence of organic impurities.
- Take a pinch of sand and taste it. If tasted salty then there exist some salt in sand.
- Take sand and rub it against the fingers. If fingers are stained, it indicates that sand contains earthy matter.
- The colour of sand will indicate the purity of sand. The size and sharpness of grains may be examined by touching and observing visually.
- For knowing fineness, durability, void ratio, etc; the sand should be examined by mechanical analysis (Koirala, M. P., & Joshi, E. B. R. 2017).

2.13. Sand-cement brick

Sand-cement bricks are made from cement and sand that is poured into forms, compressed, and air cured. Sand can be formed into all sorts of shapes and sizes and pigmented in a wide range of colors.

2.13.1. Advantages of sand-cement brick

Figure 2.8: sand-cement bricks

- **More Choice:** sand offers far more design and color options than brick. If you can imagine it, you can make it happen with sand-cement brick**.**
- **Innovation:** New and better sand-cement brick are being designed all the time, so you might even find choices that correct the known downsides of sand.
- **Easier to install:** Sand-cement brick are precisely uniform and easier to cut, so they're a popular choice.

2.13.2. Disadvantages of sand-cement brick

- **Color Can Fade:** Since they're dried with color pigments rather than natural clay, sand-cement brick can lose color over time, especially in sunny areas.
- **May Need Sealing:** Optional sealants can help prolong the color in sand-cement brick but add to maintenance.
- **Surface Erosion:** While brick tends to wear by chipping or cracking, sand wears more gradually, eroding away the smooth finish and exposing more of the aggregate underneath. Over time, the surface of sand-cement brick might look worn while brick stays retain their surface (Elsen, R. 2010)
- **Varying Quality: Sand-cement brick** varies widely in strength and durability depending on the manufacturer's recipe, and sometimes it's hard to know what kind of quality you're getting.

Table 2.5: Differences between sand-cement bricks and clay bricks*

Cement bricks	**Clay bricks**
Cement bricks are far simpler to manufacture: suitable sands together with cement are proportionately mixed together with wat.er, vibrated in a press, allowed to be cured for about 14-28 days and are then ready to be used. Total process time 15 to 30 days. Energy low and there is minimal pollution. Cement brick are then formed in a mould and allowed to be cure (preferably 28 days).	**Clay bricks** are made in a process that star with a suitable blend of days that have to be mined, aged, and then milled/mixed to even consistency. Clay is then extruded under a great pressure and sliced to a given size and shape. These unburnt bricks are dried out before being place in a kiln that is heated to between 700c and 1100c. Then after, when the firing process in complete, bricks need to be cooled and classified as to color and strength. The process is very energy intensive, generates a large amount of carbon dioxide, is quite difficult to control and takes up to 3 months to complete. If that was not all, the set-up cost of a reasonable factory is about 10 times that concrete for the square meter output.

Cement bricks are mainly used for walkways, patios and fill-ins on concrete walls. Clay ricks are used for building veneers, patios, walkways, retaining walls and more.	**Clay bricks** have a lower water absorption rates, higher strength (up to 5000psi vs. 1200-1800psi), have higher heat resistance, weather better, and hold their color better.
Cement bricks on the other hand tend to shrink about the same amount (partly curing and partly drying out) usually in the first 6 months after construction. So concrete masonry walls need contraction joints.	**Clay bricks** tend to expand after manufacture in the first few years of their life about 3mm to 5mm over 10 meters of wall length. So expansion joints need to be provided.
Cement bricks accept paint relatively well.	**Clay bricks** often exude metallic salts in their early years which cause to peel off.

2.14. Test and Methods

In this research compressive strength test was carried out on both clay burnt bricks and sand cement brick to compare

Figure 2.9: Compression Testing Machine

2.14.1. Compressive test

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension (being pulled apart). In the study of strength of materials, tensile strength, compressive strength, and shear strength can be analysed independently (Gordo, J. M., & Soares, C. G. 2008)

Compressive strength can be measured by plotting applied force against deformation in a testing machine, such as a universal testing machine.

Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures.

Compression test on clay burnt bricks

Preconditioning:

The following steps are to be done on all the specimens before they are

1. Measure the dimensions of the top surface (frog side) of the brick to the nearest 1 mm.
2. Remove any roughness observed on the bed faces (i.e., frog side and on the opposite side) by grinding (Gordo, J. M., & Soares, C. G. 2008)
3. Immerse the brick in water for a period of 24 hours. The specimen should be then removed and excess water is drained out at room temperature.
4. The frog portion and voids on the top surface if any has to be filled with cement mortar (1 cement,1 clean coarse sand of grade 3mm and down).
5. Store the brick under a damp jute bag for 24 hours. Following this immerse the brick in clean water for a period of 3 days. Remove and wipe out any traces of moisture in the brick

Figure 2.10: Frog portion of Brick filled with Cement Mortar

2.14.2. Required things:

You'll need following things for testing concrete compressive strength

- Ruler
- Paper
- Pen/Pencil

- Calculator
- Measuring tape
- Safety goggles
- Gloves
- Testing machine, and of course
- Concrete specimens(Cylinder/Cube) here it has been used sand-cement and clay brick

Figure 2.11: Compression test of a clay Brick specimen

Compression Test on sand cement bricks

Figure 2.12: Specimens of sand cement bricks

Age at test

Tests should be done at recognized ages of the test specimens, usually being 7 and 28 days. The ages should be calculated from the time of the addition of water to the drying of ingredients.

At least three specimens, preferably from different batches, should be taken for testing at each selected age. In the project five specimens were produced (Gordo, J. M., & Soares, C. G. 2008)

Compressive strength of sand cement bricks at various ages

The strength of sand cement bricks increases with age. Table below shows its strength at different ages in comparison with strength at 28 days after casting (Gordo, J. M., & Soares, C. G. 2008)

Table 2.6: Ages of sand cement bricks in comparison with strength

Age	**Strength per cent**
1 day	16%
3 days	40%
7 days	65%
14 days	90%
28 days	99%

2.14.3. Procedure of Compression Test

Step 1: Preparation: The specimens should be tested as soon as they are taken out of the water and while they are still wet. They should be treated in accordance with IS: 516 - 1959 and stored in water. Before being used for testing, specimens that are received dry should be submerged in water for 24 hours. Prior to testing, the specimens' weight and dimensions should be recorded to the closest 0.2 mm. Verify that everything you require is prepared. Verify that the compression machine is operational.

Step 2: Security : Put on safety goggles and hand gloves. Before the specimen surfaces come into contact with the compression platens, the bearing surfaces of the compression testing apparatus should be well cleaned and free of any loose sand or other debris (Gordo, 2008).

Step 3: Measuring the specimen: When measuring a cubic specimen, it is important to position it in the machine such that the load is supplied to the opposing sides of the cubes rather than the top and bottom. The axis of the specimen should be properly aligned with the center of thrust of the spherically seated platen. Between the test specimen's faces and the testing machine's steel platen, there shouldn't be any packing. To achieve uniform seating, the moveable piece should be gently moved by hand while the spherically seated block is brought to rest on the specimen. Measure the brick specimens that are being sent to the lab for analysis.

Calculate the cross sectional area (unit should be on mm^2) and put down on paper. Do the same for each specimen (Gordo, 2008)

Step 4: Turn on the machine: The load must be applied gently and increased steadily at a rate of around 140 kg/sq. cm/minute until the specimen's resistance to the rising load fails and no higher load can be maintained. After that, the specimen's maximum load should be noted, along with the concrete's appearance and any peculiarities in the failure type.
Step 5: Piston lowering By pressing the lever, lower the piston against the top of the brick specimen. Don't use load at this time. Simply put the piston such that it touches the brick specimen when it is on top of it.

Step 6: Applying load: The specimen is now positioned above the piston. Now is the moment to use load. Press the lever to lock it in place. Press the zero buttons on the display board to begin the compression test (Gordo, 2008).

Step 7: Increasing pressure: Set the piston's pressure to equal the brick compression strength rating by rotating the pressure-increasing valve counterclockwise. Don't shock the load by applying it gradually.

Step 8: The test is finished Look at the example brick. Once it starts to break, remove the load.

Step 9: Encoding Note the final load as it appears on the paper on the machine's display screen.

Step 10: Sanitize the apparatus: After the piston has returned to its original position, clean the machine's creaking brick.

Step 11 - Turning off machine: Match your record once again with the result on display screen. The result should still be on display screen. And then turn off the machine.

Step 12 - Calculate concrete compressive strength: The result we got from testing machine is the ultimate load to break the brick specimen. The load unit is generally in KN. We have to convert it in Newton (N). The purpose is, to know the brick compressive strength.

We know that compressive strength is equal to ultimate load divided by cross sectional area of brick specimen. We took the brick specimen's measurement before starting the testing and calculated cross sectional area (Gordo, 2008)

Now we got the ultimate load. So we can now calculate the brick compressive strength. Compressive strength = Ultimate load (N) / cross sectional area (mm^2). The unit of compressive strength will be N/mm^2.

Normally 3 samples of brick specimens are tested and average result is taken into consideration. If any of the specimen compressive strength result varies by more than 15% of average result, that result is rejected (Gordo, 2008)

Compressive Strength:

Compressive strength of the brick is calculated in the following way.

$$\text{Compressive Strength (in N/mm2)} = \frac{\text{Maximum load at Failure (in N)}}{\text{Average area of Bed faces (in mm2)}}$$

The averages of the 5 specimens have to be reported as the compressive strength of the bricks in the lot.

CHAPTER 3. MATERIALS AND METHODS

3.1. Introduction

The research methodology is necessary in directing the researcher to achieve the objectives and the aim of the study. This chapter was explained the methodology procedure to make sure that the information obtained for this study was been related and capable of study on the use of burnt brick via sand-cement brick. The necessary information for the analysis could not be found from the literature review. Hence data collection was been carried out by using observations and oral interviews.

The approach that have been used in this study in data collection to obtain relevant information:

- The oral interviews were designed and distributed to the difference respondents who were engaged in clay bricks making company.
- The oral interviews were designed and distributed to the difference respondents who were engaged in land use in construction.
- We also met with some engineers and site managers on field and in offices and gave us some information related to the study.

Through this project the following are the methods used to come up with tangible information.

3.2. Materials and methods

a. Tests to be done on bricks

- ➢ Burnt clay brick compression test (laboratory test)
- ➢ Unburnt clay brick compression test (laboratory test)
- ➢ Sand-cement bricks compression test (laboratory test)

b. Proposed data

The data will be collected on the field research by using different tools. Those tools will be kept, managed and analyzed in order to get a good research which will help us in the final year project.

3.3. Procedures followed in the project.

- ➢ Here are the procedures that are supposed to be followed in this project:
  - Project study (site visits).
  - Collection of materials and data.
  - Quantifying of different ratios.
  - Mixing of materials.
  - Molding and finishing.

- Burning of clay bricks.
- Curing for sand-cement bricks.
- Tests (laboratory test).

➢ Steps to be covered

- Conception of sand-cement bricks and measurements collection.
- Preparation of mold.
- Materials, tools, equipment and their collection.
- Mixing of materials.
- Molding and finishing.
- Testing of burnt bricks and sand-cement bricks.

3.3.1. Conception of sand-cement and measurements collection

Those sand-cement and clay bricks which can be used in construction are concepted so that they can be fabricated to be involved in building construction.

The measurements of sand-cement bricks are shown on the following figure and are taken by using photo camera.

3.3.2. Preparation of mold

The preparation of mould to be used in the final year project of manufacturing of sand-cement bricks made in form of 6cm thick and is made based on the measurements of needed bricks according to the building construction.

3.3.3. Colleton of materials, tools and equipment

➢ Materials used for mould fabrication:

- Sheet metals of 2mm thick.
- Welding wire grade (electrode).

➢ Tools and equipment used:

- Welding machine.
- Cutting metals, hammer, square and rule.
- Shearing machine.

3.3.4. Materials, equipment, tools and their collection of aggregates

The aggregates were needed in this project are fine gravel and sand. Those fine gravel aggregates are crushed stones. Sand is one of which was quarried from river (river sand). Sand is known as suitable material in construction because it is free from dipterous materials and has a wide impact on compression strength of such bricks (sand-cement bricks). The fine gravel sand was collected from the deposit which was on site of manufacturing and classified by using sieve analysis in soil laboratory as follows:

3.3.5. Quantifying with different ratio

Here we look for cost information for burnt bricks and we found in chosen area study (Muhanga district, Nyamabuye and Shyogwe Sector that the cost of burnt bricks is on 40 frs /one piece and we try to make a sand cement that the cost of it will be the same as that one so after test we will get which one is best.

3.3.6. Mixing of materials

When making sand-cement, it is the same way as making plain concrete and it's important to use the correct concrete mix ratios to produce a strong durable concrete mix to make sand-cement, there are 3 basic materials we use and these are Portland cement, sand, and water. The ratio of sand to cement is important factor in determining the compressive strength of the concrete mixtures.

Figure 3.1: Kayumbu sand which mostly used in sand-cement bricks making

Mixing of water with cement, sand will form a paste that will bind the materials together till the mixed shape hardens. The strength properties if the concrete are inversely proportional to the water. Accurate concrete mix ratio is achieved by measuring the mix ratios that will have a consistent of concrete mix throughout the entire project.

3.3.7. Moulding and finishing

During this process, we put a mix into mould and compact it. When sand-cement bricks are moulded, and removed from mould for staying sand-cement bricks down. The finishing was made by filling and smoothing of the upper surface of bricks.

Figure 3.2: Compaction of paste in mould

3.3.8. Curing of moulded bricks

Water curing is done by spraying or sprinkling water over the bricks surfaces to ensure that the bricks surface remains continuously moist. This prevents the moisture from the body of sand-cement bricks from evaporating and contributes to the strength gain of sand-cement brick.

3.4. Sand-cement bricks test

For determining the strength of manufactured brick, we use compression test for checking the strength of bricks is vital analysis Civil engineering design. We could be very sure about strength and worthiness of basic building until such as burnt brick and sand-cement brick.

3.5. Research strategy

A study conducted by Naoun (1998) defined the research strategy as the way in which the research objectives can be questioned. Two types of research strategies are used at studies, quantitative and qualitative research. According to Fellows and Liu (1997), Quantitative approach is used to gather factual data and to study relationship between facts and how such facts and relationships accord with theories and the findings of any research executed previously, but the qualitative approach seek to gain insights and to understand people's perception of "the world" whether as individuals or groups. The following strategies will be taken in order to achieve the objectives of the final year project proposal

i. Oral interviews to the sand-cement manufacturing company (NPD COTRACO)

ii. Oral interviews to the clay brick manufacturing company (EXACO Exact Contractors)
iii. The laboratory test
iv. Testing on different materials used as cement, sand and water absorption for determining their behavior and properties

3.6. Interview

An interview is a conversation between two or more people where questions are asked by the interviewer to elicit facts or statements from the interview. In this research we used interview as matter or as the method of collection of data by asking citizens why the use of sand cement brick is less than use of sand cement bricks in construction especially in elevation of walls construction.

3.7. Documentation

Documentation is a set of documents provided on paper, online, on digital or on analogy media. This method was used to be documented or to retrieve information from and citizen who related with EGECOR construction Ltd and NPD Ltd

3.8. Observation

For the completion of this project, observation has made because it simultaneously combines interviewing of respondents and informants, sharing intimately participation in the activities that are operated where the researcher collects data as possible as observed settings, introspection and intervention. This was done in order to develop an insider's view of what is happening but feel what is necessary to be.

This involved first-hand experience of the activities that are carried out at the place of study. This method was used for looking the use of sand-cement brick for construction and quality, cost and good strength of sand –cement brick during construction stage.

CHAPTER 4.RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter describes the data which are found from test of sand cement bricks we vie made and sample of burnt bricks we take in manufacturing company EXACO as we have taken the samples order to fit our purpose of the research, and this chapter also analysis those data depending on the properties which are needed to be discovered and gives detailed results.

Therefore, after finding results of each sample there is a comparison of analyzed data and we need to show and to clarify the difference hidden behind. And found out which one between sand cement and burnt brick can be chosen as better

4.2. Compressive strength of sand-cement brick and burnt brick

The results were obtained after conducting laboratory test on concrete specimen. The results are related to the impact and important of different bricks due to the compressive strength of those different types of bricks. The compressive strength of sand-cement brick or clay bricks are obtained from crushing of cubes (such as those which is sand-cement brick or burnt brick).

4.3. Compressive test on unburnt clay brick

- Sample size (210×100×60) mm for 3 pieces
- Compressive test for unburnt clay brick.

Table 4.1: Compressive test on unburnt brick.

Weight in kg	**Section in mm^2**	**Volume in dm^3**	**Density in kg/dm^3**	**Force in N**	**Strength in N/mm^2**	**Average strength**
2.003	21000	1.26	1.589683	160000	7.619048	**7.78413**
1.878	21000	1.26	1.490476	172400	8.209524	
2.001	21000	1.26	1.588095	158000	7.52381	

- Sample size (210×100×60) mm for 3 pieces
- Compressive test for dry burnt clay brick.

Table 4.2: Compressive test on burnt bricks.

Weight in kg	**Section in mm^2**	**Volume in dm^3**	**Density in kg/dm^3**	**Force in N**	**Strength in N/mm^2**	**Average strength**
1.581	21000	1.26	1.254762	370100	17.62381	**21.6524**
1.762	21000	1.26	1.398413	405500	19.30952	
1.865	21000	1.26	1.480159	588500	28.02381	

4.4. Compressive test on sand-cement brick

- ✓ Sample size (210×100×60) mm for 3 pieces

Table 4.3: Compressive test on dry sand-cement brick (made by hand)

Ages	**weight in kg**	**section in mm^2**	**volume in dm^3**	**density in kg/dm^3**	**force in N**	**strength in N/mm^2**	**average strength**
28	2.628	21000	1.26	2.085714	386000	18.38095	**18.3968**
	2.735	21000	1.26	2.170635	389000	18.52381	
	2.75	21000	1.26	2.18254	384000	18.28571	

Table 4.4: Compressive test on dry sand-cement brick (compressed by machine)

Ages	**weight in kg**	**section in mm^2**	**volume in dm^3**	**density in kg/dm^3**	**force in N**	**strength in N/mm^2**	**average strength**
28	2.486	21000	1.26	1.973016	851000	40.52381	**38.0429**
	2.584	21000	1.26	2.050794	753300	35.87143	
	2.623	21000	1.26	2.081746	792400	37.73333	

4.5. Compressive strength chart results

Compressive strength chart results for unburnt brick

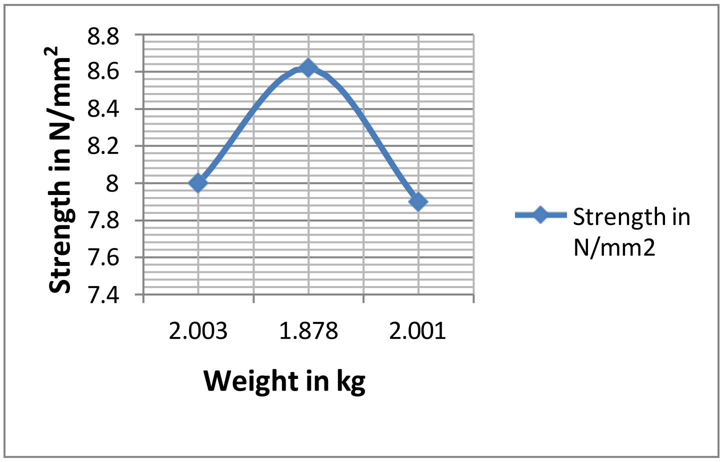

Figure 4.1: The average results of compressive strength for unburnt brick.

Compressive strength chart results for burnt brick

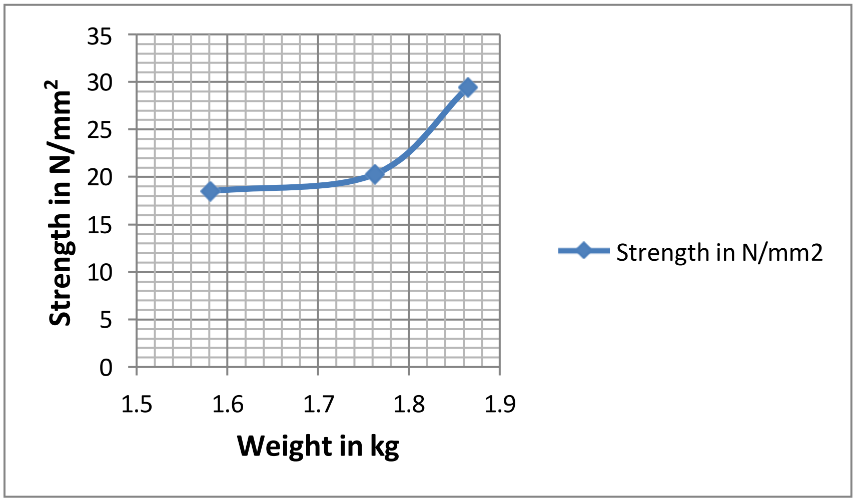

Figure 4.2: The average results of compressive strength for burnt brick.

Compressive strength chart results for dry sand-cement brick (made by hand)

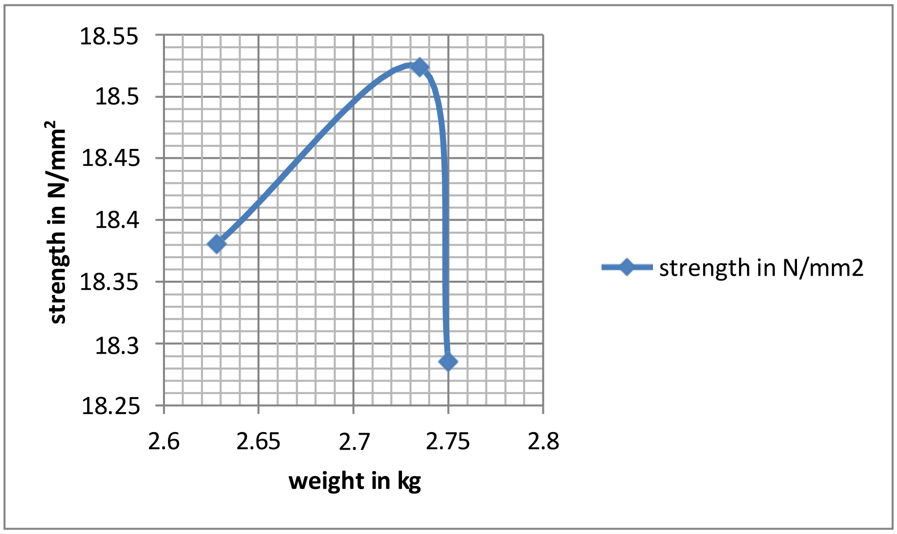

Figure 4.3: The average results of compressive strength for sand-cement brick made by hand.

Compressive strength chart results for dry sand-cement brick (compressed by machine)

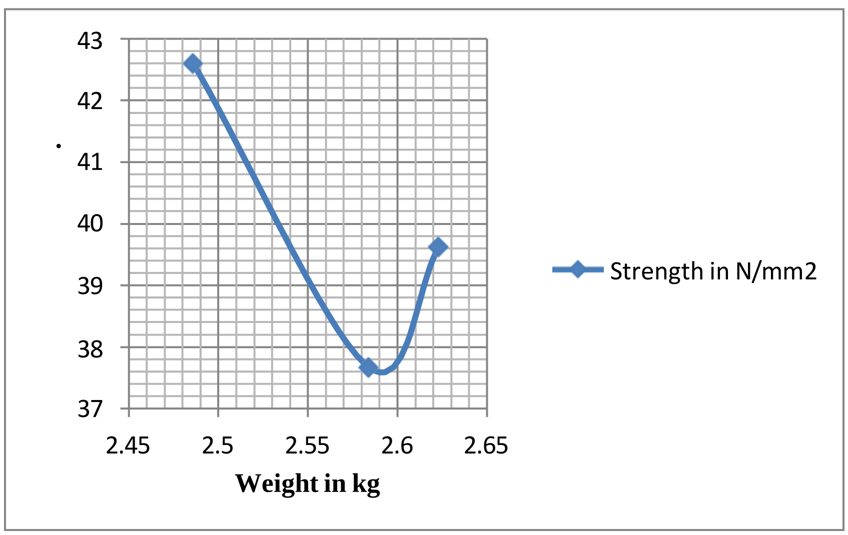

Figure 4.4: The average results of compressive strength for sand-cement brick compressed by machine.

4.6. Cost estimate

4.6.1. A wall of clay bricks

Let's assume a wall of clay brick of 20m length, 3m height and 20cm of thickness. The size of a brick to be used is assumed to be (**210×100×60**) mm.

- **Determination of number bricks**
  - Area of wall: 3m×20m= 60m^2
  - Area of 1 brick: (21×6) cm^2= 126cm^2

- Assumed thickness of wall 21cm

➢ **Horizontal joint**

- N° of horizontal joint= N° of brick layers.
- N° joint: $\frac{3000}{(60+10)}$ = 43 brick layers
- Area of 1 horizontal joint: (20000×10) mm^2= 200000mm^2
- Total area of horizontal joints: 43×200000= 8600000mm^2

➢ **Vertical joints**

- N° of vertical joint per bricklayer: $\{\frac{20000}{(210+10)}\}$-1 = 92 joints
- Total number of vertical joint: 92×43= 3956 joints
- Area of 1 vertical joint: 10×60= 600mm^2
- Total area of vertical joints: 600×3956= 2347800 mm^2
- Total number of joints: 43+92= 135 joints
- Total area of joints: = 2347800+8600000= 10947800mm^2
- Area of all bricks: 60000000-10947800= 49052200mm^2
- Number of bricks: $\frac{49052200}{12000}$= 3894×2= 7788 bricks
- 5% of wastage= $\frac{7788\times5}{100}$= 390 bricks
- Total number: 7788+390= 8170 bricks

➢ **Determination of quantities of materials in cement mortar for joint (ratio 1:4)**

- **Cement**: $\{\frac{1\times2.0}{4\times50}\}$ ×1000= 10 bags of cement
- **Sand**: $\frac{4\times2.0}{4}$ = 2m^3

➢ **Determination of number of trucks and their cost**

✓ **Capacity or quantity of trucks**

- If one truck of 5m^3 transports 5000 bricks
- 8170 bricks will be transported by: $\frac{8170}{5000}$ = 1.6 trucks
- 1.6 trucks are 1 trucks of 5m^3 and 1 truck of 3m^3
- If 1 truck of 5m^3 cost 70000Frw per 50 km
- Then 1 truck per 1km will be: $\frac{70000Frw}{50}$ = 1400Frw
- 1 trucks of 5m^3 will be: 1400Frw per 1km

- And 1 truck of 3m^3 will also be: $\frac{70000\times3}{5}$ = 42000Frw
- Total of trucks is now: (70000Frw+42000Frw = 112000Frw per 50km

➢ **Man power**

- ❖ If one mason build 500 bricks per 1 day
- ❖ 8170 bricks will be built by: $\frac{8170}{500}$ = 17 masons per day
- ❖ If 17 masons build 8170 bricks per day,
- ❖ 8170 bricks will be built by: $\frac{17}{2}$ = 9 masons in 2 days
- ❖ 5 masons will need a help of 5 labors

✓ **If one brick cost 40Frw**

- ▪ 1 truck of 5m^3: 40Frw×5000 = 200000Frw
- ▪ 1 truck of 5m^3 with transport: 200000Frw+70000Frw= 270000Frw
- ▪ 1 trucks of 3m^3: 40Frw×3000 = 120000Frw
- ▪ 1 truck of 1m^3 with transport: 120000Frw+42000Frw = 164000Frw

✓ **Total cost of bricks**: 270000Frw+164000Frw = 434000Frw.

Table 4.5: The results of total cost of clay brick wall.

Item N^o	**Description of items**	**Unity**	**Quantity**	**Days**	**Price/unity in Frw**	**Total cost in Frw**
I	**BRICKS**					
I.1.	**Bricks of wall**	1	7780	-	40	311200
I.2.	**Wastages**	1	390	-	40	15600
I.3.	**Total cost**	1	8170	-	40	**326800**
II	**SAND AND CEMENT**					
II.1.	**Cement**	Bag	10	-	10000	100000
II.2.	**Sand**	m^3	1	-	60000	60000
II.3.	**Coarse**	m^3	1	-	60000	60000
II.4.	**Total cost**					**220000**
III.	**MAN POWER**					
III.1.	**Masons**	Day	5	2	5000	50000
III.2.	**Labors**	Day	5	2	2500	25000

III.3.	**Total cost**					**75000**
IV	**TRANSPORT OF BRICKS**					
IV.1.	**Transport of bricks**	1	1 trucks of 5m^3	1	70000	70000
IV.2.		1	1 truck of 3m^3	1	42000	42000
IV.3.	**Total cost**					**112000**
V	**TOTAL COST OF WALL**					**733800**

4.6.2. A wall of cement bricks

- **Determination of quantity of cement bricks**
  - Area of wall: 3×20=60m^2
  - Area of cement brick: 21×6=126cm^2
  - Volume of cement brick: 21×6×10=1260cm^2
  - The assumed thickness of wall is 21cm.
- **Horizontal joint**

Number of horizontal joint=Number of brick layers

- $\frac{3000}{(60+10)}$ =43 brick layers
- Area of one horizontal joint: 20m×0.01m= 0.2m^2
- Total area of horizontal joints: 43×0.2m^2= 8.6m^2
- N^o of vertical joint per bricklayer: { $\frac{20000}{(210+10)}$ }-1= 92 joints
- Total N^o of vertical joints: 92×43=3956 joints
- Area of one vertical joint: 0.001m×0.06= 0.0006m^2
- Total area of vertical joints: 0.0006×3956= 2.4m^2
- Total area of joints: 2.4+8.6= 11m^2
- Volume of joints: 11m^2×0.2m= 2.2m^3
- Area of all bricks: 60m^2-11m^2= 49m^2
- Number of bricks: $\frac{49}{(0,2\times0.06)}$ = 4084 bricks, for the thickness of 21mm, the total number of bricks will be 4084×2=8168 bricks.

- 5% of wastages= $\frac{8168\times5}{100}$ = 409 bricks.
- Total number of bricks= 8168+409=8577 bricks

➢ **Determination of quantity of cement, sand and fine aggregate needed in a fabrication of bricks**

- 1m^3 of wet concrete= 1.52 dry concrete material
- Specific weight of concrete 1440kg/m^3
- Volume of wall= 20×3×0.21=12.6m^3
- Total volume of cement bricks= 1260cm^3×8577= 10807020cm^3
- Ratio (1:2:4), 1bag of cement with 2 wheelbarrows of sand and 4 wheelbarrow of fine aggregate.
- Volume of wheelbarrow= 0.3m^3

➢ **Quantity and transport of sand**

- If one bag of cement gives 380 bricks,
- 8577 bricks will be given by: $\frac{8577}{380}$ = 23 bags

➢ **Quantity and transport of sand**

- If 1 wheelbarrow has 0.3m^3
- 2 wheelbarrows have 0.6m^3
- If 1 wheelbarrow of sand gives 190 bricks
- 5m^3 of sand are equal to 16 wheelbarrows: 16×190= 3040 bricks
- If 3648 bricks are carried by 16 wheelbarrows
- 8571 bricks will be carried by $\frac{16\times8577}{3040}$ = 45 wheelbarrows
- Then 45 wheelbarrows will have: 45×0.3=13.5m^3 of sand.
- Therefore, 8577 bricks will need 13.5m^3 of sand
- If 1 truck has 5m^3, 13.5m^3 will be contained by: $\frac{13.5}{5}$ = 2.7 trucks
- Then all 13.5m^3 of sand will need 3 trucks of 5m^3.

➢ **Quantity and transport of fine aggregate**

- If 1 wheelbarrow contains 0.3m^3
- 4 wheelbarrows of fine aggregate will contain: 0.3m^3×4= 1.2m^3
- If 1 wheelbarrow of fine aggregate is 95 bricks, 16 wheelbarrow 5m^3 16×95= 1520 bricks

- If 1520 bricks is 16 wheelbarrows: $\frac{16\times8577}{1520}$ = 90 wheelbarrows
- 1 wheelbarrow contains 0.3m^3
- 90 wheelbarrows: 90×0.3 = 27m^3×2= 54m^3 of fine aggregate.
- If 1 truck contains 5m^3
- Then 54 are11 trucks
- Therefore, all 54m^3 of fine aggregate will need 11 trucks of 5m^3

➢ **Determination of quantity of materials in cement mortar for joint, Ratio (1:4)**

- **Cement**: $\{\frac{1\times2.206}{4\times50}\}$ ×1000= 11 bags
- **Sand**: $\frac{4\times2.2}{4}$ = 2.2m^3

➢ **Total quantity of materials**

- Total quantity of cement= 11 bags+23bags= 34bags
- Total quantity of sand= 2.2m^3+13.5m^3= 15.7m^3
- Total quantity of fine aggregate= 54m^3
- If 1 trucks is 5m^3
- Then $\frac{15.7}{5}$ = 3.14 trucks
- 3 trucks of 5m^3 and 1 trucks of 3m^3
- And $\frac{54}{5}$ = 10.8 trucks
- 10 trucks of 5m^3 and 1 truck of 3m^3.

➢ **Man power**

- If one mason build 950 bricks per days,
- 8577 bricks will be built by $\frac{8577}{950}$ = 9 masons per day
- If 9 masons build 8577 bricks per day,
- 5 masons will build 8577 bricks in $\frac{9}{5}$ = 2 days
- Then 5 masons will need the help of 5 labors, 1 for each mason.

- **Result of total cost of sand-cement bricks**

Table 4.6: The results of total cost of cement bricks wall (bricks are manufactured at the site)

Item No	Description of items	Unity	Quantity	Days	Price/unity in Frw	Total cost in Frw
I	**CEMENT,SAND AND FINE AGGREAGATE**					
I.1.	**Cement**	Bag	34	1	10000	340000
I.2.	**Sand**	Truck of $5m^3$	2	1	70000	140000
I.3.	**Fine aggregate**	Truck of $5m^3$	10	1	70000	700000
I.4.	**Water**	L	3000	-	50	150000
I.5.	**Total cost**					**1330000**
II	**MAN POWER**					
II.1.	**Masons**	Day	5	2	5000	50000
II.2.	**Labors**	Day	5	2	2500	25000
II.3.	**Labors for making bricks**	Day	4	1	3000	12000
II.4.	**Total cost**					**87000**
III	**TOTAL COST**					
III.1.	**Cement**					340000
III.2.	**Sand**					140000
III.3.	**Fine aggregate**					700000
III.4.	**Hand works**					87000
IV	**TOTAL COST**					**1267000**

- **Cost of brick wall with cement bricks with bricks from manufacturing company.**
  - Cost of bricks: 8577×300= 2573100Frw
  - Transport of bricks, 1 truck of $10m^3$: 3000Frw/km
  - Transport of sand and cement, truck of $5m^3$ 1400Frw/km
  - Sand in mortar: $2.2m^3$ cost 42000Frw
  - Cement in mortar: 11 bags cost 10000Frw each bag

- **Man powers**
  - If one mason build 950 bricks per day
  - 8571 bricks will be built by: $\frac{8577}{950}$ = 9 masons per day
  - 5 masons will build then $\frac{9}{5}$ = 2 days and will be paid 50000Frw
  - 5 masons will work with the help of 5 labors and they will be paid 25000Fr

Table 4.7: The results of total cost of cement bricks wall (bricks are delivered to the site from cement bricks manufacturing.)

Item No	Description of items	Unity	Quantity	Days	Price/unity in Rwf	Total cost in Rwf
I.	**Cement bricks**	m3	8577	1	300	**2573100**
II.	**Cement**	Bag	11	1	10000	**110000**
III.	**Sand**	m3	3	1	42000	**126000**
IV.	**Masons**	Day	5	2	5000	**50000**
V.	**Labors**	Day	5	2	2500	**25000**
VI.	**Water**	-	150	-	50	**7500**
VII.	**TOTAL COST**					**2891600**

CHAPTER 5.CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The general objective of the project is the comparative study on the use of burnt and sand-cement bricks for the affordable house in Rwanda. Sand-cement bricks are made from sand, cement, fine aggregates and water and clay bricks are made from clay (sometime clay is mixed with lime) that could economically be affordable in construction.

In observing this study, sand-cement bricks have strength and resistance to the compression, not only depending on the mix ratio but also to compaction of wet bricks and curing of dry brick during mixing, molding and placing.

All samples are tested and can be used as structural construction materials with the best one ratio of 1:2:4 by considering the test results done by compression test method and mixing ratio is economically.

The study came up finally with that clay bricks strengthen and resist the compression strength less than sand-cement bricks in resistance of load applied on the brick, but sand-cement bricks are higher in price (cost) more than clay burnt bricks.

Therefore, depending on cost, strength, quality and affordability of the house, we advise clients to take reference on the report while choosing the suitable bricks because this report provides sufficient information.

5.2. Recommendations

At the completion of this project, recommendations are as follow:

- ✓ It is recommended all construction companies that they should apply the main stages and stated to use sand-cement bricks than clay bricks because although sand-cement bricks are highly cost but they have a good strength. They have also many advantages more than clay bricks such as being easy to construct, easy to transport them from one place to another, no wastage at all, affordable and they correspond positively to the construction market and comparing those different bricks. Sand-cement bricks have ability to resist and other possibility to make safe construction.
- ✓ It is recommended to all clients that they should control their construction activities to check whether the procedures applied in selecting the perfect bricks are followed.

REFERENCES

Ahmed, A. M., & Rashid, M. I. (2019). Properties of bricks and their applications in construction. Journal of Building Materials, 5(2), 55-67. https://doi.org/10.1016/j.jbm.2019.04.005

Babu, S. V., & Krishnaiah, S. (2018). Manufacturing of eco-friendly brick: A critical review. International Journal of Computational Engineering Research, 8(2), 24-32.

Brick Industry Association. (2021). Applications and benefits of bricks in construction. Brick Industry Association Publications. https://www.gobrick.com

Burn, R. S. (Ed.). (2015). Masonry, bricklaying and plastering. Routledge.

Collinson, J. (2013). Brickwork and bricklaying: A DIY guide. Crowood.

Cultrone, G., Sebastián, E., Elert, K., De la Torre, M. J., Cazalla, O., & Rodriguez–Navarro, C. (2004). Influence of mineralogy and firing temperature on the porosity of bricks. Journal of the European Ceramic Society, 24(3), 547-564.

D'Orazio, M., Cursio, G., Graziani, L., Aquilanti, L., Osimani, A., Clementi, F., ... & Amoroso, S. (2014). Effects of water absorption and surface roughness on the bioreceptivity of ETICS compared to clay bricks. Building and Environment, 77, 20-28.

De Carvalho, M. H., Lucchesi, C. L., & Murty, U. S. (2006). How to build a brick. Discrete Mathematics, 306(19-20), 2383-2410.

Elsen, J., Mertens, G., & Snellings, R. (2010). Portland cement and other calcareous hydraulic binders: History, production and mineralogy.

Gordo, J. M., & Soares, C. G. (2008). Compressive tests on short continuous panels. Marine Structures, 21(2-3), 113-137.

Johnson, D. F. (2020). Advantages and limitations of clay bricks in modern construction. Construction Materials Journal, 9(4), 84-90. https://doi.org/10.1080/cmj.2020.09.004

Khaliq, W., & Bashir, M. F. (2016). High temperature mechanical and material properties of burnt masonry bricks. Materials and Structures, 49, 5195-5208.

Kostadinova-Avramova, M. (2019). Advantages and disadvantages of bricks as a material for archaeomagnetic study. Interdisciplinary Studies| Интердисциплинарни изследвания, 26.

Kumar, R., & Sharma, V. (2018). Classification and properties of bricks. International Journal of Civil Engineering, 6(3), 102-115. https://doi.org/10.1080/ijce.2018.03.007

Kumar, S. (2017). Manufacturing processes of bricks: From raw material to finished product. Journal of Construction Technology, 8(1), 12-25. https://doi.org/10.1016/j.constrtech.2017.01.002

Oti, J. E., Kinuthia, J. M., & Bai, J. J. E. G. (2009). Engineering properties of unfired clay masonry bricks. Engineering Geology, 107(3-4), 130-139.

Sarangapani, G., Venkatarama Reddy, B.V., & Jagadish, K.S.(2005). Brick-mortar bond and masonry compressive strength.Journal of Materials in Civil Engineering, 17(2), 229–237.

Sustainable Building Materials Group.(2019). Environmental impacts of burnt clay bricks and alternatives.International Journal of Sustainable Construction, 3(1), 45–59.

APPENDICES

Appendix

Appendix 1) Excavating clay for burnt brick manufacturing.

Appendix 2) Moulding

Appendix 3) Drying bricks before burning

Appendix 4) Storing bricks before burning

Appendix 5) Erecting kilns for bricks burning