USE OF LOCAL BREWERY WASTE AND BITTER CASSAVA FLOUR AS A PARTIAL REPLACEMENT OF CEMENT FOR PLASTERING ECO HOUSES

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Declaration

This thesis is my original work and has not been submitted to any other university for examination.

Signature……………………………..……Date..

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This thesis has been submitted for examination with my approval as the University Supervisor.

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Dedication

This thesis is dedicated to my late Uncle Mr. Okello Richard Anok (R.I.P) and parents Mr. Ekwang Charles and Mrs. Milly Grace Ekwang.

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Definition Of Terms

Pitti Pitti: Local name of local brewery waste

Waragi: Local name of the local brew

Enguli: Distilled local brew

Hwangtoh: A type of clay found in South Korea

MS-Req: Minimum Required Strength of plaster mortar for eco houses as per Kenyan standards

List of Abbreviations

ASTM	American Standard Testing Method
KS02-1070:1993	Minimum strength requirement for a stabilized block in Kenya
BS	British Standards
KS	Kenya Standards
P	Pitti Pitti
C	Bitter Cassava
G.H.G	Green House Gases
O.P.C	Ordinary Portland cement
C.K.D	Cement Kiln Dust

Abstract

Cement is a major construction material throughout the world. However, given the escalating costs of building materials and the environmental hazards associated with the use of cement there is need to use alternative, cost-effective, non-conventional, locally available materials, especially those that can partially or wholly replace cement. This study tested the possibility of local brewery waste and bitter cassava flour as a partial replacement for cement for plastering traditional eco-houses (earth-based) in Northern Uganda. The following were examined through standard laboratory procedures; physical and chemical properties, compressive strength, shrinkage test and durability or bonding test. The specimens were made with cement partially replaced by local brewery waste or bitter cassava of varying percentages ranging from 10-50% and tested at 7, 14 and 28 days.

The results obtained show that bitter cassava flour and local brewery waste reduces the cracking in plaster mortar. It is also determined that bitter cassava increases the shrinkage and the mixes containing only 40% and 50% bitter cassava cracked for mix ratios of 1:3 and 1:4, while local brewery waste reduces the shrinkage of the mortar and no crack was observed. The results also show that the compressive strength of the plaster mortar reduces as more cement is replaced with bitter cassava flour and local brewery waste. However, it is to be noted that the target minimum strength required is 2.5 MPa for mortar plaster for plastering earth-based walls. The results further reveal that for a mix ratio of 1:3 compressive strengths of 28.3 MPa is obtained for 0% bitter cassava flour, 21.9 MPa for 10% bitter cassava flour and 18.1 MPa for 20% bitter cassava flour. For a mix ratio 1:4 compressive strengths of 20.4 MPa is obtained for 0% bitter cassava flour, 17.5 MPa bitter

cassava flour for 10% bitter cassava flour and 13.8 MPa for 20% bitter cassava flour. For a mix ratio 1:6 compressive strengths 11.5 MPa for 0% bitter cassava flour is obtained, 8.5 MPa for 10% bitter cassava flour and 6.9 MPa for 20% bitter cassava flour. These strengths are above the minimum required compressive strength of earth stabilized block of 2.5 MPa according to Kenya Standards, 2.8 MPa according to BS and 2.0 MPa according to ASTM hence indicating the potential of using bitter cassava flour and local brewery waste in plaster mortar for traditional eco-houses.

CHAPTER 1

INTRODUCTION

1.1 Background

Cement is a major construction material throughout the world (Bentur 2002, Janotka and Mojumdar 2007). Given the escalating costs of building materials and the environmental hazards associated with the use of cement there is urgent need to source, develop and use alternative, cost-effective, non-conventional, locally available materials suitable for construction, especially those that can partially or wholly replace cement. The annual emission of greenhouse gases (GHG) from the production of ordinary Portland cement (OPC) is estimated to be nearly 1.35 billion tons globally, which constitute approximately 7% of the total green house gas emissions in the Earth's atmosphere. Furthermore, during the manufacturing of cement, a large amount of dust is generated and the huge embodied energy consumption by the plasticity temperature being over 1300 °C (Malhotra, 2002). More so the production of one tonne of cement also generates one tonne of carbon dioxide (Fernando and Said 2009).

Mehta (2002), reported that materials that use few natural resources, less energy, and minimize carbon dioxide emissions should be used to make environment-friendly concrete. Previously, (Raheem *et al*., 2012) investigated the use of saw dust as a replacement of cement and found out that the compressive strength was optimum at 5% replacement. Al-Jabri *et al* (2009) investigated the properties of hollow sandcrete blocks made from cement kiln dust as an additive and as a replacement for ordinary Portland cement. They observed that when cement kiln dust was used as a replacement for cement, the compressive strength and density of blocks generally decreased with higher replacement levels of cement. When cement kiln dust was used as an additive, an improvement in the compressive strength of up to 54% was observed and the cost of deposition of ceramic waste in landfill was saved. Ettu *et al*., (2013) investigated the compressive strengths of binary and ternary blended cement sandcrete and soilcrete blocks containing cassava waste ash and plantain leaf ash and found that the compressive strength of cement sandcrete and soilcrete blocks increased after 150 days of curing, as compared to the control mix with 10% cement replacement. Ogunbode and Akanmu (2012) tested the strengths of cassava ash blended cement in laterized concrete and found a 46% reduction in the compressive strength as cassava plantain ash is increased in the laterized concrete.

Kamudang (1997) a replacement (wholly or partially) of ordinary Portland cement of between 30-40% with by-product materials, such as fly-ash, blast-furnace slag, and condensed silica fumes, enhanced the mechanical properties of concrete. Using a termite hill as a partial replacement of cement, (Olusola *et al*., 2006) showed that the compressive strength reduces beyond 50% replacement whereas, (Faseyemei, 2012) found that cement replacement up to 10% with silica fume leads to an increase in the compressive strength of concrete.

Currently, almost 50% of the world's population lives in earth-based dwellings (Guillaud, 2008). Most of these earth constructions are found in the developing countries. In Northern Uganda, most of the houses in the villages are built with either sundried bricks or blocks lump mud and plastered with mud or rendered with cow dung slurry. Bitter cassava flour and local brewery waste is also used as a replacement of cement during plastering of traditional eco houses. Unfortunately, there is no documentation concerning the properties of bitter cassava and local brewery waste. This study examined the possibility of using bitter cassava and a local brewery waste locally known as pitti pitti as an environmentally friendly potential replacement of cement for plastering traditional eco houses in Northern Uganda.

1.2 Problem statement

Northern Uganda was faced with over 20 years of Lord's Resistance Army insurgency during which approximately 1.8 million people were displaced into internally displaced camps resulting into high levels of poverty. After their relocation back home, many people constructed traditional eco houses using sundried bricks and blocks due to the high costs of cement and protected the outer walls against damage from rain by applying mud plaster, made of soil or mud collected from village pond, rendering with cow dung slurry. Some people plaster their walls with bitter cassava flour and local brewery waste mixed with sand alone. These traditional methods are cheap and environmentally friendly but cannot withstand rains and other harsh weather conditions, with the result that they often get eroded, causing considerable damage to the house. In addition, eco houses plastered with cement sand plaster are damaged due to the poor bondage and high strength of cement sand plaster compared to the strength of the eco blocks or bricks and often peels off after a short time when plastered. Also, traditional eco houses plastered with cement sand plaster are air tight and thus very hot during the day especially during the dry season compared to those rendered with cow dung slurry. For these reasons there is need to develop an eco-friendly material for plastering traditional eco houses that bond well from a holistic approach of sustainability incorporating the socio-economic and environmental aspects. In this thesis the possibility of using bitter cassava and local brewery waste as a partial replacement for cement for plastering traditional eco constructed houses in northern Uganda was studied.

1.3 Overall Objective

To determine the feasibility of using bitter cassava flour and local brewery waste as a partial replacement of cement for plastering traditional eco houses in Northern Uganda.

1.4 Specific Objectives

1) To determine the physical and chemical properties of bitter cassava flour and local brewery waste.
2) To determine the compressive strength of different mortar mix made from bitter cassava flour and local brewery waste, hence determine mix ratios that meet the minimum compressive strength requirement of 2.5 MPa.
3) To evaluate shrinkage and bonding strengths of different mortar mix made from bitter cassava flour and local brewery waste.

1.5 Justification

Most houses in Northern Uganda are constructed using either lump mud or mud blocks and bricks. The majority of people who cannot afford to buy cement for plastering resort to use of mud plaster and rendering with cow dung slurry which is not resistant to rain. More so eco houses plastered with bitter cassava flour and local brewery waste showed a lot of cracks and often peels off after some time. Those plastered with cement are very hot due to the fact that mortar made from the cement sand is air tight and also with time it peels off.

Cassava is a popular and widely grown crop in tropical Africa (Nweke, 2002). It is a root and an annual tuber crop that grows well in all the agro-ecological zones of Uganda. According to the Ministry of Agriculture, Animal Industry and Fisheries report, 2011, Northern Uganda is the second largest producer of cassava in Uganda after Eastern Uganda. Its production is dominated by small holders growing between one to two acres, as a family enterprise, for daily food and cash.

The flour from cassava is used for the production of a local alcohol which is heavily consumed locally in this part of Uganda. During the production of this local brew, large amounts of wastes are produced which is usually poured away after the distillation process. This waste material comprises of 70% of the product distilled though it is biodegradable.

Cassava flour and local brewery waste have some bonding properties and thus could be employed as a partial or whole replacement of cement for plastering eco houses in the poverty ridden northern Uganda. Thus, there was need to study these two materials and perform various tests on their properties in the laboratory in order to explore their potential use as cheap, alternatives to cement for plastering mud houses. The intention is to produce a cost-effective, eco-friendly construction material as well as reduce the green-house gas emission.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Globally the building industry is responsible for high levels of pollution as a result of the energy consumed during extraction, processing and transportation of raw materials (Adalberth, 1996). This has attracted research globally on the use of alternative locally available materials which is environmentally friendly, minimizes the pollution and energy consumption for use in construction of buildings.

2.2 Theoretical review

2.2.1 Physical and chemical properties of cassava and other local materials

Saul (2006) investigated the physical and chemical properties of cassava powder and found out that it contains mainly carbohydrates of about 98.48% and others like Sodium (0.5%), Magnesium (0.05%), Aluminum (0.05%), Silicon (0.07%), Pottassium (0.88%), Calcium (0.06%) and has a bulk density of 1.32 g/cm^3. Ogunbode and Akanmu (2012) found that cassava peel ash powder has a specific gravity 3.04 and comprised principally of Silica (62.3%). In addition, it has cementitious compounds like calcium oxide, alumina and iron oxide (13.31%), and the total content of Silicon Dioxide (SiO_2), Aluminum Oxide (Al_2O_3) and Iron Oxide (Fe_2O_3) is 70.45%, slightly above the minimum of 70% specified in ASTM C618.

Faseyemei (2012) investigated micro silica (silica fume) as a partial cement replacement in concrete and indicated the chemical properties of micro silica as follows; Silicon Oxide 20.31% Aluminum oxide 34.81% Iron oxide 32.98% Calcium oxide 62.73% Magnesium oxide 2.97% Calcium oxide 3.09%. More so (Balwaik and Raut, 2011) tested the physical and chemical properties of paper pulp using energy X-ray fluorescence spectrometer and reported that it contains Silica 60.57%, Calcium 14.94% , Oxide 15.83%, Aluminum 6%, Magnesium 3.59% . Uodeyo *et al.,* (2006) examined the physical and chemical properties of a laterite as a partial or full replacement of cement and reported the Specific gravity 2.51 and Silica oxide 77.80%, Aluminum oxide 18.40%, Iron oxide 2.38% as chemical properties of laterite. Kula *et al.,* (2002) investigated the chemical properties of tincal ore waste, fly ash and coal bottom ash as Portland cement replacement materials and found out the following chemical properties Calcium oxide (65.49%), Silicon oxide (21.47%), Aluminum oxide (6.04%). Tincal waste contains Calcium oxide (16.94%), Silica oxide (17.11%) and Aluminum oxide (2.61%).

Ganesan *et al.,* (2007) during their study of the evaluation of bagasse ash as supplementary cementious materials reported the following physical properties; bagasse ash bulk density 590Kg/m^3, specific gravity 0.41 and chemical properties of bagasse ash Silica oxide 64.15%, Aluminum oxide 9.05%, Calcium oxide 8.14%, Iron oxide 5.52%. Yang *et al.,* (2006) reported the chemical properties in hwangtoh binder in their study of developing a cement-less mortar and found out that hangwoth binder has the two dominant chemical properties that is Silicon oxide 40%, Aluminum oxide 32.9% which forms a stable pozzolanic material by slow cohesion with $Ca(OH)_2$. Additionally they also found out that hangwoth binder also has some other chemical properties like iron oxide 7.8%, Magnesium oxide 1.5%, Calcium oxide 0.4% and Silica oxide 1.5%.

Al -Rawas *et al.,* (2004) performed chemical analysis to determine the silica, alumina, iron and calcium oxide contents in ash in their study of the use of the incinerator ash as a replacement of cement in cement mortars and reported that incinerator ash has an average of 49.95% silica, alumina and iron oxide while (Badejo, 2002) carried out chemical analysis of termite hill and reported that it has a higher concentration of Calcium and potassium.

2.2.2 Strengths of local materials as a partial replacement of cement

Ettu *et al*., (2013) tested the compressive strength of binary and ternary blended cement sandcrete and soilcrete blocks containing cassava waste ash and plantain leaf ash and found higher compressive strength than the control values beyond 90 days of hydration. Faseyemei (2012) reported that cement replacement of up to 10% with silica fume leads to increased compressive strength of concrete and above 15% there is a decrease in compressive strength for 3, 7, 14 and 28 days curing period. Yang *et al*., (2006) indicated that hwangtoh binder can be used as a highly effective performance binder. However, the workability of mortar is extremely poor when the cement/sand ratio is smaller than 1:2. It further suggested that desert sand should not be used as masonry mortar, but when the cement/sand ratio is greater than 1:2, the mortar can be used as coated mortar.

Ogunbode and Akanmu (2012) found compressive strength of cassava ash blended cement in laterized concrete to decrease with the increase of laterite and CPA content, and a gradual increase in strength was observed at 56 and 90 days. This is logical owing to the fact that reductions of ordinary Portland cement and sharp sand content in the mix with the increase of CPA and Laterite content. The finely divided silica in the CPA can combine with calcium hydroxide (from Portland cement) in the presence of water to form stable compounds like calcium silicates, which is known to possess cementitious properties. It was observed that the strength reduction is decreased gradually and experienced an increase at 56 days and dropped at 90 days of hydration age.

Balwaik and Raut, (2011) tested compressive strength on concrete during the study of the utilization of paper pulp by partial replacement of cement in concrete and reported that the workability increased up to 5% replacement of cement, above 5% the workability decreased as the paper pulp content in the concrete mixtures was increased.

Kula *et al.*, (2002) investigated the possibility of using coal bottom ash, tincal ore waste, and fly ash as cement replacements materials and concluded that the replacement of Portland cement beyond 5% by weight of tincal waste caused significant reduction in the compressive strength. When TW was replaced together with coal bottom ash, the mixtures containing up to 1% by weight tincal waste showed a considerable increase in the 28^{th} day compressive strength.

Memom *et al.*, (2012) evaluated Jehangira bentonite as partial replacement of cement and found that using bentonite reduces energy consumption and greenhouse gases related to cement production as well as improve the durability of the system. The workability, fresh concrete density and water absorption decreased as the ordinary Portland cement substitution by bentonite increased. The compressive strength analysis indicated that at 3 days of testing, the mixes containing bentonite showed lower strength than control mix while at 56 days of testing, the bentonite mixes showed higher strength than the control mix. Mixes containing bentonite performed better than control mix against acid attack.

Noor-ul-Amin (2012) reported that addition of clay in cement mortar and its chemical activation replaced equal amount of cement in mortar. Further it decreases the cost of cement mortar and consequently the emission of greenhouse gases to a considerable extent. However addition of quicklime in clay-cement systems is an effective, relatively cheap and environmentally-friendly way to accelerate the degree of clay reaction since quicklime replaced clay and the loss of active silica due to clay replacement was critical in the final performance of the newly constructed activated blends.

Use of local materials and industrial waste as an environmentally friendly and cost-effective replacement for cement is not a new phenomenon and has attracted many researchers in the world for decades. Although there have been several studies on the use of locally available materials as alternative materials for partial or whole replacement of cement; {(Ettu *et al.,* (2013), Memom *et al*., (2012), Yang *et a.*, (2006) Ogunbode and Akanmu (2012), Noor-ul-Amin (2012), Kula *et al*., (2002), Balwaik and Raut (2011), Bentur (2002), Metha (1983,1977,1992)} there are no known studies on the use of bitter cassava flour or local brewery waste as a replacement of cement for plastering mud constructed houses. These materials have the bonding capacity that can be used to partially replace cement in plastering eco constructed houses.

2.3 Overview of sustainable constructions

Sustainable construction is regarded as construction and management of the built environment and covering all aspects of sustainable human settlements and urban sustainability. It should be recognized that mankind is locked into a highly dynamic relationship with the natural world and that the two are acutely interdependent. In addressing the complex problem of construction and the environment, efforts towards sustainable construction are fundamentally an attempt to put in place practices that restore the balance between the natural and built environments. Sustainable construction implies not only new environmentally orientated construction designs, but also new environmentally friendly operation and maintenance procedures. Not only must construction materials and components be produced in a sustainable way, but their use must also answer to new requirements deriving from holistic environmental prerequisites.

2.3.1 Traditional Rammed earth construction

Rammed earth is experiencing increased interest in residential, commercial, and institutional structures around the world (Winderstorm , 2011). This increase is attributed to the growing adoption of green certification programs which recognize the benefits of rammed earth; healthy indoor air quality, longer life cycle than many other materials, reduce the energy consumption associated with heating and cooling structures.

2.3.2 Traditional plaster works

Most of the houses in villages are built either with sundried bricks or blocks, or with lump mud. Mud walls are protected against damage from rain by applying mud plaster, consisting of local soil or mud collected from village pond on outer walls, rendering with cow dung slurry. This traditional method of application of mud plaster is cheap; however cannot withstand even a few hours of continuous rains, with the result that usually the mud plaster gets eroded and considerable damage is done to the house. Thus a water proof mud rendering on mud walls can save the walls from frequent damage and increase its durability and life for 30 to 35 years with normal annual maintenance.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

To achieve the objectives of the study, each of the materials for the study was investigated to establish the material physical and chemical properties. The proportions of ingredient materials were determined for mortar mix. The viability of using these materials (bitter cassava flour, local brewery waste) as mortar for plastering was assessed by undertaking the compressive strength test, shrinkage test and bonding or durability test. Mortar cubes were cast and tested in compression in the laboratory to evaluate compressive behavior while the shrinkage specimens were cast and measured. The walls were constructed then plastered with different mortar mix.

3.2 Material preparation

3.2.1 Cement

Ordinary Portland Cement of normal compressive strength of 42.5 N/mm^2 was used as a binder material in masonry blocks construction and mortar plaster. This cement was not available within the area of laboratory works.

3.2.2 River sand

River sand was required for the production of mortar plaster. The river sand satisfied American Standards (ASTM C33-78) grading requirements for fine aggregates and therefore was used in the study.

3.2.3 Bitter cassava flour

Bitter cassava flour was also required for the replacement of cement for production of mortar plaster acting as a binder. This type of cassava which is not edible was obtained from local farmers in Northern Uganda. It was peeled, sundried and milled to obtain the fine powder for use in this study.

3.2.4 Local brewery waste (*pitti pitti*)

Local brewery waste used in this study as a replacement of cement acting as a binder was also obtained from local alcohol distillers in Northern Uganda. The brew contains mostly fermented cassava flour as the main ingredient and yeast made from millet. The local brewery waste was collected, sundried and also milled to obtain local brewery waste powder.

3.2.5 Stabilized earth blocks

Stabilized earth blocks were required for the construction of the walls. The blocks were obtained from the masonry department of Jomo Kenyatta University of Agriculture and Technology.

3.3 Physical and chemical properties test of materials

The physical properties tested on the sand, bitter cassava flour and local brewery waste included bulk density, specific gravity and gradation or sieve analysis. Herein, specific gravity data is used in describing the aggregate while bulk density is used for proportioning material in the mix design.

3.3.1 Determination of bulk density

This test was done according to standard test method for measuring the bulk density as specified by BS 812-2 1995 and ASTM D6683.

The container was first calibrated to determine the mass of water at 25+/-5^o C required to fill it so that no meniscus was present above the rim of the container and the mass was divided by 100 to give the volume in m^3.

The container was again filled to one third full with the samples (local brewery waste, cassava and sand) and given 20 blows by allowing the tamping rod to fall freely from a height of 50 mm above the surface of the sample. The samples were again added to fill the container and 10 blows given. Then the container was filled with the samples and the surfaces smoothened. The mass of the samples in the container was determined and the bulk density calculated in Kg/m^3. The above procedure was repeated to obtain the average of three tests.

3.3.2 Determination of Specific gravity for sand

This test was done according to standard test method for relative density (specific gravity), apparent density for fine aggregate as specified by ASTM C128-12 and BS EN 1097-3:1998.

The sand was thoroughly washed to remove all materials finer than 0.075 mm test sieve. The sand was placed in a tray and enough to cover it. It was then agitated vigorously and immediately poured over the sieve that was wetted before on both sides. The procedure was repeated until the water is clear. All the materials retained in the sieve were returned.

The washed materials were transferred to the tray and water was added to ensure that all the materials was immersed and the trapped air was removed by gentle agitation and the sample kept under water for 24 hours at a temperature of 25^{o}C. Then the water was carefully drained by decantation through a 0.075 mm test sieve. It was then surface dried by exposure to warm air. The saturated and surface dry sample was weighed and the sample placed in a pycometer, filled with water and trapped air removed. The sample was removed and the pycometer was then filled with water and then weighed. The sample was placed in the tray and oven dried at a constant temperature of 105^{o}C for 24 hours and weighed. Then the specific gravity oven dry, saturated and surface dry, apparent specific gravity and water absorption of sand were determined.

3.3.3 Sieve analysis or gradation test

This test was done according to standard test method for sieve analysis for fine aggregate and coarse aggregate as shown in the BS882 and ASTM C136-06.

This was done to determine the particle size distribution of the local brewery waste, cassava and sand by sieving. The following sieve sizes were used; 10.0, 5.0, 2.0, 0.84, 0.42, 0.25, 0.105 mm. The test samples were oven dried at 105^{o} C. The sieve was first weighed and recorded, then fitted according to the sieve size and the samples poured from the surface, and then thoroughly shaken. The mass retained in each sieve was again weighed and the results presented.

3.3.4 Determination of chemical properties of the samples

The chemical property of local brewery waste or bitter cassava powder was determined using X-ray fluorescence spectroscopy from the department of Nuclear Science, University of Nairobi.

X-ray fluorescence spectroscopy analyzer uses high energy photons absorbed by atoms. The inner shell electrons are ejected from the atoms. Then high energy photons (x-rays or gamma-rays) are absorbed by atoms, inner shell electrons are ejected from the atom, becoming “photoelectrons”. This leaves the atom in an excited state, with a vacancy in the inner shell. Outer shell electrons then fall into the vacancy, emitting photons with energy equal to the energy difference between the two states. Since each element has a unique set of energy levels, each element emits a pattern of X-rays characteristic of the element, termed “characteristic X-rays”. The intensity of the X-rays increases with the concentration of the corresponding element. The same underlying physics produces the optical emission spectra which are often observed in high school or college labs and used in quantitative analysis. The inner shells of heavier elements involve higher binding energies so produce photons in the X-ray wavelength range.

3.4 Studies on the mortar plaster mix

The plaster mix was designed and tested for shrinkage, compressive strength and durability. Different specimens were tested at 7, 14 and 28 days.

3.4.1 Shrinkage test

This test was done according to standard test method for drying shrinkage of mortar containing hydraulic cement as shown in the ASTM C596-09.

This test was designed to measure the shrinkage of the plaster. Cassava flour and local brewery waste is a hydrophilic material that expands when wet and contracts as it dries. The expansive properties of these materials can be tempered in a plaster by additions of sand and overall shrinkage of a particular plaster. This test was done to predict cracking behavior and/or to examine the relative performance of different plaster mixtures with differing proportions of cassava flour, local brewery waste and cement. To perform shrinkage test the ready mix plaster was packed in a wooden formwork with interior dimensions of 50x300x300mm. The plaster was mixed to the same consistency that is used for application in the field, tamped firmly into the box and the top surface was screeded off level with the top of the formwork. The sample was completely cured. Then the shrinkage was measured by pushing the entire sample (including separated lumps) tightly up to one end of the box and measuring the gap created by the shrinkage for 7 days, 14 days and 28 days (Figure 3.1).

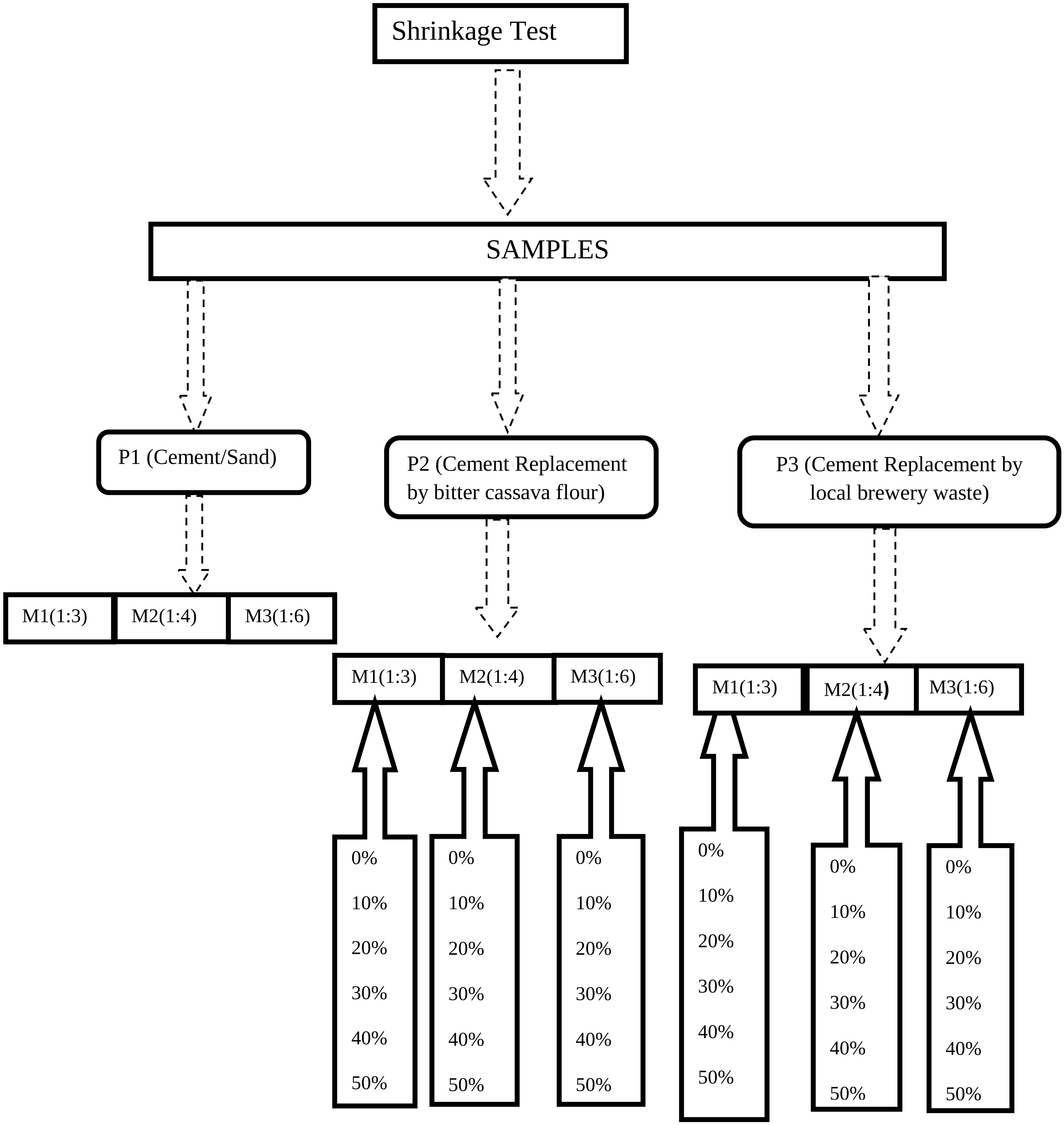


Figure 3.1: The schematic design for the shrinkage test

(a) Casting of shrinkage specimens

(b) Shrinkage specimens

Plate 3.1: The casting of the shrinkage specimens

3.4.2 Compression tests

Specimens test for compressive strength for plaster cubes was conducted from the laboratory according to the Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (ASTM C109).

To perform this test, different plaster mixes were made from the cement-sand mix, cassava-flour-sand mortar mix, local brewery waste-sand mortar mix, cement-cassava sand mortar mix, cement-local brewery waste-sand mortar mix. A total of three cubes were made from each sample and tested for the compressive strength for 7, 14 and 28 days of curing.

The testing was done in accordance with the standard procedures of cube testing using a Universal Testing Machine (UTM). The cube was removed from the curing place and dried by exposing it to air for a period of about two hours and then weighed with 0.5 g accuracy.

The dimension of the cube was measured and the cube loaded in the compression test machine with trowelled faces perpendicular to the vertical axes to the machine.

The Universal testing machine was the set and the cube tested, the maximum load and the compressive strength recorded.

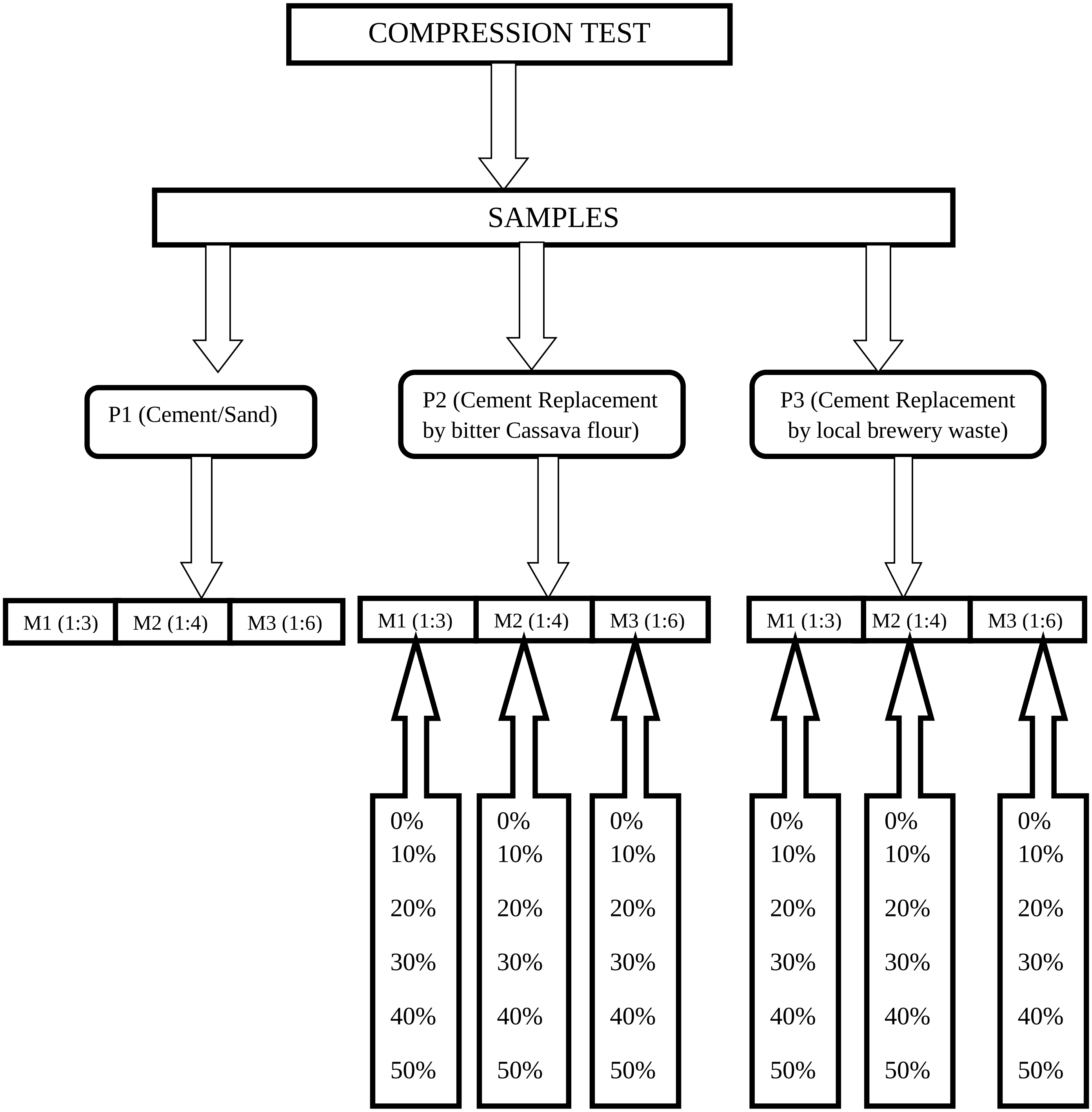
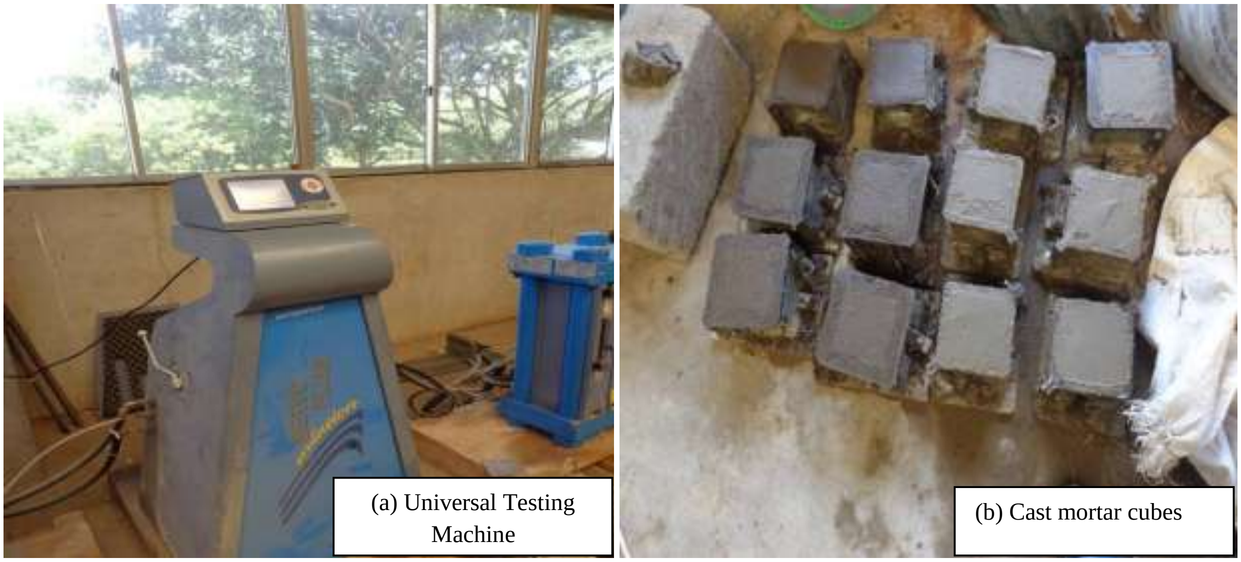


Figure 3.2: The schematic design of compression test



(a) Universal Testing Machine

(b) Cast mortar cubes

Plate 3.2: The Universal Testing Machine and cast cubes

3.4.3 Bonding/Durability test

To perform this test a 500×500mm wall was constructed using stabilized earth blocks bedded and jointed together in cement sand mortar of mix 1:3 in header bond and allowed to set. Then different mix of plaster was used to plaster the wall to observe bonding between the stabilized earth block and the plaster, durability when exposed to the real life weather and the cracking of the plaster. The wall was tested after 3 months of exposure.

Plate 3.3: The walls being plastered with different mortar mix

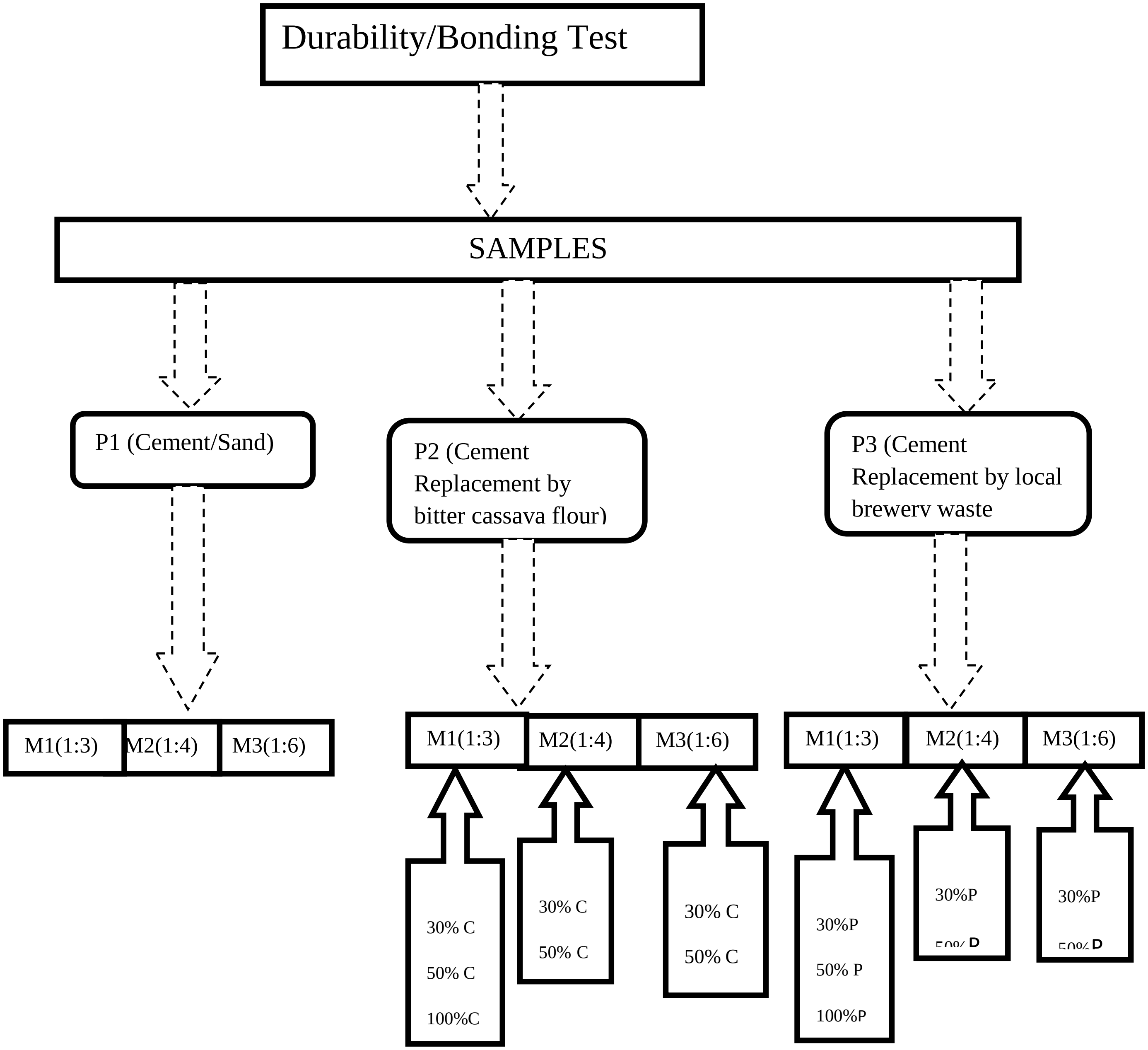


Figure 3.3: The schematic design for bonding test

Plate 3.4: The walls plastered with different mortar mix

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Physical and chemical properties of bitter cassava flour, pitti pitti and sand

4.1.1 Physical properties of bitter cassava flour, pitti pitti and sand

The physical properties of the materials determined included the specific gravity, bulk density and sieve analysis. Bitter cassava flour had finer particles passing through the sieve size of 0.59 mm and 0.3mm while local brewery waste had more fine particles passing through the 0.07mm sieve than bitter cassava. This showed that the particle size of these two materials is less finer than the particles of ordinary Portland cement. This deviation is as a result of the fact cement clinker is ground with a special machine while the local brewery waste was milled with an ordinary milling machine. Celik (2009) studied the effect of particle size and surface area upon strength development of cement. He correlated the variation in fineness of cement on the basis of its particle sizes and strength of cement and concluded that fineness has a great effect on 2 days strength. At increased ages, strength is affected more by the concentration of coarser particles as compared to finer ones. Celik's argument was also confirmed by Bentz, *et al.,* (1999) who conducted research over effects of cement particle size distribution on operational properties of Portland cement-based materials and reported that coarse grains require more time to set, although they practically set at a lower degree of hydration. Their gain in strength will go slowly than that of finer cement. Also coarser cement will show a lower initial heat release rate than that of finer cement, also coarser cements will show lower initial heat release rate.

Table 4.1: Sieve analysis of bitter cassava flour, local brewery waste and sand

Sieve analysis for Bitter Cassava Flour			
Sieve size	**% Retained**	**Cum. % Retained**	**Cum. % Passing**
0.59	7.00	7.00	93.00
0.30	54.95	61.95	38.05
0.07	37.05	99.00	1.00
Sieve analysis for Local brewery waste			
Sieve size	**% Retained**	**Cum. % Retained**	**Cum. % Passing**
1.20	4.40	4.40	95.60
0.59	10.00	14.40	85.60
0.30	70.50	70.50	15.10
0.07	13.80	97.90	2.10
Sieve analysis for sand			
Sieve size	**% Retained**	**Cum. % Retained**	**Cum. % Passing**
10.00	1.00	1.00	99.00
5.00	1.98	2.98	97.02
2.36	1.78	4.76	95.24
2.00	11.18	15.94	84.06
1.70	19.38	35.32	64.68
0.59	35.50	70.82	29.18
0.15	27.05	97.87	2.13

The percentage passing and retained on each sieve size was determined and the results was showed in the table 4.1 above. Cummulative percentage passing was used to draw the gradation curve for each material in order to explain the particle size distribution of each material.

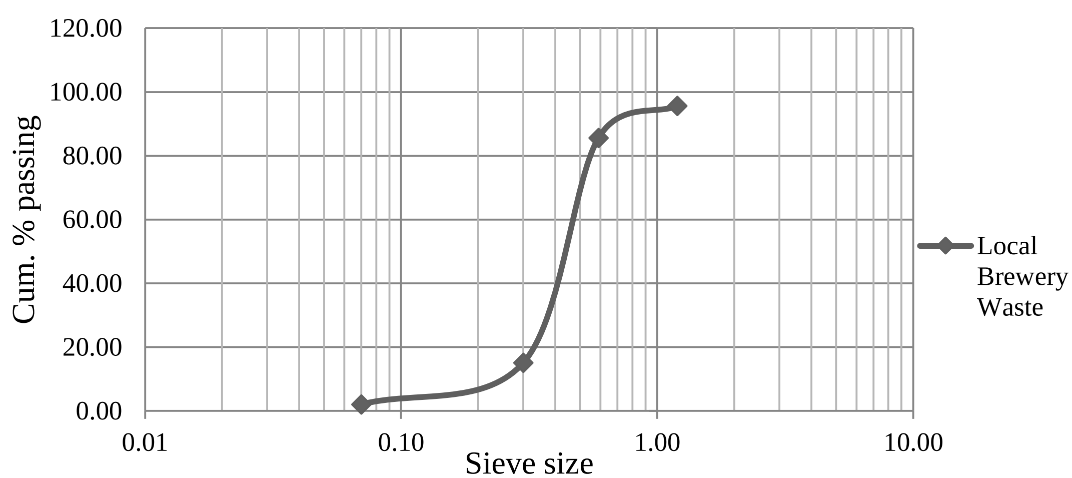


Figure 4.1: Sieve analysis curve for local brewery waste

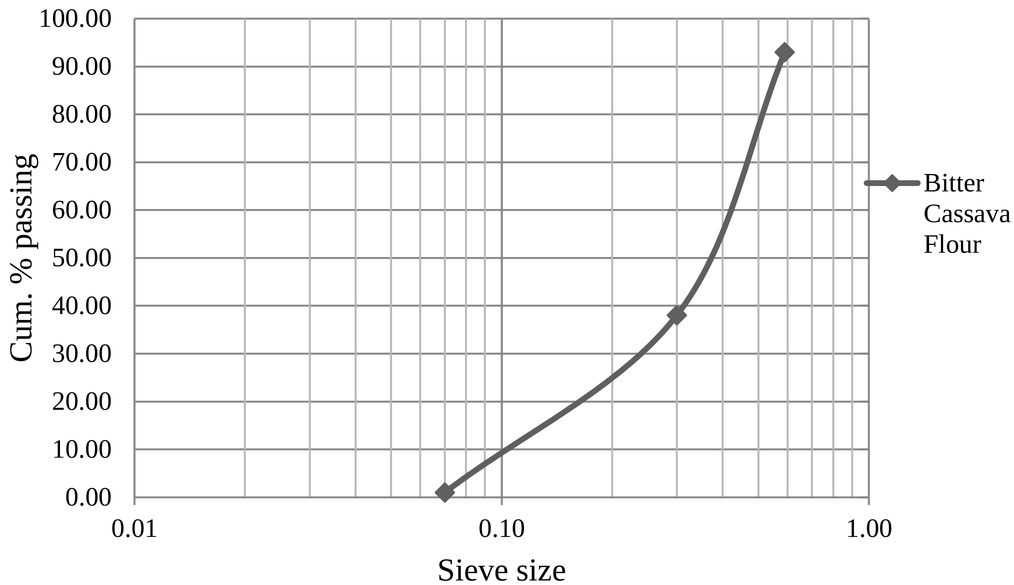


Figure 4.2: Sieve analysis curve for bitter cassava

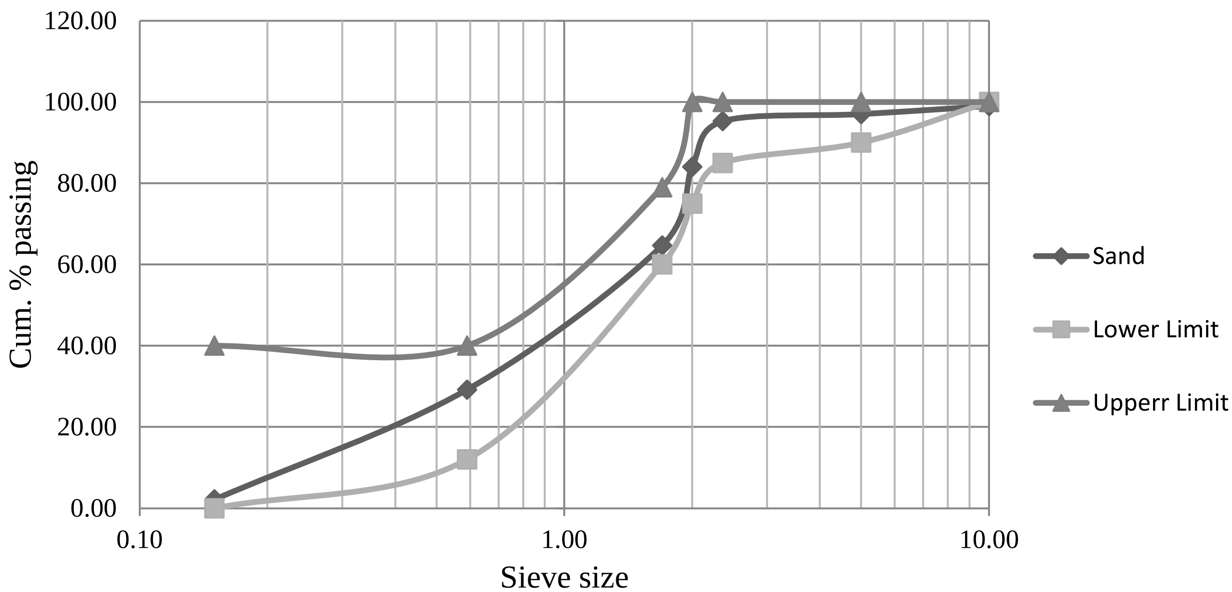


Figure 4.3: Sieve analysis curve for sand

Sand used in the study fitted the grading Zones 3 of the BS 882:1973 and also the ASTM Standard C33-78 grading limits. This gradation made it possible for the sand to be used in this study. Bitter cassava and local brewery waste did not fall on the required limit. Musiomi, (2009) reported that physical properties of alternative materials greatly differ from the conventional materials.

Bulk density of sand obtained in this study was 1560 kg/m^3 which compared very well with the one obtained by (Musiomi, 2009) while bulk density of local brewery waste was 840 kg/m3 which is slightly lower than the bulk densities reported by other researchers on local materials. Bitter cassava flour had a bulk density of 560 kg/m^3 contrary to the previous report by Saul (2006) on cassava powder as 1320 kg/m^3. Ganesan *et al* (2007) reported that the bulk density of baggase ash is 590 Kg/m^3 similar to bulk density of bitter cassava 560 Kg/m^3.

Specific gravity of the sand determined conformed to the standards specified by the ASTM C128-12. (Kelly and Kevin (2003), Yang *et al.*, (2006)).

Table 4.2: Determined physical properties of local brewery waste, bitter cassava and sand

Physical properties	**Determined value**
Bulk density of sand	1560 Kg/m^3
Bulk density of local brewery waste	840 Kg/m^3
Bulk density of bitter cassava flour	560 Kg/m3
Specific Gravity (Oven Dry) of sand	0.441
Specific gravity (saturated and surface dry) of sand	2.573
Determined Apparent Specific gravity of sand	2.594
Water absorption of sand	2.724%

4.1.2 Chemical properties of cassava flour, local brewery waste

Chemically, local brewery waste and bitter cassava consisted mostly of 73.5% and 89.4% of potassium, respectively. Calcium was the second highest element in both local brewery waste and bitter cassava flour and the least elements were arsenic and yttrium, respectively (Table 4.3). The chemical property of local brewery waste (pitti pitti) has never been previously documented. Saul

(2006) reported the chemical properties of cassava powder as comprising of carbohydrates of about 98.48%, Ca 0.06%, K 0.88% which is contrary to the elements in the bitter cassava. Badejo (2002) also reported that termite hill also has higher concentration of Potassium (K), Calcium (Ca) which is similar to the chemical properties of bitter cassava flour and local brewery waste.

Table 4.3: Chemical properties of local brewery waste and bitter cassava flour

Element	**Local brewery waste (%)**	**Bitter Cassava Flour (%)**
Potassium (K)	73.5	89.4
Calcium (Ca)	16.3	10.15
Titanium (Ti)	1.01	0.25
Manganese (Mn)	0.35	0.18
Iron (Fe)	8.19	2.25
Copper (Cu)	0.11	0.07
Zinc (Zn)	0.25	0.29
Arsenic (As)	0.05	0.09
Rubidium (Rb)	0.08	0.12
Strontium (Sr)	0.15	0.11
Yttrium (Y)	0.08	0.05

4.2 Compressive strength

Plaster cubes were made using 100 × 100mm steel concrete cubes moulds. The cubes were tested at 7, 14 and 28 days respectively. The conventional mortar consisting of cement and sand only was investigated in the mix ratios of 1:3, 1:4 and 1:6 and the results showed very high compressive strength of 28.3 MPa, 20.4 MPa and 11.5 MPa respectively which is very high compared to the minimum compressive strength of earth stabilized blocks specified in the Kenya standard (KS02-1070:1993) of 2.5 MPa, American Standards (ASTM D1663) of 2.0 MPa, BS 2.8 of MPa. Mbereyaho *et al.*, (2014) reported that the minimum compressive strength of brick is 4 MPa for simple house and 7 MPa for storey houses and that of unburnt clay brick 1.14 MPa. Considering the fact that most of the plaster works done is according to the mix ratio of 1:3, 1:4 and 1:6 this study showed that different surfaces should be plastered with different mix of 1:3, 1:4 and 1:6 depending on the compressive strength of the material used for construction.

4.2.1 Compressive strength of mortar of mix 1:3

Cement replacement with bitter cassava flour (C) and local brewery waste (P) was investigated in this study ranging from 10-50% and plaster cubes of 100×100mm. The cubes were cast in triplicates and tested on 7, 14 and 28 days of curing and the average compressive strength was determined.

4.2.1.1 The compressive strength of bitter cassava flour mortar

The results showed that at 10% bitter cassava replacement the strength was 21.9 MPa at 28 days of curing then dropped to 18.1 MPa at 20%. However, there was a great reduction in the compressive strength at 30% to 3.7 MPa but this strength is above the minimum requirements of plaster for eco house (BS 5628 part1, ASTM D1663, KS02-1070:1993). At 40 and 50% the strength was below the minimum requirement for the above standards. However, it can still be used for plastering other low cost houses constructed from weak materials of below 2 MPa Mbereyaho *et al*., (2014) reported that the compressive strength of unburnt brick is 1.14 MPa. Saul (2006) found that the compressive strength of stabilized block using cassava powder increased at 1.5% then greatly reduced to beyond 7% replacement. Several studies on the replacement of cement with other locally available materials reported a reduction in compressive strength. Ogunbode *et al*., (2012) reported reduction in compressive strength when cement was replaced with cassava ash, (Kula *et al*., 2002) reported that a cement replacement with tincal waste at 5% caused a significant reduction in the compressive strength. All the above studies finding relates well to the results found in this study. The reduction in the compressive strength could have been due to the increased water/cement ratio in the mix because the floor table results showed that the required water/cement ratio of 0.5 could not be used even at 10% cassava replacement. Therefore the water cement ratio was adjusted from 0.5 to 0.6,07, and 0.8 for different levels of replacement (Neville, 1995).

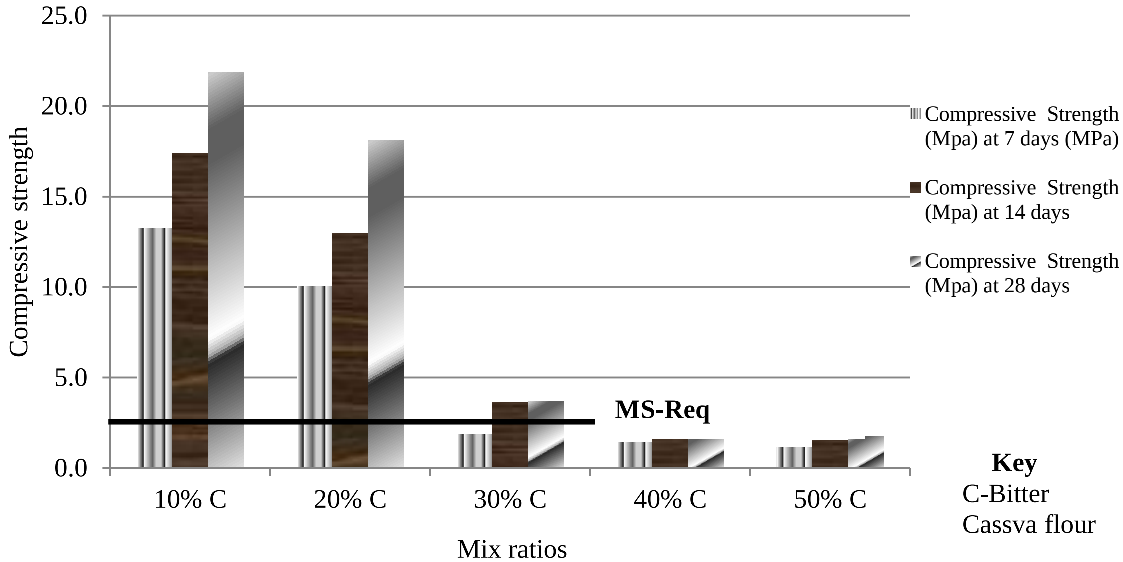


Figure 4.4: The compressive strength of bitter cassava ,cement and sand mortar

4.2.1.2 The compressive strength of local brewery waste mortar

Local brewery waste is a by-product of cassava fermented alcohol after distillation. This waste was also investigated in this study ranging from 10-50% replacement of cement by weight. The results showed a reduction in compressive strength at 10% as compared to the bitter cassava flour and cement sand mortar. This great reduction in strength could be attributed to the increase in the water cement ratio (Neville, 1995), the presence of high amount of iron (Fe) about 8% as compared to that in cement and also due to the fact that cassava is mixed with other ingredients during the fermentation of the alcohol. At 10% replacement the attained compressive strength at 28 days was about 2.1 MPa which is slightly above the minimum requirement of the ASTM D1663 and the New Mexico Standards of 2.0 MPa. This strength can be used to plaster houses made from the above blocks. However, mortar cubes made of the local brewery waste and cement showed little reduction in the compressive strength as more cement is being replaced that is 20% 1.9 MPa, 30% 1.7 MPa, 40% 1.3 MPa and 50% 1.0 MPa. Mbereyaho *et al.*, (2014) reported that the compressive strength of un burnt brick is 1.14 MPa. Several studies on the replacement of cement with other locally available materials reported a reduction in compressive strength. For example, Ogunbode *et al*., (2014) reported a reduction in the compressive strength when cement was replaced with cassava ash. This finding relates well to the findings of this study. All levels of replacement with local brewery waste did not meet the minimum requirement for mortar for low cost housing as specified in ASTM C270 of 2.4 MPa.

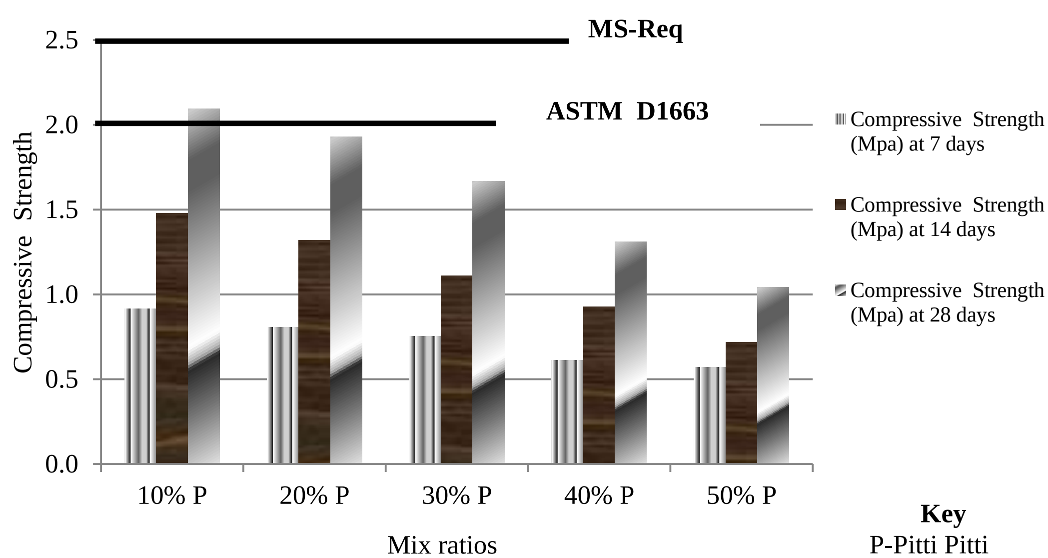


Figure 4.5: The compressive strength of local brewery waste ,cement and sand mortar

4.2.1.3 The compressive strength of local brewery waste and cow dung powder mortar

Traditionally this eco houses in the villages are plastered with mud and rendered with cow dung slurry which plays a role of either improving the bonding or reducing cracking. There for incorporating cow dung in this study was done in an attempt to try to improve on the compressive strength of local brewery waste. Cow dung was collected, sundried and milled using a milling machine to produce cow dung powder which was used in this study. It was found out that at 10% replacement with 5% constituting cow dung powder and 5% local brewery waste the compressive strength (1.6 MPa) reduced as compared to the one earlier on found with local brewery waste (2.1 MPa) and this trend was observed up to 30%. These were still below the required standards specified in the BS 5628, KS 02-170:1993 and ASTM D1663 as the minimum strength for earth stabilized blocks. It was also below the minimum requirements for ASTM C270 for mortar requirements for low cost housing. But at 40% and 50% the compressive strength increased as compared to local brewery waste alone (1.3 MPa and 1.0 MPa Vs 2.0 MPa and 2.6 MPa) which satisfy the minimum compressive strength for mortar for a stabilized earth block constructed house as specified by the ASTM D1663 and Kenya standards KS 02-170:1993. This improvement in the compressive strength could be attributed to the improvement in the workability of the mortar as more cow dung is added whereby the water cement ratio was reduced at 40% and 50% replacement.

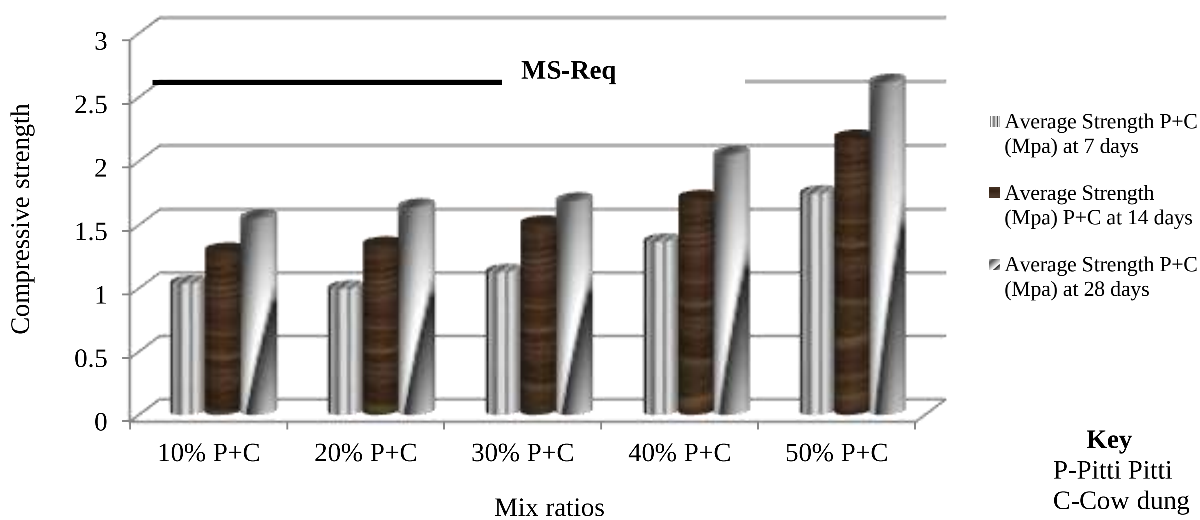


Figure 4.6: The compressive strength of local brewery waste , cow dung cement and sand mortar

4.2.2 Compressive strength of mortar of mix 1:4

Cement replacement with bitter cassava flour (C) and local brewery waste (P) was investigated in this study ranging from 10-50% and plaster cubes of 100x100 mm. The cubes were cast in triplicates and tested on 7, 14 and 28 days of curing and the average compressive strength was determined.

4.2.2.1 The compressive strength of bitter cassava flour mortar

The results showed that at 10% bitter cassava replacement, the strength was 17.8 MPa at 28 days of curing then dropped to 13.8 MPa at 20% but this strength is above the minimum requirements of plaster for eco house (BS 5628 part 1, ASTM D1663, KS02-1070:1993). However, as compared to the previous mix ratio there was a great reduction in the compressive strength at 30% to 2.0 MPa which was still above the minimum requirements specified by the ASTM D1663. At 40% and 50% the compressive strength was below the minimum requirement for the above standards. However, it can still be used for plastering other low cost houses constructed from materials of below 2 MPa (Mbereyaho *et al.,* 2014) reported that the compressive strength of un burnt brick is 1.14 MPa. Saul (2006) found that the compressive strength of stabilized block using cassava powder increased at 1.5% then greatly reduced to beyond 7% replacement. Several studies on the replacement of cement with other locally available materials reported a reduction in compressive strength. Balwaik and Raut (2011) reported that reduction in the compressive strength when cement was replaced with paper pulp, (Ogunbode *et al.,* 2012) found a reduction in compressive strength when cement was replaced with cassava ash, (Kula *et al.,* 2002) reported that a cement replacement with tincal waste at 5% caused a significant reduction in the compressive strength. All the above research findings relates well to the results found in this study. The reduction in the compressive strength could have been due to the increased water/cement ratio in the mix because the floor table results showed that the required water/cement ratio of 0.5 could not be used even at 10% cassava replacement. Therefore the water cement ratio was adjusted from 0.5 to 0.6, 07, and 0.8 for different levels of replacement (Neville, 1995).

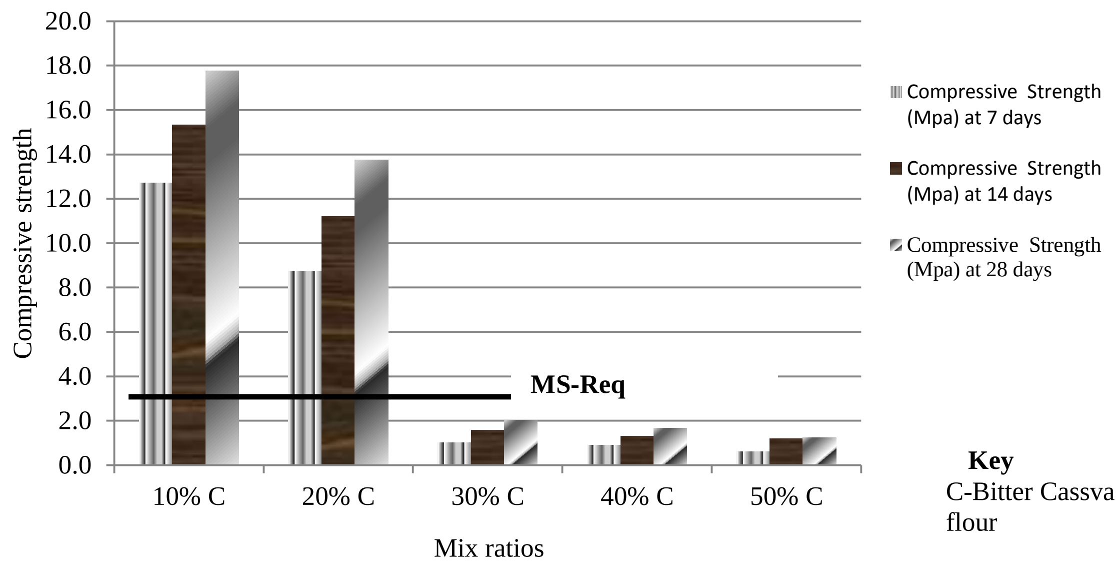


Figure 4.7: The compressive strength of bitter cassava ,cement and sand mortar

4.2.1.2 The compressive strength of local brewery waste mortar

Pitti pitti is a by-product of cassava fermented alcohol after distillation. The results showed a reduction in compressive strength at 10% as compared to the bitter cassava flour and cement sand mortar. This great reduction in strength could be attributed to the increase in the water cement ratio (Neville, 1995), the presence of high amount of iron (Fe) about 8% as compared to that in cement and also due to the fact that cassava is mixed with other ingredients during the fermentation of the alcohol. However, mortar cubes made from the local brewery waste and cement sand showed small reduction in the compressive strength as more cement is being replaced. Mbereyaho *et al*., (2014) reported that the compressive strength of unburnt brick is 1.14 MPa. Several studies on the replacement of cement with other locally available materials reported a reduction in compressive strength (Olusola *et al*., 2006, Kamudang, 1997, Balwaik and Raut, 2011). These finding relates well to the findings of this study. All levels of replacement with local brewery waste did not meet the minimum requirement for mortar for low cost housing as specified in ASTM C270 of 2.4 MPa.

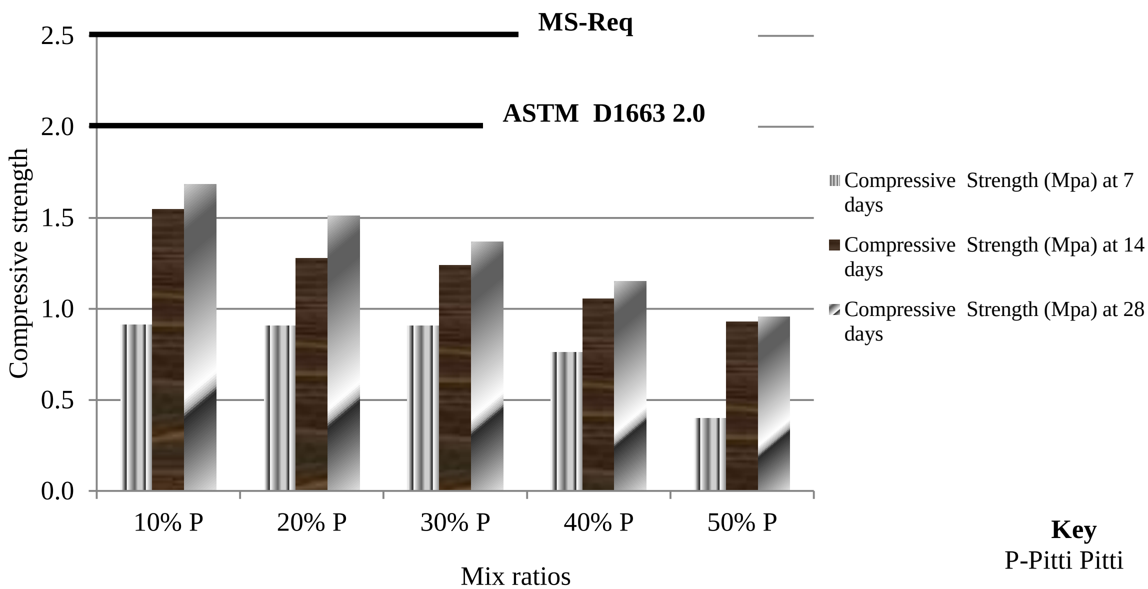


Figure 4.8: The compressive strength of local brewery waste ,cement and sand mortar

4.2.1.3 The compressive strength of local brewery waste and cow dung powder

It was found out that at 10% replacement with 5% constituting cow dung powder and 5% local brewery waste the compressive strength (1.5 MPa) increased as compared to the one earlier on found with local brewery waste (1.6 MPa) this trend was observed up to 50%. These were still below the required standards specified in the BS 5628, KS 02-170:1993 as the minimum compressive strength for earth stabilized blocks. It was also below the minimum requirements for ASTM C270 for mortar requirements for low cost housing of 2.4 MPa. This improvement in the compressive strength could be attributed to the improvement in the workability of the mortar as more cow dung is added whereby the water cement ratio was reduced at 40% and 50% replacement.

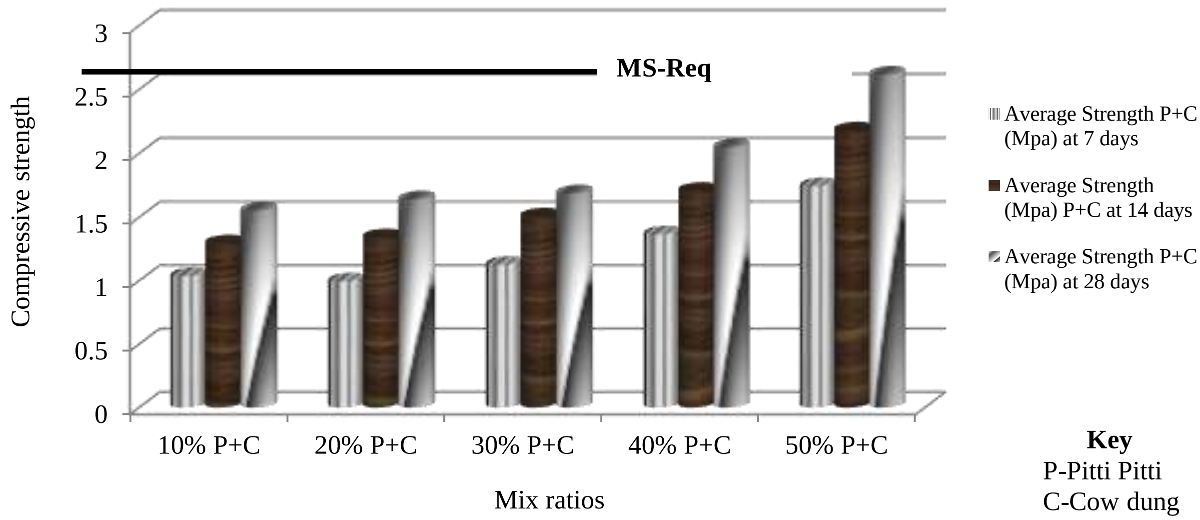


Figure 4.9: The compressive strength of local brewery waste, cowdung, cement and sand

4.3.3 Compressive strength of mortar of mix 1:6

Cement replacement with bitter cassava flour (C) and local brewery waste (P) was investigated in this study ranging from 10-50% and plaster cubes of 100x100mm. The cubes were cast in triplicates and tested on 7, 14 and 28 days of curing and the average compressive strength was determined.

4.3.3.1 The compressive strength of bitter cassava flour

The results showed that at 10% bitter cassava replacement the strength was 11.5 MPa at 28 days of curing then dropped to 8.5 MPa at 20% replacement. But this strength is above the minimum requirements of plaster for an eco-house (BS 5628 Part1, ASTM D1663, KS02-1070:1993). However, there was a great reduction in the compressive strength at 30%, 40% and 50% the strength was below the minimum requirement for the above standards. However, it can still be used for plastering other low cost houses constructed from materials of below 2 MPa compressive strength. Mbereyaho *et al.*, (2014) reported that the compressive strength of unburnt brick is 1.14 MPa. Saul (2006) found that the compressive strength of stabilized block using cassava powder increased at 1.5% then greatly reduced to beyond 7% replacement. Several studies on the replacement of cement with other locally available materials reported a reduction in compressive strength. Balwaik and Raut (2011) reported that reduction in the compressive strength when cement was replaced with paper pulp, (Ogunbode *et al.*, 2012) reported reduction in compressive strength when cement was replaced with cassava ash, (Kula *et al.*, 2002) reported that a cement replacement with tincal waste at 5% caused a significant reduction in the compressive strength. All the above studies finding relates well to the results found in this study. The reduction in the compressive strength could have been due to the increased water/cement ratio in the mix because the floor table results showed that the required water/cement ratio of 0.5 could not be used even at 10% cassava replacement. Therefore the water cement ratio was adjusted from 0.5 to 0.6, 07, and 0.8 for different levels of replacement (Neville, 1995).

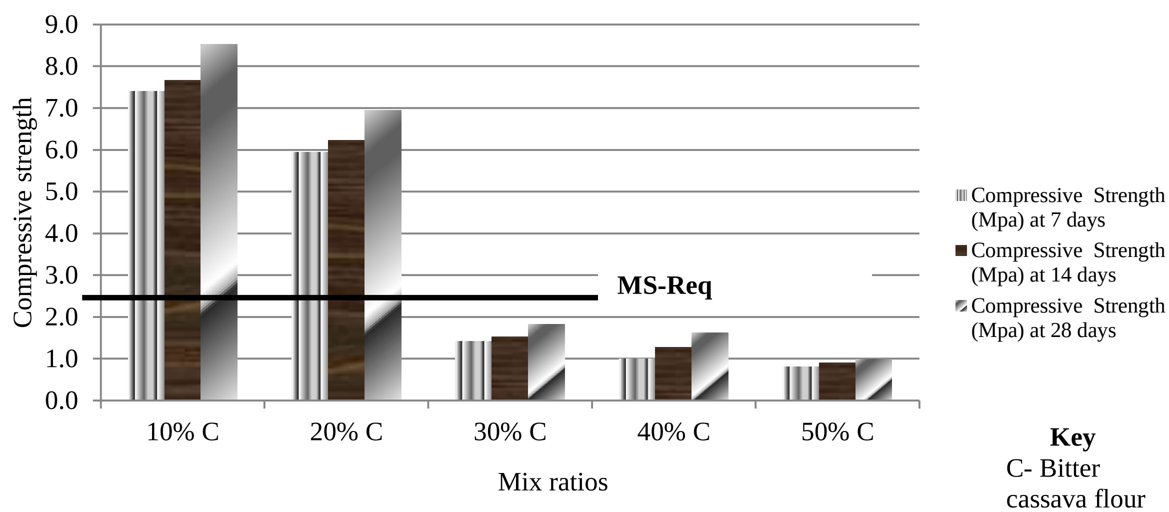


Figure 4.10: The compressive strength of bitter cassava flour ,cement and sand mortar

4.2.1.2 The compressive strength of local brewery waste

The result showed a significant reduction in compressive strength at 10% as compared to the bitter cassava flour and cement sand mortar. This great reduction in strength could be attributed to the increase in the water cement ratio (Neville, 1995), the presence of high amount of iron (Fe) about 8% as compared to that in cement and also due to the fact that cassava is mixed with other ingredients during the fermentation of the alcohol. This mix ratio attained very low compressive strength below all the specified standards as the minimum required compressive strength of a stabilized blocks used for the construction of an eco house. However, this plaster can still be used for plastering mud houses since Mbereyaho *et al*., (2014) reported that the compressive strength of unburnt brick is 1.14 MPa. Balwaik and Raut (2011), Ogunbode *et al.*, (2012), Yang *et al.*, (2006) reported reduction in compressive strength when cement was replaced with locally available materials. This finding relates well to the findings of this study. All levels of replacement with local brewery waste did not meet the minimum requirement for mortar for low cost housing as specified in ASTM C270 of 2.4 MPa.

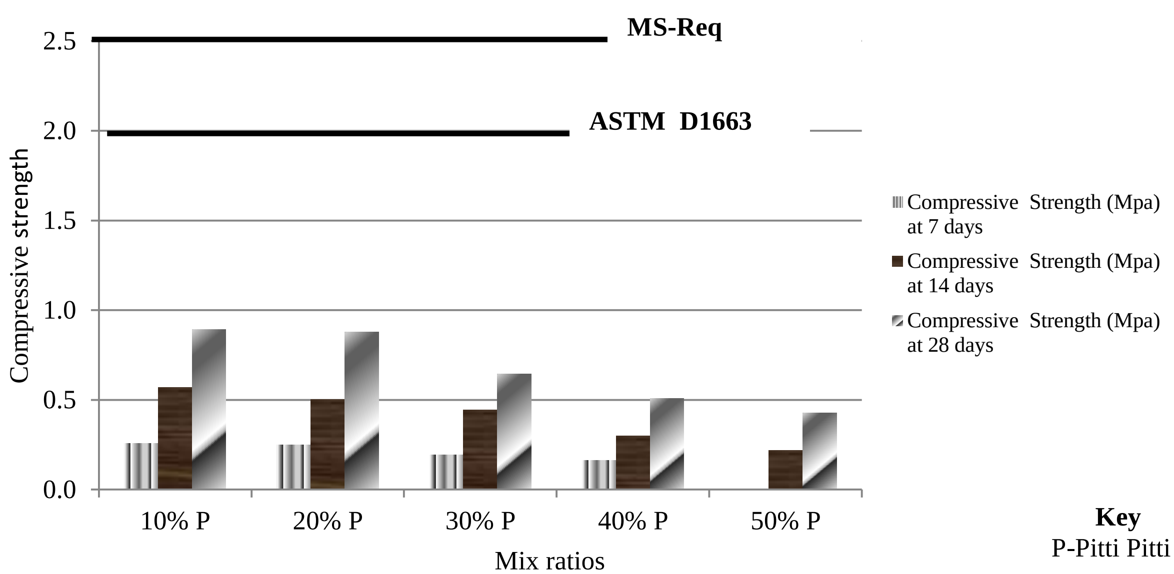


Figure 4.11: The compressive strength of local brewery waste,cement and sand mortar

4.3.3 The compressive strength of local brewery waste and cow dung powder

It was found out that at 10% replacement with 5% constituting cow dung powder and 5% local brewery waste the compressive strength (0.89 MPa) increased as compared to the one earlier on found with local brewery waste (0.96 MPa) and this trend was observed up to 50%. Much as there was increase in the compressive strength they were still below the required standards specified in the (BS 5628, KS 02-170:1993) as the minimum strength for earth stabilized blocks. It was also below the minimum requirements for ASTM C270 for mortar requirements for low cost housing. This improvement in the compressive strength could be attributed to the improvement in the workability of the mortar as more cow dung is added whereby the water cement ratio was reduced at 40% and 50% replacement.

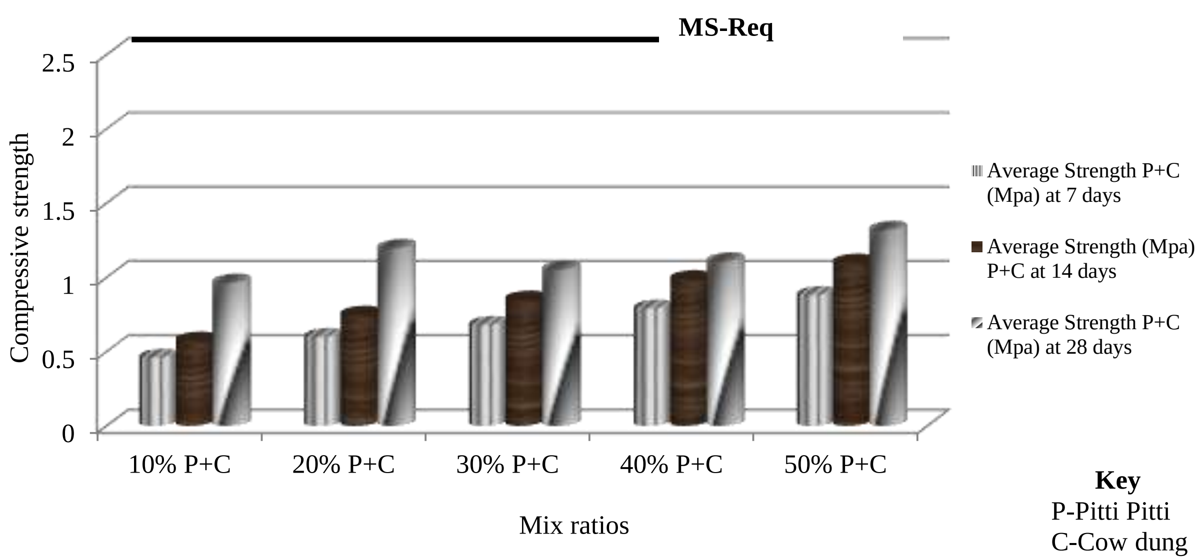


Figure 4.12: The compressive strength of local brewery waste,cow dung, cement and sand mortar

4.4 Shrinkage Test

The shrinkage property of the mortar was evaluated in this study. Mortar were mix in various proportions of bitter cassava flour and local brewery waste. It was also done to evaluate the cracking propagation of the mortar mix.

4.4.1 Shrinkage for mix ratio 1:3

Drying shrinkage was evaluated using mortar method. Increase in drying shrinkage was noted for increase substitution with bitter cassava flour. At 10% 0.4mm and at 50% 0.8mm the maximum shrinkage determined in this study. This finding compared well with that of (South, 2009). There was no further shrinkage observed after 14 days of curing. Only 40 and 50% of bitter cassava cracked in the mix ratio of 1:3 and 1:4, previously (Markus, 2011) reported that shrinkage should be minimized to avoid cracking of the mortar.

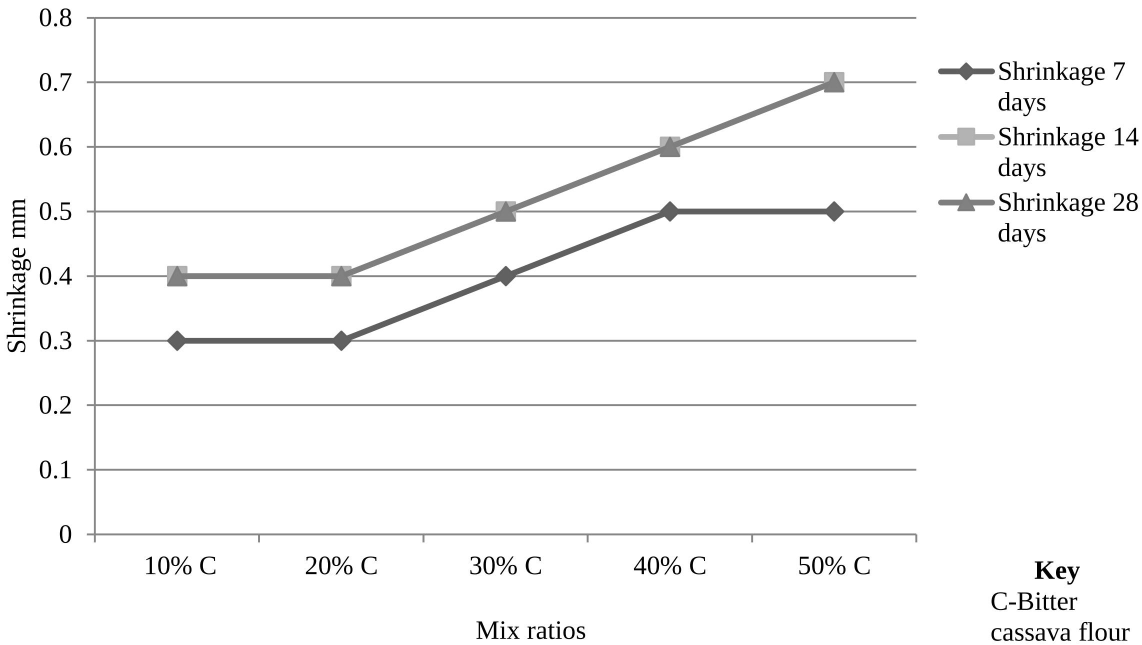


Figure 4.13: The shrinkage of bitter cassava flour and cement blended mortar

Plate 4.1: The cracking of cassava flour mortar

Generally lower drying shrinkage was noted for increased substitution with local brewery waste. At 10% 0.5mm and at 50% 0.1 mm. There was no further shrinkage observed after 14 days of curing. This finding is in line with (Markus, 2011) who reported that shrinkage should be minimized to avoid cracking of the mortar. This could have been why the mortar showed no crack at all level of replacement with local brewery waste and also the presence of yeast was also responsible for the expansion in the mortar at 100% replacement.

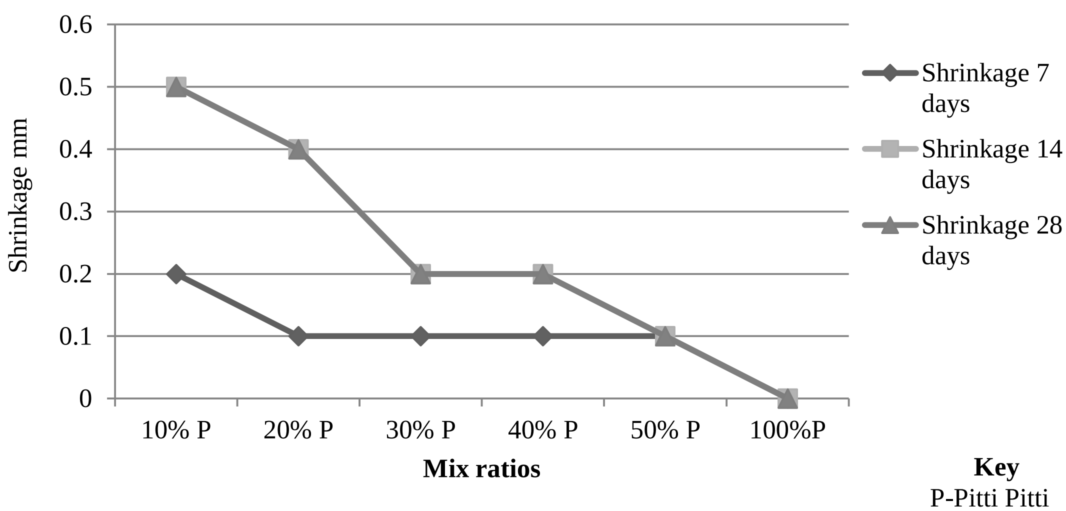


Figure 4.14: The shrinkage of local brewery waste and cement blended mortar

4.4.2 Shrinkage for mix ratio 1:4

Drying shrinkage was evaluated using mortar method. Increase in drying shrinkage was noted for increase in substitution with bitter cassava flour. At 10% 0.3mm and at 50% 0.7mm and there was no further shrinkage observed after 14 days of curing. This finding compared well with that of (South, 2009). Only 40% and 50% of bitter cassava cracked in the mix ratio of 1:4, respectively previously (Markus, 2011) reported that shrinkage should be minimized to avoid cracking of the mortar.

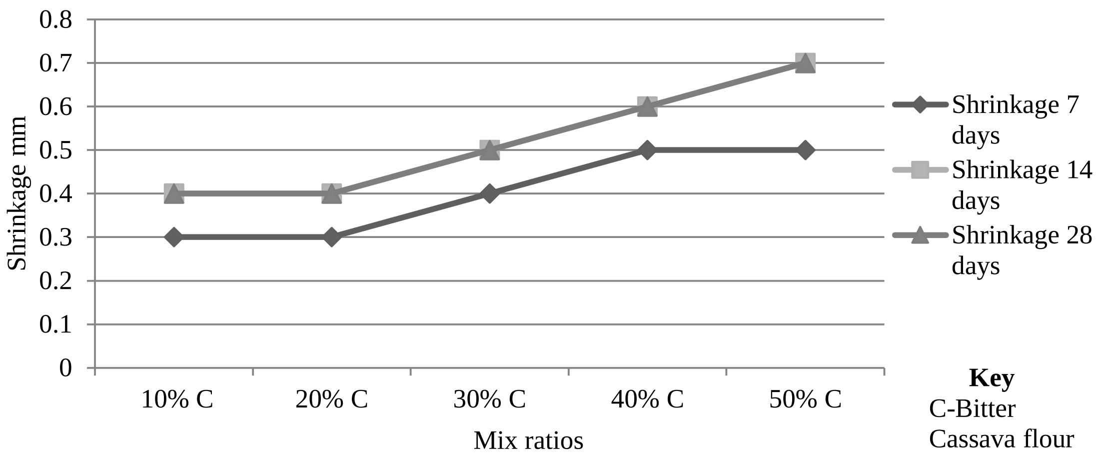


Figure 4.15: The shrinkage of bitter cassava flour and cement blended mortar

Plate 4.2: The cracking of cassava flour and cement blended mortar

Lower drying shrinkage was noted for increase substitution with local brewery waste. At 10% 0.6 mm, at 50% 0.0 mm and there was no further shrinkage observed after 14 days of curing. This finding is in line with (Markus, 2011) reported that shrinkage should be minimized to avoid cracking of the mortar. This could have been why the mortar showed no crack at all level of replacement with local brewery waste and also the presence of yeast was also responsible for the expansion in the mortar.

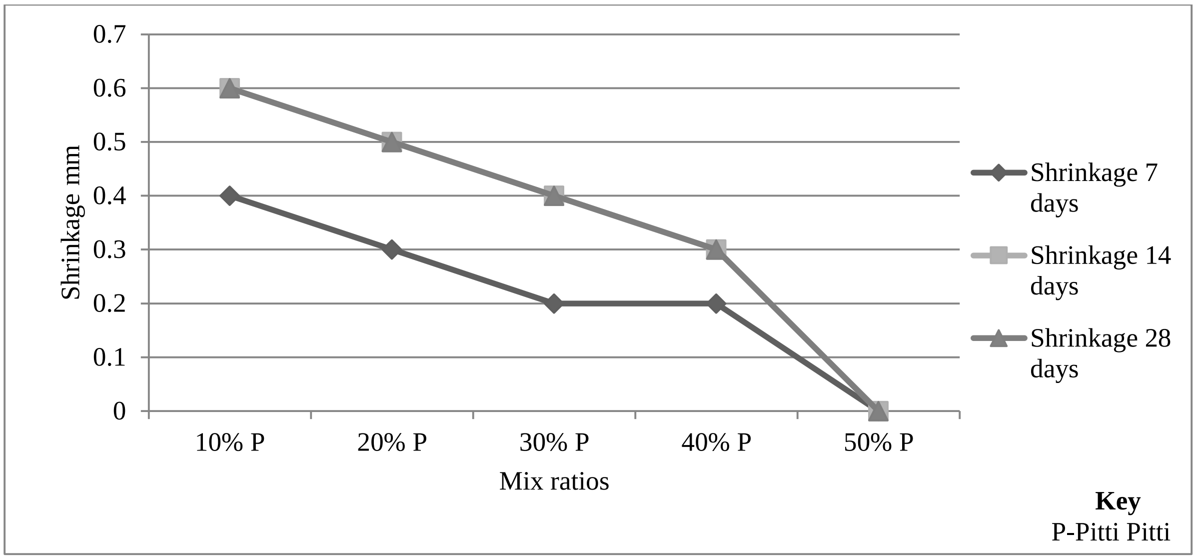


Figure 4.16: The shrinkage of local brewery waste and cement blended mortar

4.4.2 Shrinkage for mix ratio 1:6

Drying shrinkage was evaluated using mortar method. Increase in drying shrinkage was noted for increased substitution with bitter cassava flour. At 10% 0.3mm, at 50% 0.7 mm and there was no further shrinkage observed after 14 days of curing. This finding compared well with that of (Markus, 2011) reported that shrinkage should be minimized to avoid cracking of the mortar.

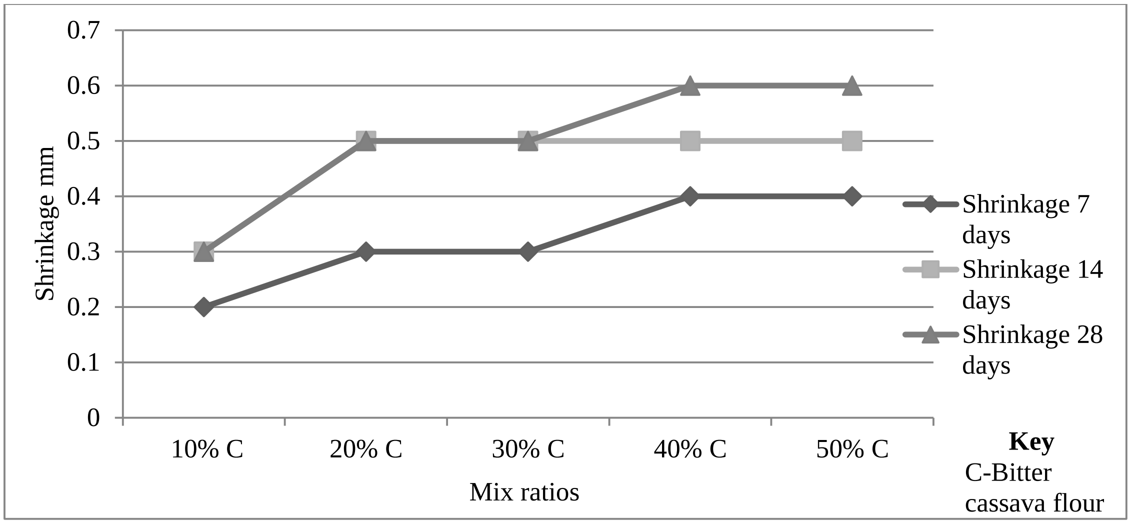


Figure 4.17: The shrinkage of bitter cassava flour and cement blended mortar

Generally lower drying shrinkage was noted for increase substitution with local brewery waste. At 10% 0.6mm, at 50% 0.0mm. This finding is in line with (Markus, 2011) reported that shrinkage should be minimized to avoid cracking of the mortar. This could have been why the mortar showed no crack at all level of replacement with local brewery waste and also the presence of yeast was also responsible for the expansion.

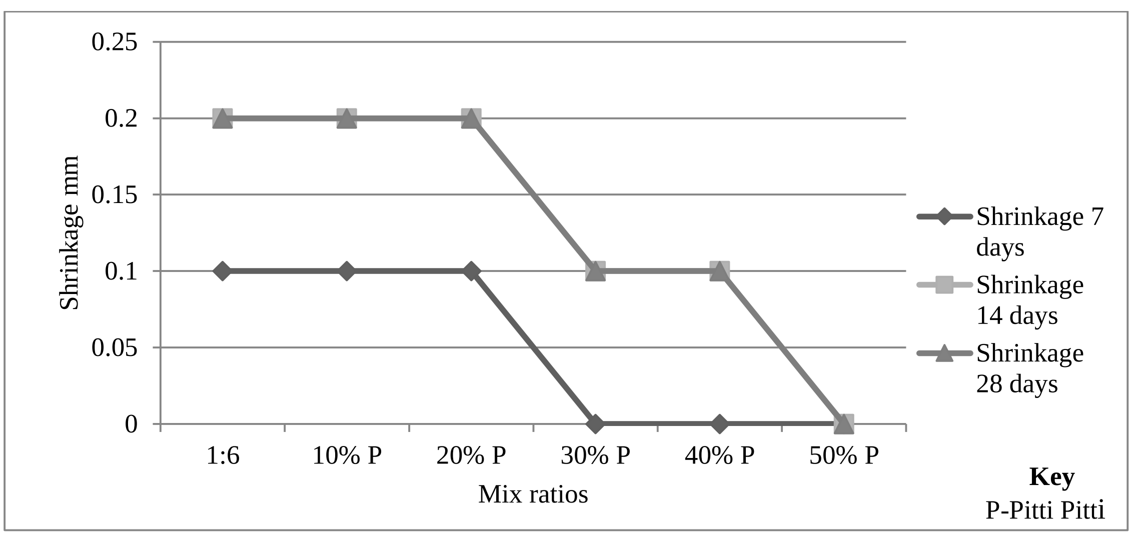


Figure 4.18: The shrinkage of local brewery waste and cement blended mortar

4.4 Bonding/Durability Test

This test was done by constructing a 500×500 mm walls and plastering with different mix of plaster. It was monitored for a period of 3 months. Properties monitored included the cracking propagation on the surface, effect of rain on the plastered surface. The main aim was to determine the extent of durability of the different plaster with the different cement replacement with pitti pitti and bitter cassava flour. The results showed that the different mix can be used as mortar plaster for plastering eco house which performs better than the mud plaster which is being used currently in northern Uganda. Bitter cassava flour and local brewery waste is strong but when used without cement it had so many cracks and becomes very weak when exposed to water. Therefore bitter cassava and local brewery waste mix with cement at any percentage of replacement bonds well with earth blocks and also the cracks are minimized better than the earlier practice of using bitter cassava flour mortar and local brewery mortar.

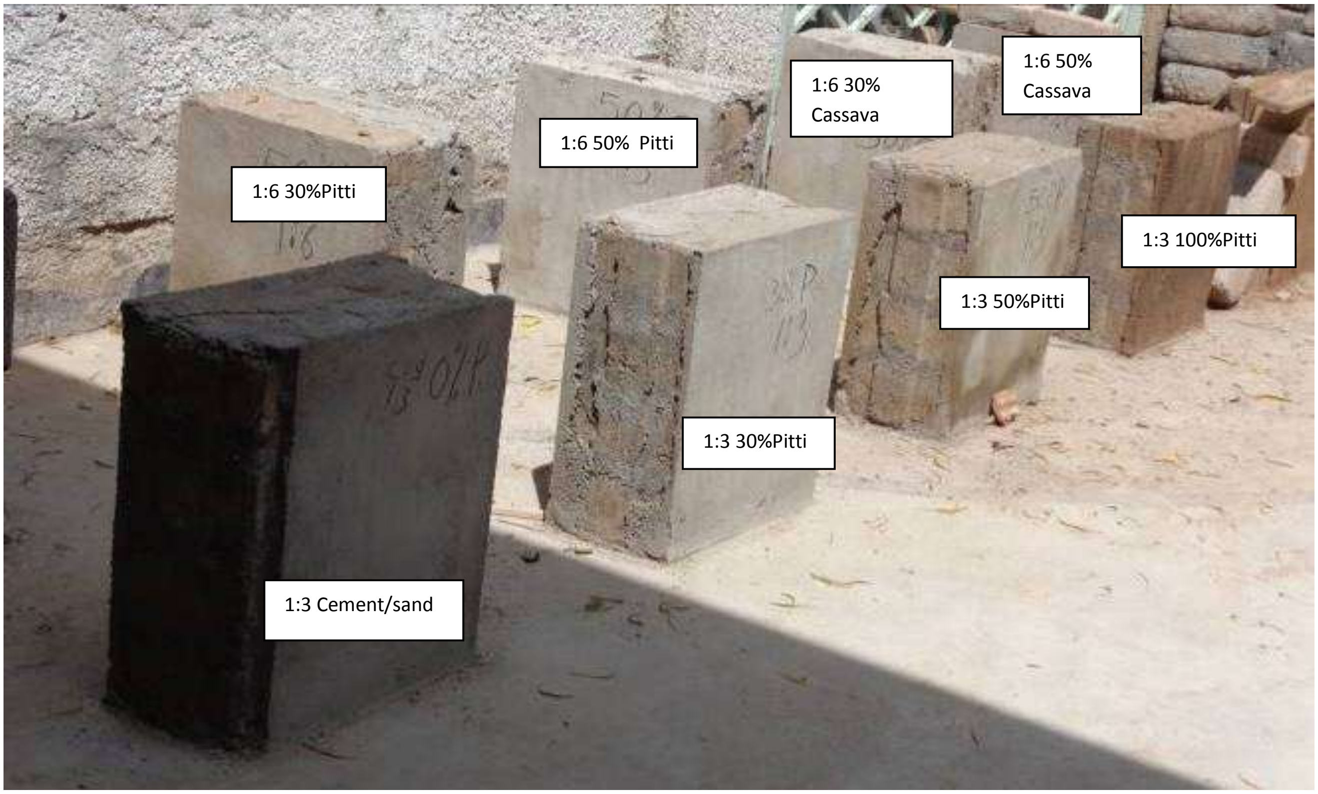


Plate 4.3: The photos of the walls that was constructed for bonding/durability test

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.0 CONCLUSIONS

This study examined the use of local brewery waste and bitter cassava flour as a partial replacement of cement for plastering eco houses in Northern Uganda. The findings of this study demonstrate clearly that local brewery waste and bitter cassava flour has a great potential for use as plaster mortar for eco house in sustainable building construction. More specifically, it is concluded that:

1. The physical and chemical properties of bitter cassava flour and local brewery waste are different from the conventional materials. In particular the percentage of the chemical elements of local brewery waste and bitter cassava flour which contains more of potassium (73.5% and 89.4% respectively) and Calcium (16.3% and 10.1% respectively) fall outside the range of percentage of chemical elements in cement which contains more of Calcium oxide 62% and Silicon oxide 21%.

2. Addition of local brewery waste and bitter cassava flour reduces the workability of mortar as more cement is being replaced with these two materials. Therefore the water cement ratio had to be increased from a range of 0.6-0.8 water cement ratio for 10-50% cement replacement which is different from the water cement ratio of conventional mortar of 0.5 water cement ratio.

3. Bitter cassava increases the level of shrinkage of mortar as its proportion is increased where the shrinkage increased from 0.4mm to 0.7mm for 10% to 50% replacement and the mixes containing only 40% and 50% bitter cassava cracked for mix ratios of 1:3 and 1:4. On the other hand, local brewery waste reduces the level of shrinkage of the plaster as more of

cement is replaced with local brewery waste where the shrinkage reduced from 0.5mm to 0.1mm from 10% to 50% replacement. There was no crack observed from all levels of replacement with local brewery waste.

4. Addition of bitter cassava and local brewery waste reduced the compressive strength as compared to the conventional mortar. Bitter cassava showed satisfactory compressive strength up to 20% replacement which gave strengths above the minimum strength of a stabilized soil block as per Kenya standards, American standards and British standards. However there was still a reduction in the strength by 28% from 10-20% replacement which further reduced by 43% to 30% replacement with bitter cassava flour. Local brewery waste showed 10% reduction in the compressive strength from 10% to 20% replacement.

5. At 40% and 50% replacement levels the compressive strength of mortar made from local brewery waste and cow dung increased as compared to the compressive strength of local brewery waste mortar. There was a 30% increment in the strength.

6. The plastered walls observed showed cracks when local brewery waste and bitter cassava are used as a binder in plaster mortar alone without cement. Bitter cassava flour and local brewery waste mortar crumbles when exposed to water but this improve greatly when cement is added to the mix. In general cement replacement up to 20% with bitter cassava flour can be used as plaster mortar for high cost houses with compressive strength above 7 MPa for all mix ratios examined in this study. Furthermore 30% of bitter cassava flour, 10% of local brewery waste and 50% with local brewery waste and cow dung can be used as plaster mortar for traditional eco houses for all mix ratios which satisfies the minimum compressive strength requirements.

5.1 RECCOMENDATIONS

The above study showed the potential use of bitter cassava flour and local brewery waste as a partial replacement of cement. The following recommendations can be made:

1. The conventional mortar made from cement and sand is not recommended to be used as mortar plaster for plastering eco house because they are too strong compared to the strength of eco house walls. Furthermore 10%-20% replacement with bitter cassava flour is also not recommended as mortar plaster for eco house because of high compressive strength. Only from 30-50% replacement with bitter cassava flour and all levels of replacement with the local brewery waste is recommended for plastering eco house because the strength attained is within the strength of the walls of the eco house. Therefore making it a good plaster for eco house.

2. Local brewery waste and bitter cassava flour mortar is not recommended to be used alone as mortar plaster for eco house because it produces a lot of cracks when used alone and it's not water resistant. However when mixed with cement much as the compressive strength is low, it is recommended to be used as mortar plaster for eco house especially the mix ratio which meets the minimum strength of a stabilized block as specified by the Kenyan standards or any other standards.

3. Local brewery waste should be investigated in its original state as it is believed that some of the important bonding ingredients are lost during the process of drying to obtain the powder. Furthermore the mix of cow dung and local brewery waste showed improved compressive strength of the blend therefore further investigation on these materials is recommended especially beyond 50% replacement as investigated in this study and also

be studied further in ash form after burning at a lower temperature to supplement what has been found in this study.

4. Deeper investigation on the chemical reaction between bitter cassava flour, pitti pitti and cement should be investigated to identify what other factors not mentioned in this study which could have caused the reduction in the compressive strength, shrinkage.

5. Local brewery waste should be investigated in its original state as it is believed that some of the important bonding ingredients are lost during the process of drying to obtain the powder. Furthermore the mix of cow dung and local brewery waste showed improved compressive strength of the blend therefore further investigation on these materials is recommended especially beyond 50% replacement as investigated in this study and also be studied further in ash form after burning at a lower temperature to supplement what has been found in this study.

REFERENCES

Adalberth, K. (1996). Energy demand during the life cycle of a building. CIB Symposium Energy Mass and Flow in the life Cycle of building, Vienna.

American Society for Testing and Materials. (2005). Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolana for Use as a Mineral Admixture in Portland cement Concrete, ASTM C 618.

Al-Jabri, K.S., A.W. Hago., R. Taha., A.S. Alnuaimi and A.H. Al-Saidy .(2009). Strength and Insulating Properties of Building Blocks Made from Waste Materials. Journal of Materials in Civil Engineering, Vol.21, No. 5, pp. 191-201

American Society for Testing and Materials (2004). C 1324-03, Standard Test Method for Examination and Analysis of Hardened Masonry Mortar, C 1329-04,Standard Specification for Mortar Cement.

Badejo, M.A .(2002). Termite and man-who wins? Entomological Society of Nigeria; no. 34

Balwaik , S.A and S.P. Raut .(2011). Utilization of paper pulp by partial replacement of cement in concrete. International journal of Engineering Research and Applications Vol.1 pp. 300-309.

Bentur, A. (2002). Cementitious materials-nine millennia and a new century: Past, present and future. ASCE J Mater in Civil Engineering Vol 14(1), pp.1-22.

Bentz, D.P., J.G. Edward., C.J. Haeker., O.M. Jensen. (1999). Effect of cement particle size distribution on performance properties of Portland cement based materials. Cement and concrete research. Vol 29. pp. 1663-1671

Biricik, H., F. Akoz., I. Berktay., A.N. Tulgar. (1999). Study of pozzolanic properties of wheat straw ash. Cement Concrete Research Vol.29. pp. 637- 643.

Celik, I. B. (2009). The effects of particle size distribution and surface area upon cement strength development. Powder Technology, Vol.188 , pp. 272-276.

Etuu, L.O., M.S.W. Mbajirorgu., J.I. Arimanwa. (2013). Strength of blended cement sandcrete and soilcrete blocks containing cassava waste ash and plantain leaf ash. American Journal of Engineering Research. Vol. 02. pp. 55-60

Faseyemi, V.A. (2012). Investigation on Microsilica (Silica Fume) As Partial Cement Replacement in Concrete. Global Journal of Researches in Engineering Civil and Structural Engineering. Vol 12. Issue 1.

Fernando, P.T and Said, J. (2009). Compressive strength and durability properties of ceramic wastes based concrete. Materials and Structures, Vol.44. pp.155-167

Ganesan, K., K. Rajagopal., K. Thangavel. (2007). Evaluation of bagasse as supplementary cementious material. Cement and concrete composite. Vol. 29. pp. 515-524

Guillaud, H. (2008). Characterization of earthen materials. An overview of research in earthen architecture conservation. Los Angeles (United States): The Getty Conservation Institute. pp. 21-31

Hardjito, D., S.E. Wallah., D.M.J. Sumajouw., B.V. Ragan. (2004). On the development of fly ash based geopolymer concrete. ACI materials Journal. Vol. 101(6)

Janotka, I., SC. Mojumdar. (2007). Degree of hydration in cement paste and C3A–sodium carbonate–water systems. J Therm Anal Calorim Vol. 90 pp. 645–652.

Kula, I., A. Olgun., V. Sevinc., Y. Erdogan. (2002). An Investigation on the use of tincal ore waste, fly ash, and coal bottom ash as Portland cement replacement materials. Vol. 32 pp. 227-232

Malhotra, V.M. (2002). Introduction to Sustainable development and concrete technology. Concrete International. Vol 24 (7). pp. 22-29

Markus, G. (2011). Measuring the early shrinkage of mortars. Dry mix mortar yearbook. www.schleibinger.com/cmsimple/?download=shrinkage_nbg_2011.

Metha, P.K. (2001). Reducing the environmental impact of concrete. Concrete international Vol. 23(10). pp. 61-66

Mehta, PK. (1992). Rice husk ash-A unique supplementary cementing material. Proceeding of the international symposium on advances in concrete tech, Athens, Greece. pp.407-430.

Musiomi, T.M. (2009). Laterized quarry dust and recycled concrete as alternative building materials. Master degree thesis, school of civil engineering, Jomo Kenyatta University of Agriculture and Technology.

Neville, A. M. (1995). Properties of Concrete. (Fourth and Final Edition), Pearson Educational Limited,

Nweke, F., D. Spencer, J. Lynam. (2002). The cassava transformation: Africa's best kept secret. Michigan State University Press, East Lansing, USA.

Ogunbode, E.B., and W.P. Akanmu (2012). Turning waste to wealth: Potential of laterized concrete using cassava peels ash (CPA) blended cement. International Journal of engineering research and technology. Vol 4. Issue 3.

Olusola K.O., E.A. Alanipekun., O.T. Olateju. (2006). Studies on termite hill and lime as a partial replacement of cement in plastering. Building and Environment Journal. Vol. 41 pp. 302-306.

Paul , B. (2011). A report on contemporary rammed earth construction and research in North America. International Workshop on Rammed Earth Materials and Sustainable Structures & Hakka Tulou Forum.

Rawas, A., A.W. Hago., R. Taha., K. Al-Kharousi. (2004). Use of incinerator as a replacement for cement and sand in cement mortars. Building and Environment Journal. Vol. 44 pp. 545 -555

Saul, S. N. (2006). Development of Cost-Effective Earthen Building Material for Housing Wall Construction: Investigations into the Properties of Compressed Earth Blocks Stabilized with Sisal Vegetable Fibres, Cassava Powder and Cement Compositions. A Doctoral Dissertation, Approved by the Faculty of Environmental Science and Process Engineering of the Brandenburg Technical University Cottbus. pp 38 and 148.

South, W. (2009). A study of compressive strength and drying shrinkage of cementitious binders prepared using natural pozzolans. Doctor of philosophy thesis, school of civil engineering, mining and environmental engineering, University of Wollongong. pp 4

Winderstorm , B. and A. Schmidt. (2011). A report on contemporary rammed earth construction and research in North America. Sustainability ISSN 2071-1050.

Yang K.H., H.Z Hwang, S.Y. Kin ., J.K. Song. (2006). Development of a cement less mortar. Building and Environment Journal, Vol. 42, pp. 3717-3725.

Zhang M.H and Malhotra V. (1996). High-Performance concrete incorporating rice husk ash as supplementary cementing material. ACI Material Journal. Vol. 93(6). pp. 629-636.

APPENDICES

Summarized raw data

Compressive strengths at 7 days

Mix Ratio 1:3	Average Weight (g)	Average Load (KN/mm^2) at 7 days	Compressive Strength (Mpa) at 7 days
10% C	2134	132.4	13.2
20% C	2100	100.3	10.0
30% C	2059	18.8	1.9
40% C	2026	14.3	1.5
50% C	2002	11.4	1.1
10% P	2066	9.2	0.9
20% P	2147	8.1	0.8
30% P	2048	7.5	0.8
40% P	2036	6.1	0.6
50% P	1991	5.7	0.6
Mix Ratio 1:4	Average Weight (g)	Average Load (KN/mm2) at 7days	Compressive Strength (Mpa) at 7 days
10% C	2189	127.0	12.7
20% C	2209	87.2	8.7
30% C	2035	10.3	1.0
40% C	1998	8.9	0.9
50% C	1850	6.1	0.6
10% P	2180	9.1	0.9
20% P	2150	9.1	0.9
30% P	2115	9.1	0.9
40% P	2171	7.6	0.8
50% P	2010	4.0	0.4
Mix Ratio 1:6	Average Weight (g)	Average Load (KN/mm2) at 7days	Compressive Strength (Mpa) at 7 days
10% C	2210	74.1	7.4
20% C	2055	59.4	5.9
30% C	1995	14.2	1.4
40% C	1890	10.0	1.0
50% C	1750	8.1	0.8
10% P	2142	2.9	0.3
20% P	2107	2.6	0.3
30% P	1960	2.5	0.3
40% P	1895	1.9	0.2
50% P	1750	1.6	0.2

Compressive strength at 14 days

Mix Ratio 1:3	Weight (g)	Average Load (KN/mm2) at 14 days	Compressive Strength (Mpa) at 14 days
10% C	2199	174.244	17.424
20% C	2114	129.538	12.954
30% C	2098	36.323	3.629
40% C	2004	19.44	1.944
50% C	1980	15.107	1.511
10% P	2040	14.784	1.478
20% P	2008	13.203	1.32
30% P	1985	11.108	1.111
40% P	1978	9.277	0.928
50% P	1972	7.194	0.719
Mix Ratio 1:4	Weight (g)	Average Load (KN/mm2) at 14 days	Compressive Strength (Mpa) at 14 days
10% C	2234	153.2915	15.329
20% C	2139	112.052	11.206
30% C	2078	15.793	1.579
40% C	2040	13.105	1.311
50% C	2000	11.961	1.196
10% P	2200	15.481	1.548
20% P	2180	12.795	1.279
30% P	2100	12.406	1.241
40% P	2029	10.566	1.057
50% P	1980	9.283	0.928
Mix Ratio 1:6	Weight (g)	Average Load (KN/mm2) at 14 days	Compressive Strength (Mpa) at 14 days
10% C	2235	76.682	7.668
20% C	2031	62.285	6.229
30% C	1998	15.303	1.53
40% C	1890	12.743	1.274
50% C	1750	9.031	0.903
10% P	2160	5.713	0.571
20% P	2120	5.044	0.504
30% P	1980	4.453	0.445
40% P	1915	2.984	0.298
50% P	1880	2.19	0.219

Compressive strength at 28 days

Mix Ratio 1:3	Average Weight (g)	Average Load (KN/mm2) at 28 days	Compressive Strength (Mpa) at 28 days
10% C	2111	219.02	21.902
20% C	2088	181.261	18.126
30% C	2029	36.828	3.683
40% C	2008	19.117	1.974
50% C	1980	17.278	1.728
10% P	2104	20.943	2.094
20% P	2091	19.287	1.929
30% P	1916	16.691	1.669
40% P	1899	13.123	1.312
50% P	1780	10.419	1.042
Mix Ratio 1:4	Average Weight (g)	Average Load (KN/mm2) at 28 days	Compressive Strength (Mpa) at 28 days
10% C	2250	177.655	17.765
20% C	2160	137.629	13.763
30% C	2055	20.134	2.013
40% C	2038	16.799	1.679
50% C	1990	12.398	1.239
10% P	2240	16.847	1.685
20% P	2188	15.123	1.512
30% P	2048	13.67	1.367
40% P	1990	11.506	1.151
50% P	1977	9561	0.956
Mix Ratio 1:6	Average Weight (g)	Average Load (KN/mm2) at 28 days	Compressive Strength (Mpa) at 28 days
10% C	2266	85.258	8.526
20% C	2166	69.465	6.947
30% C	2008	18.294	1.829
40% C	1996	16.215	1.622
50% C	1800	9.896	0.989
10% P	2168	8.929	0.893
20% P	2140	8.765	0.877
30% P	1998	6.459	0.646
40% P	1912	5.079	0.508
50% P	1800	4.27	0.427

Shrinkage test results

Mix	Initial value	Final Value 7 days	Final Value 14 days	Final Value 28 days	Shrinkage 7 days	Shrinkage 14 days	Shrinkage 28 days
1:3	29.9	29.8	29.7	29.7	0.1	0.2	0.2
10% C	30	29.7	29.6	29.6	0.3	0.4	0.4
20% C	30	29.7	29.6	29.5	0.3	0.4	0.5
30% C	30	29.7	29.5	29.5	0.3	0.5	0.5
40% C	29.8	29.4	29.2	29.2	0.4	0.6	0.6(Crack)
50% C	29.2	28.8	28.6	28.4	0.4	0.6	0.8(Crack)
10% P	30.1	29.9	28.6	28.6	0.2	0.5	0.5
20% P	30	29.9	29.6	29.6	0.1	0.4	0.4
30% P	29.7	29.6	29.5	29.5	0.1	0.2	0.2
40% P	30.3	30.2	30.1	30.1	0.1	0.2	0.2
50% P	29.9	29.8	29.8	29.8	0.1	0.1	0.1
100%P	29.8	29.8	29.8	29.8	0.0	0.0	0.0
1:4	30	29.8	29.7	29.7	0.2	0.3	0.3
10% C	30	29.7	29.6	29.6	0.3	0.4	0.4
20% C	30	29.7	29.6	29.6	0.3	0.4	0.4
30% C	30	29.6	29.5	29.5	0.4	0.5	0.5
40% C	30	29.5	29.4	29.4	0.5	0.6	0.6(Crack)
50% C	29.8	29.3	29.1	29.1	0.5	0.7	0.7(Crack)
10% P	29.9	29.5	29.3	29.3	0.4	0.6	0.6
20% P	30	29.7	29.5	29.5	0.3	0.5	0.5
30% P	29.7	29.5	29.3	29.4	0.2	0.4	0.4
40% P	29.5	29.3	29.2	29.2	0.2	0.3	0.3
50% P	30.1	30.1	30.1	30.1	0.0	0.0	0.0
1:6	30	29.9	29.8	29.8	0.1	0.2	0.2
10% C	29.8	29.7	29.5	29.5	0.2	0.3	0.3
20% C	30	29.7	29.5	29.5	0.3	0.5	0.5
30% C	30	29.7	29.5	29.5	0.3	0.5	0.5
40% C	30	29.6	29.5	29.4	0.4	0.5	0.6
50% C	29.8	29.4	29.3	29.2	0.4	0.5	0.6
10% P	30	29.9	29.8	29.8	0.1	0.2	0.2
20% P	30	29.9	29.7	29.7	0.1	0.2	0.2
30% P	29.8	29.8	29.7	29.7	0.0	0.1	0.0.1
40% P	30.1	30.1	30	30	0.0	0.1	0.1
50% P	30	30	30	30	0	0	0

Plate 1: Showing walls plastered with local brewery waste and bitter cassava flour and sand

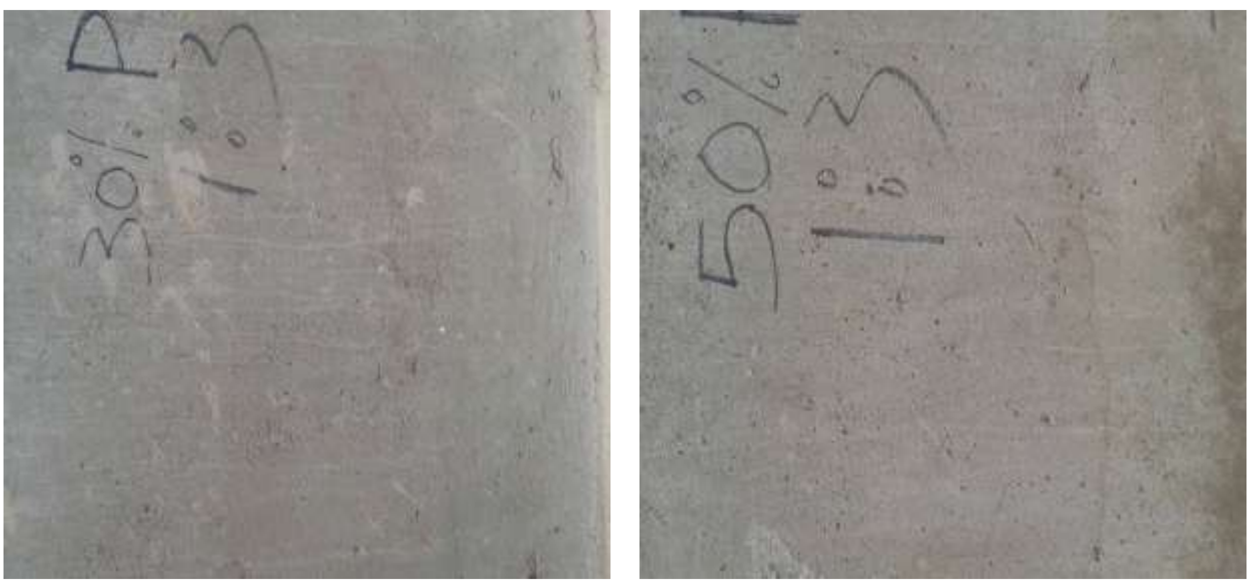


Plate 2: Showing walls plastered with local brewery waste at 30% and 50% cement replacement

Plate 3: Showing walls plastered with bitter cassava flour at 30% and 50% cement replacement

Plate 4: Showing walls plastered with different mortar mix

Plate 5: Showing different specimens cast for shrinkage test

Plate 6: Showing universal testing machine