Effect of Cow Dung, Cement and Fiber on Earthen Brick

MSc Thesis

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Effect of Cow Dung, Cement and Fiber on Earthen Brick

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APPROVAL SHEET

As member of the examining board of the final MSc open defense, we certify that we have read and evaluate thesis prepared by Aster Memiru entitled Effect of Cow Dung, Cement and Fiber on Earthen Brick and recommended that it can be accepted as fulfilling the requirements for the MSc thesis.

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Declaration

I declare that this thesis, entitled as "Effect of Cement, Cow dung and Fiber on Earth Brick" is my reliable work done under Dr. Temesgen Wondimu advice, and all sources of materials used for this thesis have been duly acknowledged.

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I hereby certify that I have read this thesis and it is prepared under my direction. So I recommend that it accepted as fulfilling the thesis requirement.

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Acronym

ASTM American standard test manual

CEB Compressed Earth Block

KN Kilo Newton

LL Liquid limit

MPa Mega Pascal

PL plastic limit

PI Plasticity index

TGA Thermal Gravimetric Analysis

USCS Unified soil classification system

Abstract

Now days demand for housing is increasing because of fast population growth. To fulfill this need it is better to search for alternative construction materials, which are economically affordable. Earth is one of the potential construction materials, which can fill this gap. Earth housing is the most common housing used around the world. In Ethiopia, the "cob" type of housing method is the most common one. This research focuses on Adobe blocks that constructed from earth material. The aim of this research is to study the effect of cement, fiber and cow dung on the property (compressive strength and water resistance) of adobe block. Types of stabilizer used are Enset fiber, cement and cow dung. The amount of stabilizer used for this study is 0.2, 0.4 and 0.6% for Enset fiber, 2, 4 and 6% for cement and 5, 10 and 15% for cow dung of the dry mass of the soil. The result of this research indicate that both type and amount of stabilizer (cement, fiber and Cow dung) used affect the property of Adobe block produced. Comparison between the effects of Enset fiber and chid fiber on compressive strength and water resistance of Adobe block is also studied and also their property at failure. The results indicate that blocks stabilized with Enset fiber performed well under compression load and water when soaked. The optimum amount of fiber for compressive strength and water resistance is also determined. The other important finding in this research is the positive effect of cow dung on Adobe block. Loss of material, water absorption and loss of strength after soaking of adobe block stabilized with Cow dung is very less than block stabilized with cement or fiber. Therefore, cow dung significantly improves durability of block. Generally, from this research it can be concluded that well stabilized Adobe block can serve as potential construction material.

1.0 **INTRODUCTION**

Ethiopia is a country that is well endowed with natural resources, forest. However, deforestation has gone for the last five decades. Forests, which were above 40% of the country's landmass in the beginning of 20th century, are reduced into 2.36% in 2000. The main causes are agricultural expansion; the increasing demand for construction material, industrial use, fuel wood and charcoal; lack of a forest protection and conservation policy, etc. (Tigabu Dinkayoh, 2016). Out of the cause listed above for deforestation, growing demand for timber for construction purpose is one. So to support agents striving for restoring the past coverage of forest in Ethiopia the construction industry must find an alternative construction material and construction technique which minimize consumption of trees because the current construction system is becoming the leading cause for the degradation of the ecosystem. It is resulting air pollution by the emitting non environmentally friendly gases to the air, greenhouse effect by consuming large amount of trees for building construction. In addition to the effect on the environment, durable high strength construction materials are not affordable by the majority of society in most developing countries (including Ethiopia). Therefore, the need to strive for alternative construction material is for not only giving solution for the environment but also providing affordable construction material for the society as responsible body.

Most of the buildings constructed in our country made up of timber and concrete. Especially among society with low income, almost all of the building elements are timber made. The walling system are the Cob type of wall construction method. In this walling methods fter wood placed, mud mixed with straw (locally named "Chid") applied to fill the opening between the woods. The fiber (chid) applied in to mud to enhance the tensile strength of mud. Fibers in mud also enhance the compressive strength of the compressed mud brick preventing the region near the surface form crushed and falling off.

The best answer to the current environmental and community problem is limiting deforestation (enhancing reforestation) and delivering best alternatives construction material. Without locating alternative material to the society conducting regulation on deforestation is not the correct solution because why they need it is to fulfill their necessity. Our community deserves the local governments to deliver them systematic ways how to construct "high performance building". A ―high-performance building is as defined in the Energy Policy Act of 2005 —a building that integrates and optimizes all major high performance building attributes, including energy efficiency, durability, life cycle performance, and occupant productivity. For low cost housing building system for our country earth brick (Adobe) without timber addition can replace walling system.

The first evidence of earth being formed into a brick was discovered in the upper Tigris basin and dates back as far as 7500 BC [Vendana Sharma, et.al 2016] .This will reduce amount of timber consumed for building construction. Also since source and preparation of Earth brick (Adobe) performed easily by the owners within home, it reduces the construction cost.

Research done on earth as construction material revealed that, without addition of stabilizer using earth for construction purpose is dangerous because it is easily degenerated by water and its tensile strength is very weak. According to the researches by applying different stabilizer, the mechanical strength of mud can be improved. Therefore, it can be potential alternative construction material. Hamifi Binici et al., (2004) have investigated fiber reinforced mud brick for using as a building material. According to the study fiber reinforced mud brick shows high improvement in compression, water absorption and loss of water as compared to mud without fiber. However, the fiber effect differ based on the type of fiber used and amount of material used. Hamifi Binici et al. during their research used different types of fiber with varying fraction. Their effect on water absorption and material loss was investigated, and the results obtained show the difference among fibers type.

The important thing in earth construction is durability problem. Though earth building constructed in dry region can serve long period of time, those constructed in rainy area experience erosion due to wind driven rain. To improve durability of earth construction research by Younoussa Millogoa et.al. , (2016) was conducted. To achieve this they use cow dung as stabilizer. They study the effect of addition of cow dung on the physical and mechanical property of the mud material. According to the study, incorporation of cow dung in to mud shows significant improvement in water resistance of adobe. This is because cow dung reacts with kaolinite and fine quartz to produce the insoluble silicate amine. Therefore, if different research is conducted on mud to study its feasibility as construction material, on good finding can be reached.

1.2 Statement of the problem

The current frequently used construction material in our country is wood and concrete. Both the materials are not environmentally friendly. Consumption of wood is leading to environmental degradation, deforestation, resulting global warming. The same is true for concrete also. Cement is the important constituent of concrete which binds the aggregate together for good stress transmission between the materials so that material to act as single material. But cement and aggregate manufacturing are causing air pollution by the gas emitted from the factories. So strive to the best alternative construction material which is environmentally friendly, cheap, which require unsophisticated professional skill is unquestionable. Stabilized mud blocks with improved water resistance if is introduced in to the society can fulfill the above requirement. Mud bricks have several advantages over the conventional fired brick and concrete block. This is because mud blocks are constructed form abundantly available material, soil. The stabilizers like straw, kancha, etc. are also available in large quantity in our country. From thermal and sound conductivity point of view stabilized manually compressed mud bricks perform well. If sort term training is given to the community they can adopt the technique easily.

1.3 objective of study

Therefore, the main objective of this paper is to study the effect of addition of cement, cow dung and fiber (Chid and kancha (Enset fiber)) on physical and mechanical property of brick earth brick (Adobe). The optimum amount of cow dung and Enset fiber that must be used to achieve durable and high compression block will be determined. Different mixes containing different proportion of cement, cow dung and Enset fiber prepared to know the effect of the stabilizer on physical and mechanical property of adobe block. Fiber used for this research is Enset fiber; its difference with respect of commonly used fiber, chid is also considered. The other stabilizer used is PPC cement made by Dangote and cow dung. Younoussa Millogoa et al. on their study used 1, 2 and 3% of cow dung to study its effect. Their findings indicate that increasing amount of cow-dung increase water resistance of block and improve compressive strength of block. However, in this research 5, 10 and 15% of cow dung was used in order to determine optimum amount of cow dung required to achieve maximum compressive strength and water resistance. Generally, their effect on compressive strength, and crack and water absorption was determined.

2.0 LITERATURE REVIEW

2.1 Enset Fiber and cow dung

Enset fiber is wastea product of plant called false banana (Enset) which used as food source (kocho) in Ethiopia. More than 20% of population in southern part Ethiopia depends on Enset for food, fiber, dodder, construction material and for medicines (Ayele and Sahu; Gabel and Karlesson 2013). Domestic Enset grow to produce a starchy food, pseudo stem and corm. Different types of residues are disposed commonly during kocho preparation. Among them fiber, leaf and inner part of pseudo stem are the main one. Fiber collected after scraping of the leaf sheath and leaf bases around the pseudo stem. The residues of Enset fiber used for many purposes. For example use in textile industries (Ayele and Sahu, 2014), paper making and packing industries (Johansson et al. 2012), pharmaceutical application (Kadajji and Betageri, 2011) etc.

Cow dung has a significant role in plant growth promotion and plant protection. Importance of cow dung includes:

- Used as purifier and in preserving environment by burning it in home
- Used as fertilizer, it has significant role in crop growth as manure
- As fuel in biogas production

2.2 Related works

Making adobe brick is an art, so making best adobe work require experience (Thomas Dominguez. 2011). Different things affect the performance of adobe. It including soil type (amount of clay, silt and sand), amount of water added, the type and amount of stabilizer used to stabilize adobe,(cement, lime, gypsum, fiber,…etc). The important part of adobe soil is clay. Clay gives cohesion and waterproof for adobe. But its amount matter. Clay by its nature is unstable under moisture condition variation. So its amount should not be much greater. The acceptable clay content with adobe soil varies among different literatures and codes.

To optimize the characteristics of adobe soil different studies are conducted. Among additives used to stabilize soil for adobe block production includes, cement, lime, gypsum, fiber, emulsified asphalt, ashes, …etc. most of researches conducted on adobe focused on improving compressive strength, flexural strength, durability (due to water) , linear shrinkage and crack and so on by adopting different mechanisms.

Gernot Minke, (2007) performed researches and development on university of Kassel, Germany for 30 years on earth building. He studies the effect of cement on compressive strength and water absorption of adobe blocks. His studies showed that addition of 2-6% of cement would normally decrease the resistance against compression and flexure, also not improve water resistance of adobe blocks. Block with 2% cement absorbs 2.4times and with 4%, cement absorbs 3.5times as much water as without cement. G, Minke recommended not to use if grain size distribution and content of loam is acceptable; so that we decrease construction cost and reduces environmental pollution.

Hanifi Binici, et.al, (2004) published the paper on fiber reinforced mud brick. Thy try to fill the knowledge gap exist on home brick-makers on balancing ingredient during proportioning of fiber and mud. Fibers on the mud brick hinder transverse expansion due to Poisson's effect, increase compressive strength, and improve the elasticity of mud brick. Though fibers improve the characteristics of brick the amount added has to be balanced. They believe that balancing of ingredient affect the optimization of the production. This research study the compressive strength of fiber (straw, plastic fiber and polystyrene) reinforced mud brick made out of clay, cement, basaltic pumice, lime and gypsum. During the research thin horizontal layer of fibers was placed at 1/3 and 2/3 height of brick. Compressive strength of fiber reinforced brick recorded higher improvement as compared to Turkish standard for traditional mud brick, 0.1-1N/mm^2. The range of compressive strength recorded in the study was 3.7-7.1N/mm^2, plastic fiber record the highest value. Since the strength increased substantially, the thickness of the outer load-bearing wall can be reduced, which lower the cost of material and reduce the weight of the structure as whole. The compressive strength of brick with plastic fiber recorded 19% and 36% higher than brick with straw and polystyrene fiber respectively. For the improvement of brick characteristics soil type, stabilizer type and amount of stabilizer added has great contribution.

Younoussan Millogo, et.al, (2016) published their research work that tries to investigate the effect of cow dung on earth blocks. The main objective of this work was to produce low cost, resistant and durable (good resistant to water) blocks with a thermal behavior enabling quality comfort indoor. To achieve this effect of cow dung on the microstructural changes of earth blocks investigation by means of X-ray diffraction, thermal gravimetric analysis, scanning electronic microscopy coupled with energy dispersive spectrometer and video microscopy. Cow dung effect on physical property (water absorption and linear shrinkage) and mechanical property (flexural and compressive strength) of adobe block investigated. The material used for this research was lateritic clay and cow dung. These two materials first dried and crushed to make ready for the past preparation. Cow dung amount used for the mix preparation was 0, 1, 2, and 3%. Constant amount of water was added in all mix group; w (%) = (liquid limit + plastic limit)/2. The mix left on the plastic bag for 72hr before specimen preparation to allow cow dung fermentation. After then the block having (4x4x16) cm dimension was prepared by manually pressing the mix in to the mold. And the as molded adobes were stored for 21 day at room temperature. The chemical composition of the raw material was estimated on digested crushed samples of size <80micro meter by inductive coupled plasma- Atomic Emission Spectrometer (ICP_AES). X-ray diffraction and Thermal Gravimetric Analysis (TGA) used to study the mineralogical composition of the raw material. TGA carried out on a crushed sample of cow dung heated to 1000^{o}c.

The flexural strength and compressive strength was determined at loading rate of 50N/m and 2400N/m respectively. In addition, their accuracy was 5% and 3% respectively. For each formulation 3 specimens was used. The water absorption for this study performed according to the NF p13-305 standard on three specimens as recommended.

The soil sample used for this research made up of 43% sand, 17.5% silt and 36% clay; the soil selected was rich in fine fraction. And the plasticity index of the material was 24% , indicating medium plastic sample according to the standard XP P94-011. The methylene blue value of the raw material was 1.57g/100g and its clay activity was 4.9, which is quite close to that of kaolinite; the soil does not contain swelling clayey minerals. The soil mineral composition was 66w% kaolinite, 21w% quartz and 18w% of goethite.

According to this research, both water absorption and linear shrinkage of adobe decrease as the cow dung content increase. This is because the cow dung reacts with the mineral (kaolinite and quartz) in the soil to form the insoluble silicate amine, which glues the isolated soil particles together. According to this research cow dung addition improve the both the flexural and compressive strength of adobe. Because of the above finding the researchers concluded that adobe stabilized with cow dung can be used as building material in wet climate.

Aime` Jules Fopossi et.al (2014) published their work on compressed earth block to investigate the effect of stabilizer on the water absorption of compressed earth blocks.

B.O.Ugwuishiwu et.al (2013) published the work on compressed earth block to study the effect of natural fiber reinforcement on water absorption of compressed stabilized earth blocks. The material used for the study was soil, stabilizer, and fiber. The soil taken was lateritic soil type. Its particle size distribution was78% coarser fraction and 22% fine fraction for type 1 soil and 92% coarser fraction and 8% fine fraction for type 2 soil. And plastic index was 11% and 22% for type 1 and 2 soil respectively. Cement which is manufactured by Dangote cement factory was used as stabilizer. The fiber consumed was palm kernel from a privately owned oil palm processing mill in Anambah state, Nigeria. The specimen is prepared after the materials are well mixed both in dry and wet form. During this research the dry mixing was done for about four minutes. After then water which is sufficient for hydration was added in to the dry soil, fiber and stabilizer mix. Specimen preparation was done using a locally manufactured press. Compression procedures were done in three stages: mound filling, molding and de-molding. After the mold is prepared it is left for curing. Primary curing last for 7 days by covering the specimen with plastic bags to prevent cracking due to rapid water loss from the blocks. The secondary curing last for 28 days; then it be ready to perform the required water absorption test.

The test performed revealed that as the fiber content increase the water absorption of block increase.

Water absorption of different blocks of different fiber content ranges from 5.68%-12.53%. The larger value corresponds to 5% fiber content. But there is no significant difference between 0, 1 and 2% fiber content. The result of this study shows that compressed stabilized earth blocks with fiber have higher permeability as compared to block without fiber. This is because during drying process fiber losses its moisture and get shrink; it gets reduce in size leaving free space between the soil mass and the fiber, aiding easy ingress of water in to the block.

Vendana Sharma et.al (2016) studies the effect of natural fiber on adobe block durability property. The need for adobe for construction purpose in India is shifting towards the modern construction material; cement, glass, burnt brick and similar other material because of the drawback of adobe (low durability and low compressive strength).

The abandonment of the vernacular construction material initiates this research to improve its draw back by modifying it physical and mechanical property by addition of natural fiber Grewia Optiva and Pinus Roxburghii. The main aim of this work was to provide a sustainable way to address rural housing problem due to constraint of construction material.

The soil they used for the study is sandy having the following characteristics, Classification as per Indian Standard SC

Specific gravity of soil solids, G 2.67

Liquid limit % 23.29

Plastic limit % 17.79

Plasticity index, PI 5.512

Water content % 12.5

The fiber they used is Pinus Rox-burghii (Chir Pine) and Grewia Optiva (Beul) indigenous in India. For conducting the test the specimen with dimension 19cmx9cmx9cm, as per Indian code provision (Is: 1725, 1985: IS: 4332-1, 1967) produced using the soil fiber mix. The mix was prepared as per Indian standards (IS: 2110, 1980 for cylindrical sample and IS: 1725, 1982 for cubic sample). The soil fiber mixture was first mixed in dry state and then kneaded properly with hands after addition of water to achieve randomly distributed in soil. Then fiber-soil matrix was compacted mechanically as per code provision (IS: 2110, 1980; IS:4332-1; 1967; IS: 4332-2, 1967). The fiber-soil matrix was compacted in to three equal layers in the mold and each layer was compacted before filling in the subsequent layer. The samples were dried for 4 weeks after they prepared. Durability test (wetting and drying, water absorption, spray, total absorption test and wet to dry strength ratio test) was conducted.

The result of the study revealed that addition of fiber Grewia Optiva and cement leads to maximum improvement in durability. From wetting and drying cycling test those samples which are untreated and unsterilized and stabilized and unreinforced broken after the 1^{st} and 4^{th} cycle respectively, but the sample with 2% Grewai Optiva showed maximum improvement in durability with 95.42% reduced weight loss. Water absorption and expansion test showed that the sample with 2% Grewai Optiva showed minimum water absorption as compared to other samples; it followed by sample with 1% pinus Roxburghii. Sponge water test (performed to imitate moderate and low rain fall condition accompanied by occasional wetting and drying) display that minimum weight loss occur in sample with 2 % Grewai Optiva with 48% reduced water absorption, followed by sample with 1% pinus Roxbughii with 42% reduced water absorption. The other test performed in this study was spray test that imitate heavy rain fall condition. Sample with 2% Grewai Optiva experience no erosion after test conducted. Sample with 2% Pinus Roxburghii and 2.5% cement showed average erosion during the test. From this test we understand that when adobe stabilized with cement and Grewai Optiva its durability increase proportionately. The total water absorption test conducted to identify the maximum water absorption capacity of adobe. In this test, there is also proportionate improvement in durability. The researcher has recommended that stabilization of adobe with Grewai Optiva (2% by weight) and Pinus Roxbughii (1% by weight) is advantageous for producing improved and durable adobe for rural house wall construction.

Esther Obonyo et.al (2010) published the paper on compressed earth brick. Their aim was to assess the erosion resistance of compressed earth bricks that are stabilized using cement and lime using the modified Spray Testing. Compressed earth blocks are environmentally friendly construction material resulting lower cost to the owner and environment during construction phase. Nevertheless, its durability problem and its associated short service life reduce the sustainable use of this material. The major deteriorating agent for this material is wind driven rain splashing on the adobe. The durability of the brick was therefore assessed based on their resistance to wind driven rain erosion. During the studies different specimen were sprayed with water at 2.07Mpa and 4.14Mpa for one hour to know the depth of erosion.

The soil selected (11% clay, 2% silt and 87% sand) was not ideal for use in the production of compressed earth brick, so to improve its workability chemical stabilizer; cement, lime and natural fiber was added according to the guidelines developed by Haro Streeter (*Determining Optimal Stabilizer*; HSI: Pleasanton, CA, USA, 2008). After preparing the mix a specimen was prepared. The fabricated brick was cured for 2-3 weeks by exposing to sunlight followed by air drying for a week. During that water was sprinkled over the brick to optimize the curing process. Then the specimen was subjected to durability and compressive strength test. The effect to stabilizer on compressive strength was summarized in the following table.

Types of Brick	Compressive strength (kPa)
Soil-Cement	7,584
Soil-Cement-lime	8,274
Interlocking block	9,653
Soil-Cement-fiber	7,929
Soil-Cement-lime-fluid	6,895

From above result we can observe that brick with cement and lime score the highest compressive strength. All the specimens have passed the durability criteria based on the 1mm/hour criterion for assessing the depth of erosion in bulletin 5. Minimum depth of erosion for 2.07Mpa water pressure was recorded for soil-cement brick (0.008mm/hur) followed by soil-cement-lime brick (0.375mm/hur). For 4.14Mpa water pressure minimum was recorded for soil- cement brick (0.13mm/hur) followed by soil-cement-lime brick (0.333mm/hur). The factory produced brick which is taking as bench mark for this research showed total resistance to the erosion and have maximum compressive strength of9.653Kpa. From the result they conclude that soil-cement brick registered negligible erosion rate; using lime and fiber such as coconut husks can be problematic as far as durability is concerned.

Hunphrey Danso et.al ( ) conducted a research to identify the effect of fiber aspect ratio on the mechanical strength of adobe. Two parameters of fiber accounts for strength development of fiber stabilized earth blocks, fiber content and fiber aspect ratio. Lots of research focused on fiber content to know its effect on earth blocks. But less attention is given on search for aspect ratio of fiber resulting optimum compressive strength and tensile strength. Coconut, baggas and palm fibers, which are agricultural waste, with different aspect ratio (25-125) was used for the study. The soil used is low plastic soil containing 12% gravel, 46% sand, 28% silt and 14%clay and 1.8% organic content. To prepare the specimen (290x140x100mm) the fiber were cut to aspect ratio of 25, 50,75, 100 and 125, which was limited by the fiber length available. Soil and fiber mix of each group was mixed until uniform mixture was obtained. After then water is added. The blocks were made with pressure gauge hydraulic block making machine with constant pressure of 100bar. The block dried for 21 days at average 27oc temperature and 27% humidity. The compressive strength test was performed according to BS EN 771-1 (22) using controls 50-C46G2 testing machine with maximum capacity of 2000KN. The load was applied at rate of 0.05N/mm2/s until the block fail. The tensile test was done in accordance with BS EN 12390-6(23) with testing machine and splitting jig which were placed centrally above and below the block. The load applied continuously at loading rate of 0.05N/mm2/s until faller recorded. The result show advancement in mechanical property of earth blocks with aspect. Blocks with coconut fiber shows increase in compressive and tensile strength up to 125 aspect ratio, producing 25% improvement in compressive strength as compared to block having fiber with 25 aspect ratio. Baggase fiber achived optimum compressive and tensile strength at 100 aspect ratio, 80mm in terms of length. Block with baggase at 100 aspect ratio show 25% improvement in compressive strength over the smallest fiber aspect ratio. Due to length limit the available aspect ratio for palm fiber was 100. At this aspect ratio highest value of compressive and tensile strength was recorded. The improvement was 20% in compressive strength over the smallest aspect ratio, 25. The study concluded that, in general, an increase in fiber aspect ratio has a positive effect on the strength of enhanced soil blocks. The fiber aspect ratio for all the fiber type produces the maximum strength at aspect ratio of 100 and 125. This finding supports Halpin and Kardos assertion that reinforcing fiber for composite material should be equal to or greater than an aspect ratio of 100. So in addition to fiber content the fiber aspect ratio also greatly influence the mechanical behavior of earth blocks.

The important part of soil used for earth construction is its clay content that gives cohesion and water proofing of wall (Younoussan Millogo, 2016). Waitakere City Council's Sustainable Home Guidelines about adobe soil says that soil selected should contain no more than 50% and not less than 5% of clay, and acceptable range of amount of silt and sand content is 20%-55% and 45%-80% respectively. Guide about selection of appropriate soil for adobe block preparation vary from literature to literature and among different codes. Unified building code set certain characteristics that soil selected should satisfy. According to this code the soil selected should contain not less than 25% and not more than 45% material passing #200 sieves. This mean sand content should not be less than 55% of soil. Guideline set by NM state university for adobe block making says that soil selected should not contain less than50percentage sand and greater than 30% clay. All literatures agree sand content not to be less than 50%.

3.0 MATERIAL AND METHODS

3.1 Material

The soil selected for this study is extracted from Gedeo zone, Dilla city. Different tests are conducted to characterize the soil selected. From the test result the soil selected characterized as fine soil containing very little amount of sand in percentage. According to USCS, soil classification the soil selected classified as high plastic (CH) soil. Although similar studies were done before, the geographic location of the soil site used in this study is different. Hanifi Binici, et.al, (2004) used soil containing 32.04% clay, 43.44% sand and 24.52% silt extracted from Turkey. Younoussan Millogo, et.al, (2016) for their studies used the lateritic clay from Burkina Faso. However, this research focused on material take out of Dill, Ethiopia. In addition, the Enset fiber for this study extracted from Dilla; but cow dung and straw fiber (chid) collected from Hawassa city. Cement used is Dangote cement.

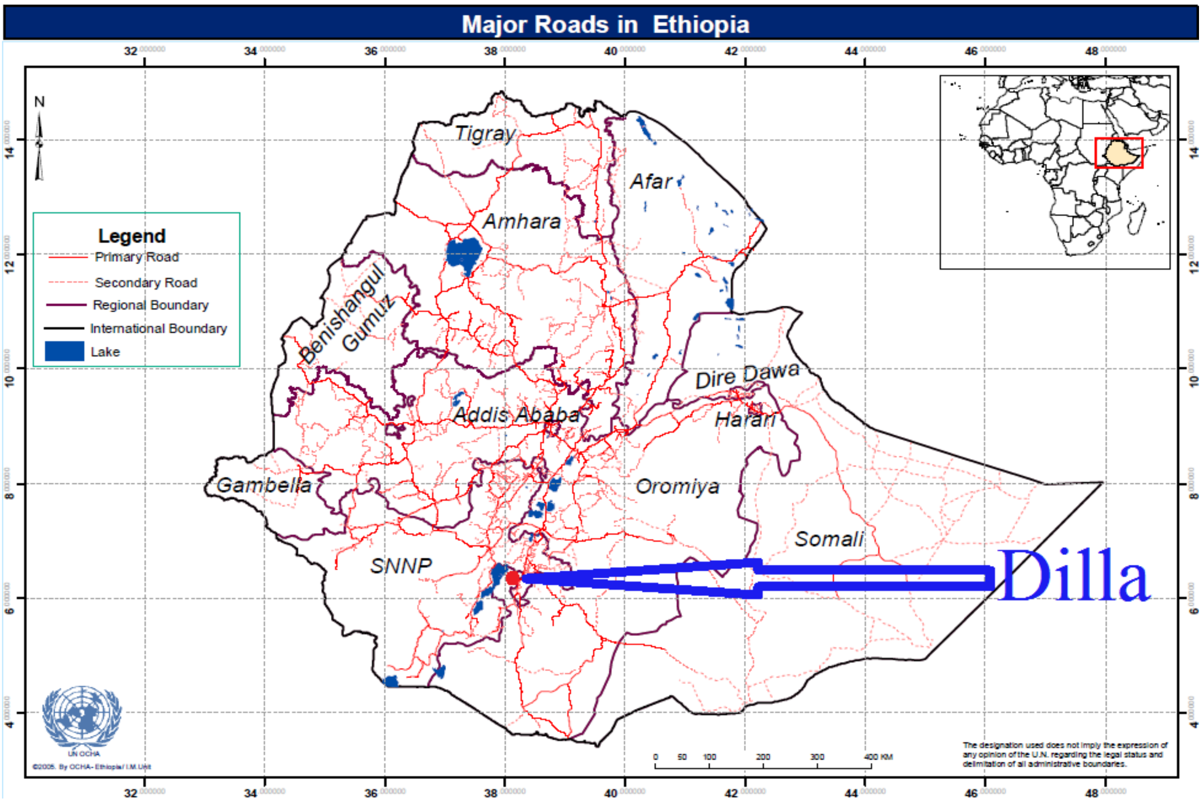


Figure 3.1 Map of area (Dilla) where soil and fiber used for the study delivered

3.2 Experimental method

After delivering the soil in to the laboratory, soil test (moisture content, Atterberg limit, grain size distribution, specific gravity) conducted in order to classify the soil type used for the investigation. After classification of the soil, the test specimen prepared. Three specimens prepared for each group of specimen in order to show the repeatability of the results through which experimental errors minimizing.

Amount of soil, water content are kept constant. In order the mix to be workable during mold preparation, the amount of water added for all mix was fixed to 53% of the dry mass of the matrix. The material used for stabilizing Adobe brick includes; fiber (straw and kancha), cement, cow dung.

Different amount of dried and crushed Cow dung content is used. Research performed using cow dung content 1%, 2% and 3% shows water absorption variation of 1 between the maximum and minimum cow dung contained mix. So to have higher improvement and to show the effect in water absorption capacity, higher cow dung content, 5%, 10% and 15% is used. For the case of fiber previously done research showed that maximum compressive strength is achieved for compressed earth block reinforced with 0.4% of polypropylene fiber. Since the fiber type used for the study is not polypropylene, optimum fiber amount is determined by varying fiber content (0.2, 0.4 and 0.6% of dry mass of soil). According to the research finding there is significant increase in water absorption as the fiber content increase. Therefore, I take fiber content less than 1%.

After making material ready, the past is prepared manually and filled in to the wooden mold to prepare the specimen. During specimen preparation the no compaction machine is used, just tamped with hand to fill mold corner with past.

3.3 Soil test

3.3.1Wet sieve test

This test conducted because the soil is fine grained so it is difficult to know accurate estimate for the percentage of fine in the soil. According to ASTM D 1140 to conduct the test 3 sample oven to dry, overnight each weighing 500g used. The soil is soaked for 30 minute to allow particle separation easy. After then the soil washed on #200 sieves and the particle retained on the sieve is dried using oven and weighted to know the percentage of fine that passing #200 sieve. The total percentage of fine, which passes through #200 sieves, is 86.6%. This implies the soil contain 86.8% fine and 13.2% sand.

3.3.2 Specific gravity test

This test conducted to know the specific gravity of the soil using pycnometer. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The test is conducted according to ASTM D 854-00 test standard. Test procedure is as follows,

1. Weigh and record the weight of the empty clean and dry pycnometer (W_P=95.5g)
2. Place 25g of a dry soil sample passed through no 10 sieve in the pycnometer, then weigh it (W_{PS}=120.5g)
3. Add distilled water to fill about half to ¾ of pycnometer and soak it for 10 minutes
4. Fill the pycnometer with distilled water to the mark, and weigh it (W_B=361g)
5. Empty the pycnometer and fill it with water to the mark and weigh it (W_A=345.8g)
6. Empty the pycnometer and clean it

The specific gravity G_s calculated as; $G_S = \frac{wo}{wo+(wA-wB)}$ ………………..equation (3.1)

$\frac{25}{25+(345.5-361)} \approx 2.63$

3.3.3 Atterberg limit test

This test is performed to determine the plastic and liquid limits of a fine-grained soil. The liquid limit (LL) arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2 in.) when subjected to 25 shocks. From the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content, in percent, at which a soil can no longer deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling. This test performed according to ASTM D 4318- standard test method.

Liquid limit of soil=67.4%

Plastic limit of soil=33.33%

Plasticity index of soil= LL-PL= 67.4%-33.33%≈ 35%;

The used characterized as fine-grained soil containing silt and clay in high content. More than 50% of soil particle (86.8%) pass through #200 sieve, its liquid limit is >50% which is 68% and its PI plots above "A" line. According to USCS soil classification system such types of soil selected is classified as high plastic (CH) soil.

3.4 Procedure for Preparation of adobe past and specimen

3.4.1 Mixing and casting

Adobe brick can be produced in different methods, traditional handcraft method; semi mechanized method or mechanized method (Edward W. Smith, (1981)). For this study the first method is adopted to make it feasible to the community since the latter two methods require mixing and molding equipment to increase adobe brick production. This relatively simple process involves the mixing of soil, water, and sometimes straw in a shallow mud pit by using a hoe or by foot treading (Edward W. Smith, (1981). Wooden forms that will produce a single brick or multiple bricks laid out on smooth and level ground and the mud is placed in them and tamped into the corners. The top smoothed off and the form removed. From, the following procedure is adopted to produce the adobe past and to prepare the specimen.

Procedures:

1. The soil is crushed to size less than 0.4mm size and sieved to have uniform soil matrix which can be easily mixed with stabilizer added
2. Prepare the stabilizer ,(crush cow dung, weigh cow dung, cement and fiber) as per the proportion set for the studies
3. For each group of mix design mix the soil and stabilizer at its dry state(soil-cow dung or soil-cement or soil-cow-dung-cement matrix) and add fiber slowly simultaneously with water,
4. Add adequate amount of water to the matrix and mix slowly with hand, which simulate foot treading mixing process. Usually the amount of water added found necessary to prepare a workable past was less than the liquid limit (James R.

Clifton et.al, (1979)). Amount of water added has its Owen effect on mechanical property of brick. To know this effect was not the objective of this research. The soil selected for this research has liquid limit of 67.4%. The amount of water added to the mix made to be constant, 53% of the dry mass of the matrix. But for the case of past containing dung additional water is added because from the past preparation I understand that unlike other material cow dung absorb much amount of water without becoming muddy. 53% water make workable for past without cow dung but for those having cow dung 53% is not adequate for making workable mix, 80% make it workable.

5. After gaining uniform mix the paste is placed in to the wooden mold which is placed on smooth surface and the paste is tamped into the corner by hand.
6. Slowly remove the mold and make it ready for the next preparation by washing and oiling the surface
7. After 2-3 days the specimen turned on edge to allow the bottom face drying
8. The specimen is left for 4 weeks in dry shaded area to control the variation of temperature on the specimen prepared at different time
9. After 4 week of drying the specimen subjected to different test, compressive strength, water absorption

Figure (3.2) Preparing the past and the specimen

3.5Experimental set-up

3.5.1 Water absorption

Procedures:

- Specimen which cured for 28 day put in oven for 24 hour
- Oven dried specimen was removed from the oven and put on open air to cool for 24 hour
- Then specimen placed in to water tank filled with water and left it for 24 hour
- After 24 hour of soaking, absorption, loss of material and loss in compressive strength for specimen which sustain the test determined

Figure (3.3) : Soaking bath to know water effect on blocks

4.0 RESULTS AND DISCUSSION

4.1 Compressive strength test result

To conduct this test different adobe block specimen with difnt stabilizer and proportion was prepared according to the preparation procedure set at section 3.4.1. After the specimens are prepared and cured, they are subjected to compression strength testing machine having a capacity of 500/1500KN. Its mode is H011PN168. Its maximum press and its piston area is 643, 10/589,50bar and 77.716/254.46 respectively.

Type and amount of specimen prepared are listed below. For each type of test three specimens each (having 10x10x10 cm dimension were prepared to minimize the error and to show the repeatability of the result.

The specimens are grouped in to four different groups each with the following percentage of ingredients.

- Group I - consists of 27 specimen constructed from mix of cow dung, fiber, and soil with the following percentages
  - 5% cow dung, 0.2% fiber(B_{D5F2})
  - 10% cow dung, 0.4% fiber(B_{D10F4})
  - 15% cow dung, 0.6% fiber(B_{D15F6})
- Group II- is constructed from mixture of soil and fiber. Types of fiber used for this case is the frequently used fiber, straw.(27 specimens)
  - 0.2% fiber(B_{F2})
  - 0.4% fiber(B_{F4})
  - 0.6% fiber(B_{F6})
- Group III- contains brick constructed from mixture of cement, fiber and soil and number of specimen prepared is (27 specimen)
  - 2% cement, and 0.2% fiber(B_{C2F2})
  - 4% cement, and 0.4% fiber(B_{C4F4})
  - 6% cement, and 0.6% fiber(B_{C6F6})

- Group IV - contain brick constructed from cement, cow dung, fiber, and soil mix (27 specimen)
  - 5% cow dung,2% cement, and 0.2% fiber(B_{D5C2F2})
  - 10% cow dung,4% cement, and 0.4% fiber($B_{D10C4F4}$)
  - 15% cow dung,6% cement, and 0.6% fiber($B_{D15C6F6}$)

4.1.1 Compressive strength result for 28 day cured Adobe specimen

The load is applied at a rate so that the maximum load was reached between 20 to 80 seconds after start of loading (James R. Clifton and Frankie L. Davis, 1979). The maximum standard deviation determined for compressive strength data gathered was 0.57 (Adobe containing 0.6% Enset fiber).

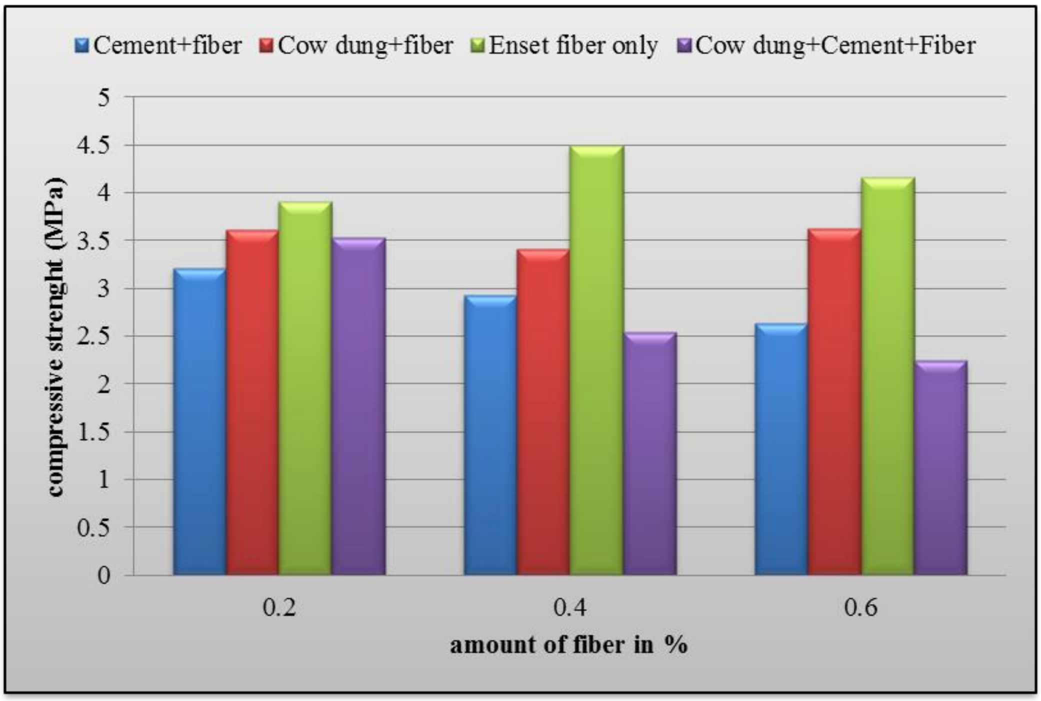


Figure 4.1: Effect of fiber, cow dung and cement on the compressive strength of Adobe block

. The above chart shows the effect of fiber, cement and cow dung addition in adobe block. The result includes for the following Adobe block groups. Adobe blocks containing 0.2% Enset fiber includes B_{F2}, B_{C2F2}, B_{D5F2}, and B_{D5C2F2}. Adobe blocks containing 0.4% Enset fiber include B_{F4}, B_{C4F4}, B_{D10F4}, and $B_{D10C4F4}$. Adobe blocks containing 0.6% Enset fiber includes B_{F6}, B_{C6F6}, B_{D15F6}, and $B_{D15C6F6}$. For each abbreviation, detail information about their material composition is written under section 4.2.

From the result, it can be seen that adobe blocks with fiber only showed maximum compressive strength. Addition of both cement and cow dung significantly decrease compressive strength. The worst case is observed in case of addition of cement. For example, for block stabilized with 0.4% Enset fiber, result show that their compressive strength is 4.5MPa, 2.927MPa, 3.408MPa and 2.548MPa for block stabilized with 0.4% Enset fiber, with 4% cement and 0.4% Enset fiber, with 10% cow dung and 0.4% Enset fiber, and for block stabilized with 4% cement, 10% cow dung and 0.4% Enset fiber respectively. With 4%, cement addition compressive strength reduced from 4.5MPa to 2.927MPa with 35.7% reduction. However, when 10% cow dung is added compressive strength reduced from 4.5MPa to 3.408MPa with 24.3% reduction. When both cement (4%) and cow dung (10%) added at the same time compressive strength decreased with 43.4%. Compressive strength fall is large for cement addition as compared to cow dung addition. This verified for cement addition up to 6% by mass of dry mass of the soil. Cement addition up to 6% of dry soil mass have no contribution for compressive strength improvement.

The reason for decrease in compressive strength for case of cow dung addition is due to reduction in density of Adobe matrix when very light weight cow dung added. Previous study by Younoussan Millogo et al. (2016) about cow dung effect on compressive strength did not agree with this result. The reason for this gap can be the difference in cow dung content used for the study. In the previous study amount of cow dung used was 1%, 2% and 3% of mass of clay material. Previous result on cement effect on compressive strength by Gernot Mink, (2007) agrees with this result too. His studies showed that addition of 2-6% of cement would normally decrease the resistance against compression and flexure, also not improve water resistance of adobe blocks

Effect of addition of cow dung as stabilizer can also be seen in the above chart. As compared to block containing fiber, only addition of cow dung reduces compressive strength of the block. This is because addition of cow dung reduces the density of the material, so compressive strength. Previous study conducted by Younoussan Millogo, et.al, (2016) contradicts with this result. The reason for this difference could be soil material difference and difference in percentage of cow dung used for stabilization purpose. Percentage of cow dung used for the previous study was 1, 2, and 3% but for this current study the percentage was 5, 10 andb15% of dry mass of the soil.

4.1.2 Compressive strength result for Adobe specimen oven dried after 28 day of curing

This group is the same in their material composition as those specimens whose results are presented in the above section. What makes these specimens different is before conducting compressive strength they are oven dried for 24 hour in oven dry machine. This is done in order to identify amount of moisture remaining in the block after 28 day curing, and to know the effect of water present on the block on its compressive strength. The effect of moisture present on adobe block is shown in figures below.

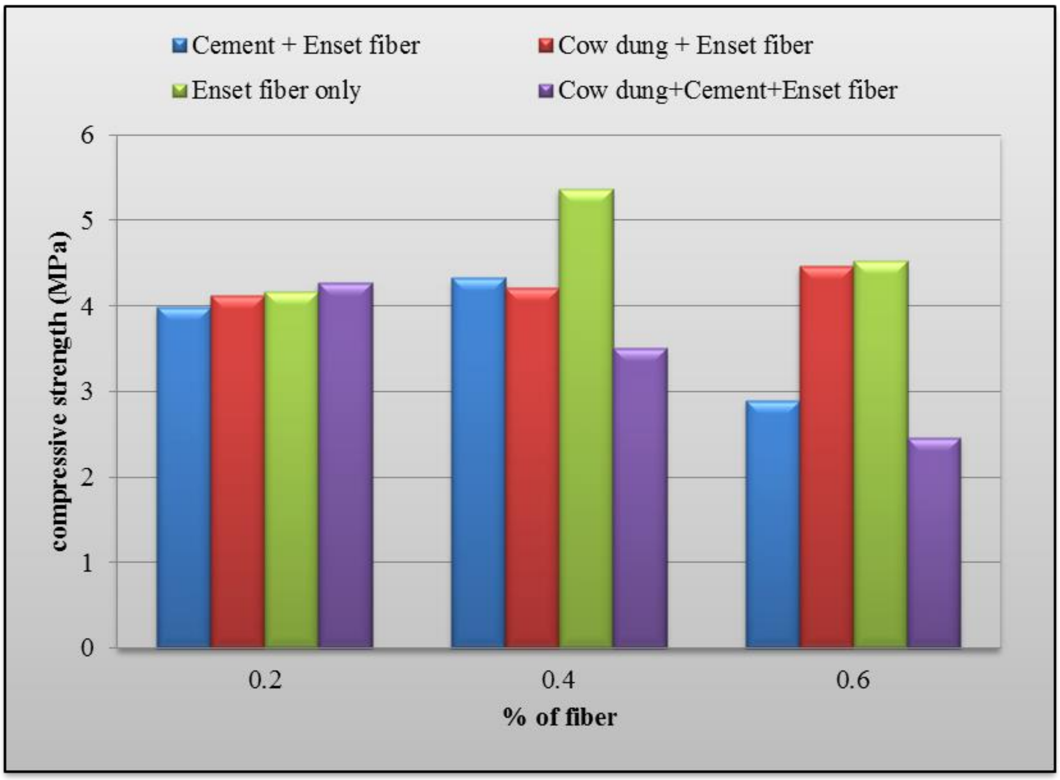


Figure 4.2: Effect of water on compressive strength of Adobe block

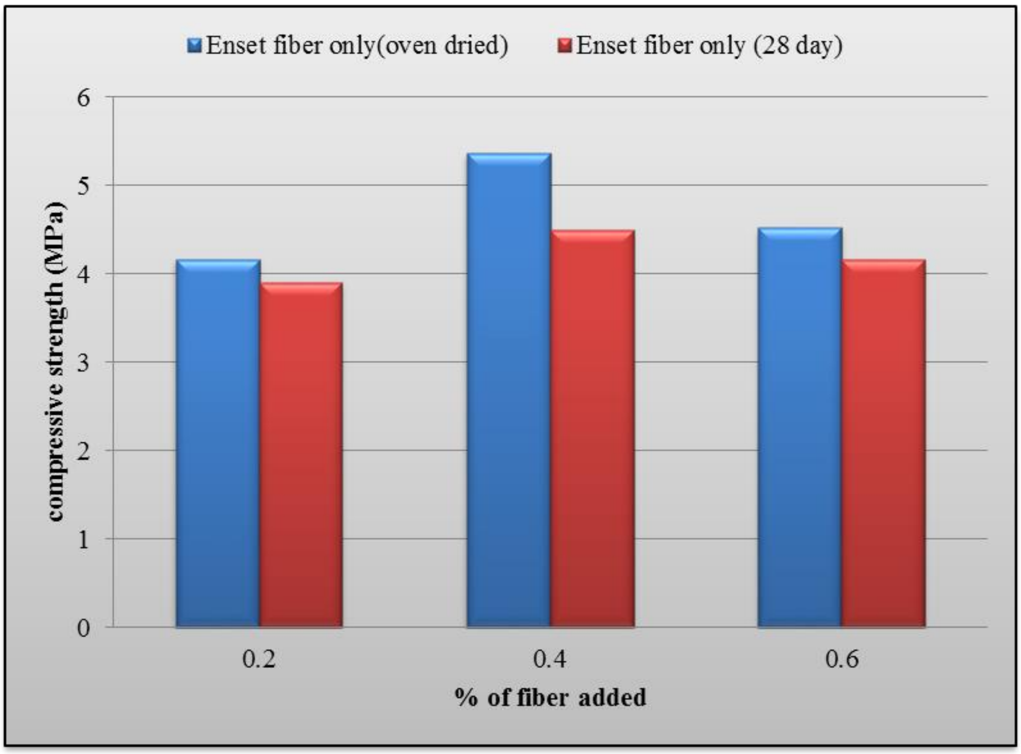


Figure 4.3: Effect of water on Adobe block containing Enset fiber

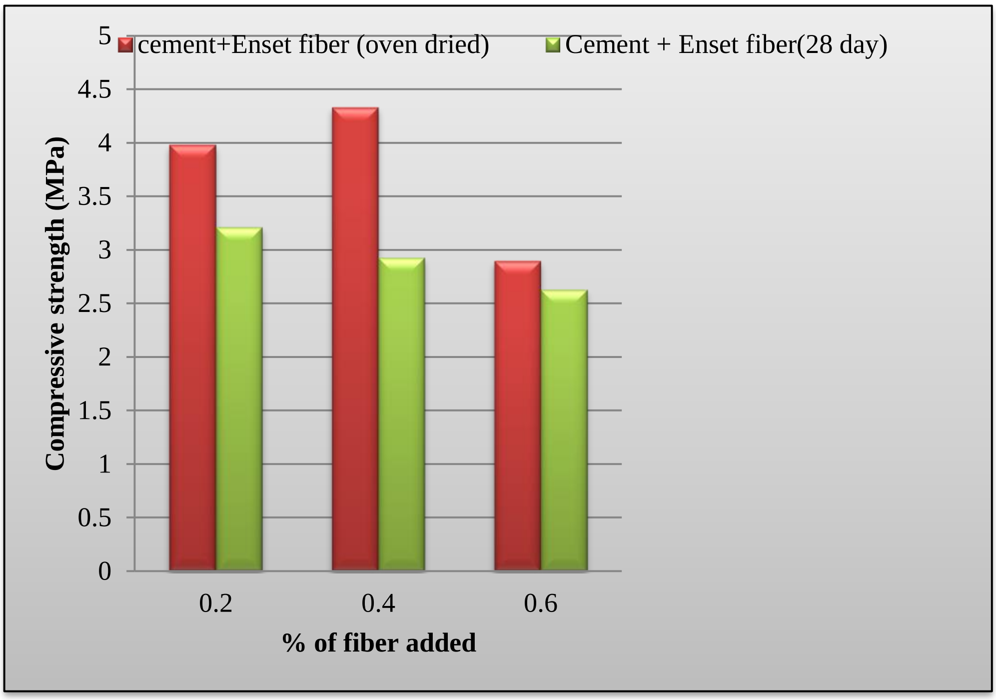


Figure 4.4: Effect of water exist on compressive strength of Adobe block stabilized with cement and Enset fiber

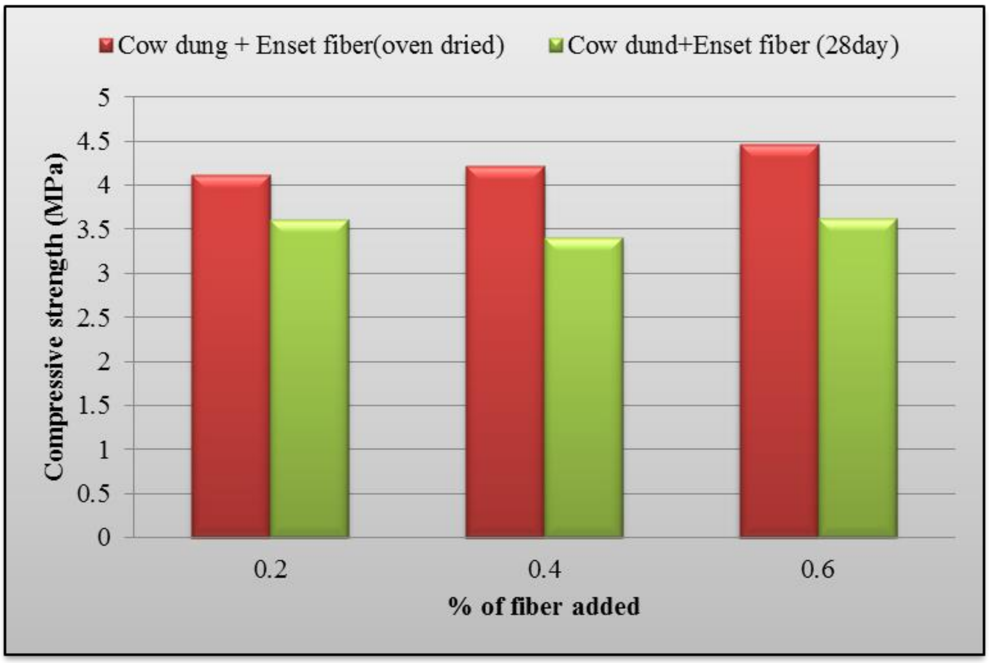


Figure 4.5: Effect of water on comp. strength of Adobe block stabilized with dung, and Enset fiber

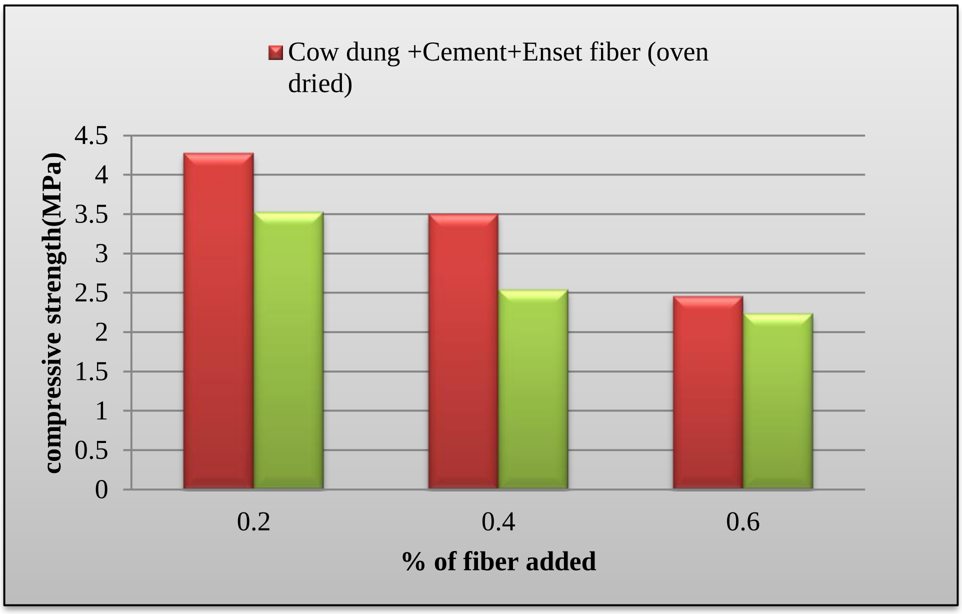


Figure 4.6: Effect of water on compressive strength of block stabilized with dung, cement and Enset fiber

Table 4.1: increase in compressive strength due to oven drying

Name	B_{C2F2}	B_{C4F4}	B_{C6F6}	B_{D5F2}	B_{D10F4}	B_{D15F6}	B_{F2}	B_{F4}
Increase in comp. streng (%)	23	48	10	14	23	23	7	19
Name	B_{F6}	B_{D5C2F2}	$B_{D10C4F4}$	$B_{D15C6F6}$	B_{S2}	B_{S4}	B_{S6}	
Increase in comp. streng (%)	8.6	21	37.7	9.6	22	12	24	

The only difference between data presented for Adobe block in figure (4.1) and figure (4.2) is the former one show compressive strength of adobe dried for 28 day in open air but the later one represents data for blocks, which dried on oven for 24 hour after dried in open air for 28 day. Nevertheless, the material composition is the same. The moisture present in the adobe block significantly affects the compressive strength of the material. Increase in compressive strength ranges from 6.68% (for block containing 0.2% Enset fiber) to 47.97% (for block containing 4% cement and 0.4% Enset fiber). So water present in Adobe block which remain in block after curing, have potential of reducing the compressive strength of the block. Therefore, to achieve adobe block with high compressive strength it will be better to cure it for more than 28 days in dry environment.

4.2 Resistance to moisture when soaked in water tank

To identify the effect of stabilizer on the Adobe block water resistance capacity, the blocks are subjected to the worst moisture condition; by soaking them in water tank. After soaking, the water effect on the block examined after 24 hour. For blocks, which sustain 24 hours, soaking water absorption, loss of material after soaking and strength loss due to soaking is determined. House constructed with the material, which sustain this test, if invaded by water for some hours (up to 24 hour), can stay stand without failure up to maintenance action is undertaken.

Table 4.2 Water absorption, material loss and loss in compressive strength of blocks, which survive 24 hour soaking, containing varying Enset fiber content

Sample name	W_{oven} dried sample (gm)	W_{after} soaking for 24 Hr. (gm)	Water absorption	W_{oven} dried sample after 24hr soaking	% of material loss due to soaking	Compressive strength after soak (MPa)	Decrease in compressive strength (%)
B_{F6}	1160			950	18.1		
B_{D5F2}	1150			1060	15.275		
	1100			850			
B_{D10F4}	1040			1030	2.85	2.44	42.1
	1060			1040			
B_{D15F6}	940	1390	48.7	1000	No material loss	3.07	31.2
	900	1340		950			
	930	1390		1010			
$B_{D10C4F4}$	980	1440	47.44	1040	No material loss	1.841	47.43
	980	1450		1050			
	970	1430		1020			
B_{15C6F6}	930	1410	50.7	980	No material loss	2.083	15.3
	960	1450		1030			
	990	1480		1040			

Adobe soaking result shows that block which survive this test are that containing cow dung. Adobe blocks stabilized with cement and Enset fiber, fiber only and fiber and cow dung (5% cow dung) did not sustain this test. Except blocks stabilized with 0.6% Enset fiber, and 2% Enset fiber and 5% cow dung, other blocks are washed by the water when soaked in to the water. In addition, they lost much of their material even after one hour soaking. B_{D15F6}, $B_{D10C4F4}$, and B_{15C6F6} completely withstand the test with minor material loss. B_{D10F4} lose 2.85% of its material due to soaking process. Loss of compressive strength recorded to be 31.2, 47.43, 42.1 and 15.3% for B_{D15F6}, $B_{D10C4F4}$, B_{D10F4}, and $B_{D15C6F6}$ respectively.

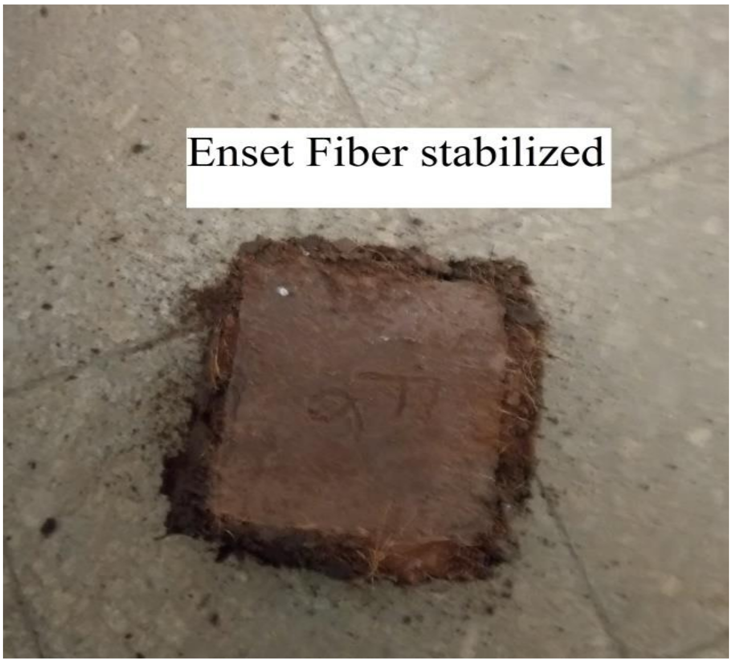
Cow dung stabilized Adobe blocks resistance to water attack as compared to those stabilized with cement or fiber only is high. Cow dung incorporation in to adobe block production improves resistance to water attack. Those block stabilized with greater than 10% cow dung showed significant improvement on water resistance, even with negligible material loss after soaking. Previous study conducted by Younoussan Millogo, et.al, (2016), which stressed on effect of cow dung on mechanical strength of adobe block, support the this result. Their finding showed that because the cow dung reacts with the mineral (kaolinite and quartz) to form insoluble silicate amine which glued the material together, adobe stabilized with cow dung resist water attack.

Loss in compressive strength after 24 hour soaking is recorded as42.1, 31.2, 47.43 and 15.3% for B_{D10F4}, B_{D15F6}, $B_{D10C4Fn4}$ and B_{15C6F6} respectively. The minimum loss in strength is recorded by B_{15C6F6} and B_{D15F6}. Those blocks having large amount of cow dung experience lower loss in compressive strength after subjected to adverse water condition. The other thing observed is, addition of cement in Adobe block results in higher loss in compressive strength after soaking.

The figure showen on Appendix A showes effect of water on block due to imersion of block in to water. The only block 4which sustain its origional shaped after this test is the one stabilized by cow dung. But block stabilized by cement (2-6%) and Enset fiber (0.2-0.6%) didn’t endure the test. But with cow dung addition we come up with better water resistant Adobe block. From this picture we can understand that Addition of cow dung better glue soil material to act together in water effect resistance than those added stabilizer.

4.3 Failur of Adobe block stabilized with Enset fiber and with Chid fiber

(a)



(b)

Figure 4.7: Failure at maximum compressive strenght (a) chid stabilized block (b) Enset fiber stabilized

As can be seen from the above figure, Adobe block stabilized with Enset fiber perform well in compressive strength failure as compared to one stabilized with Chid fiber. Adobe with Enset fiber at maximum strength did not collapsed (broken) in to pieces at failure, beyond maximum strength it left with additional carrying capacity. But in case of Adobe block stabilized with Chid fiber since broken in to pieces at failure there is no left resistance after it reach maximum compressive strength. Therefore as compared to Chid fiber, Enset fiber better clamp the material together.

When block stabilized with fiber subjected to stress the two fiber behave in different way. Straw fiber rupture at maximum compressive strength, but Enset fiber didn't at maximum compressive strength that is why block with Enset didn't brock in to pieces at its maximum strength. So it will be effective to choose Enset fiber over Chid fiber for stabilization purpose, therefore we can achieve Adobe block with high ductility behavior.

4.4 Effect of Cow dung, and cement on compressive strength of Adobe block for constant Enset fiber

Adobe specimens having 0.4% fiber content and varying cement and cow dung content is studied. The effect of cement and cow dung on compressive strength and water resistance capacity of Adobe block for constant Enset fiber is discussed. The following groups of adobe are prepared for investigation.

The group includes;

- Group I: - is brick constructed from mix of cow dung, fiber, and soil extracted. With material content of,(27 specimen)
  - 5% cow dung, 0.4% fiber(B_{D5F4})
  - 10% cow dung, 0.4% fiber(B_{D10F4})
  - 15% cow dung, 0.4% fiber(B_{D15F4})
- Group II: - contains brick constructed from mixture of cement, fiber and soil and number of specimen prepared is (27 specimen)

- 2% cement, and 0.4% fiber(B_{C2F2})
- 4% cement, and 0.4% fiber(B_{C4F4})
- 6% cement, and 0.4% fiber(B_{C6F6})

- Group III - contain brick constructed from cement, cow dung, fiber, and soil mix (27 specimen)

- 5% cow dung,2% cement, and 0.4% fiber(B_{D5C2F4})
- 10% cow dung,4% cement, and 0.4% fiber($B_{D10C4F4}$)
- 15% cow dung,6% cement, and 0.4% fiber($B_{D15C6F4}$)

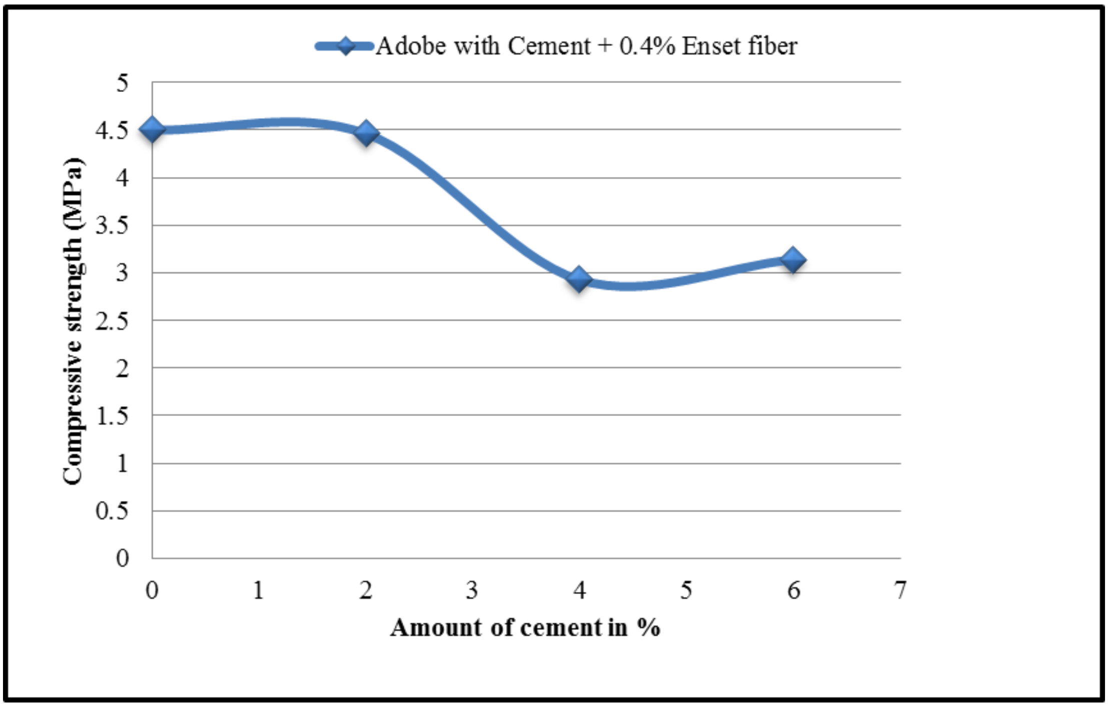


Figure 4.8: Effect of amount of cement on compressive strength of Adobe block for 0.4% Enset fiber

Figure (4.8) shows the effect of cement on compressive strength of Adobe block for constant 0.4% of Enset fiber content. Adding cement up to 6% of dry mass of the soil does not have contribution for compressive strength improvement. However, in contrary makes compressive strength decrease. After around 5% cement amount compressive strength starts to rise. So to have higher compressive strength block using cement greater than 10% will be effective, but will not be economical and affordable for the majority of low income society. This result is the same as previous study conducted by Gernot Mink (2007). In general using cement up to 6% does not have effect in improving compressive strength of block.

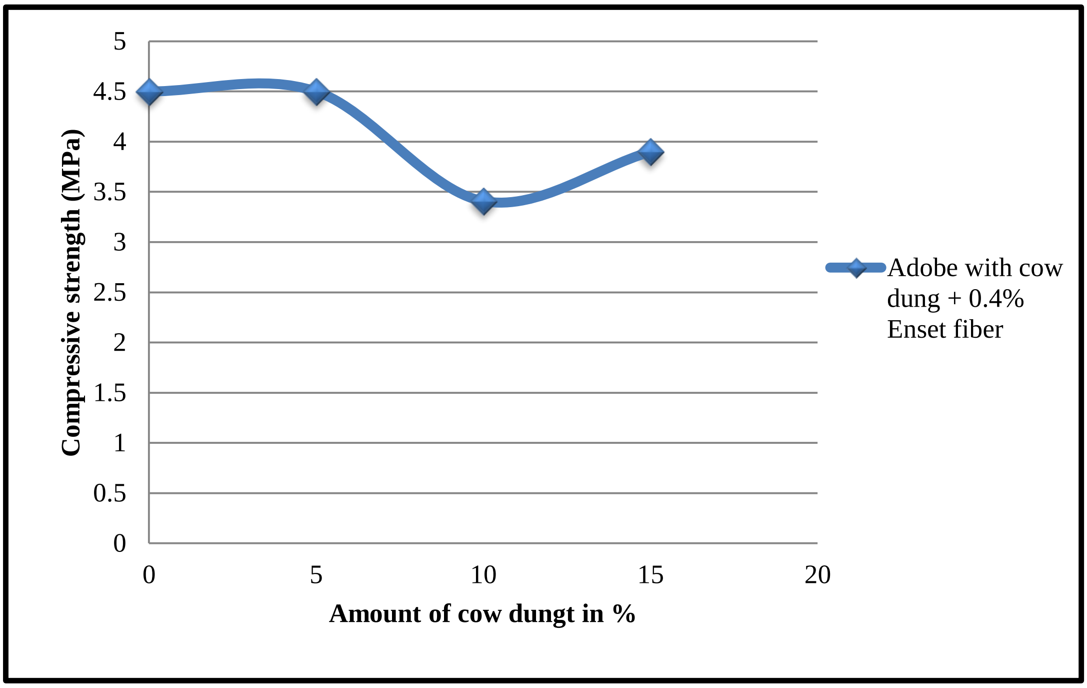


Figure 4.9: Effect of amount of cow dung on compressive strength of Adobe block for 0.4% Enset fiber

Effect of cow dung on compressive strength of block is presented in the above chart. Like cement adding, cow dung addition in block do not has positive impact on its compressive strength. However, unlike cement for the case of cow dung, the effects remain constant up to 5%. But, beyond that there is probability of having higher compressive strength block if cow dung greater than 15% added. This result do not resemble with the result reached by Younoussan Millogo, et.al, (2016). Their investigation showed improvement in compressive strength as cow amount of cow dung increase. The reason for this variation can be linked to difference in soil used and amount of cow dung used. The other difference between this two research is, in the previous fiber is not used, the only material which play the fiber role is fiber like material in animal dung used for the investigation. The improvement in compressive strength could be because of fiber exist in cow dung. But for this current research optimum fiber content for compressive strength is already exist on the mix, so effect of fiber exist on cow dung on compressive strength will not be improvement but decline.

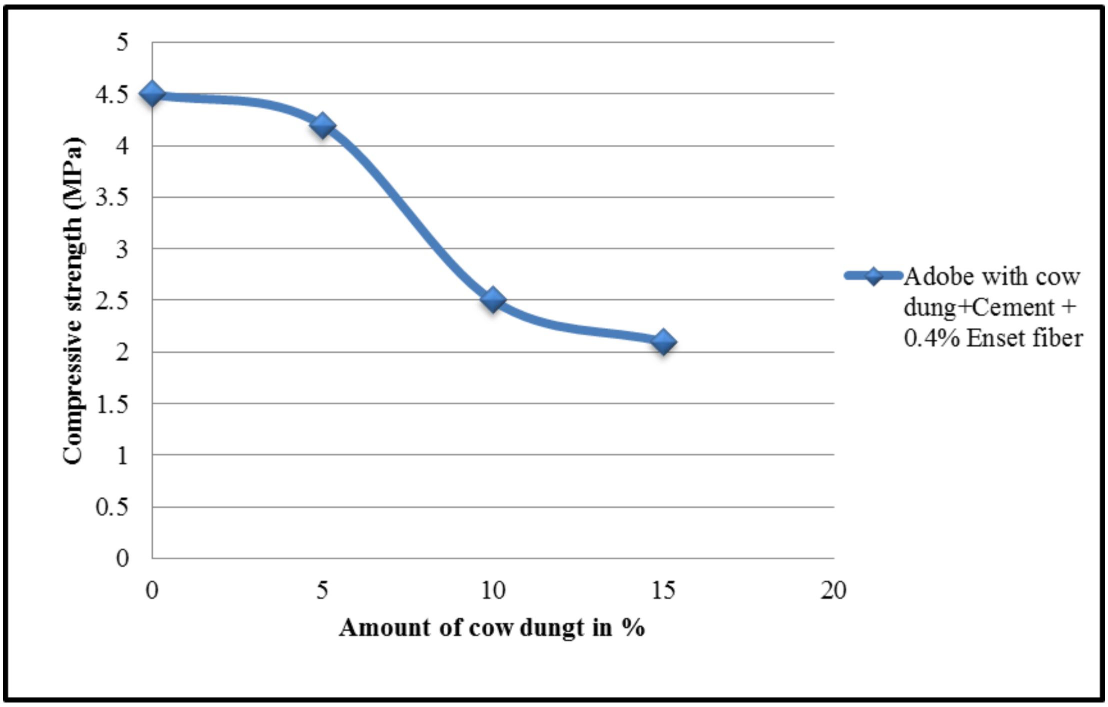


Figure 4.10: Gross effect of cement and Cow dung on compressive strength of Adobe block for 0.4% Enset fiber

Cement and cow dung gross effect on compressive strength of adobe block is presented on the above figure. The gross effect is not much different from the individual effect of cement and cow dung. Adding cow dung and cement at the same time, decrease compressive strength of block. What we can understand from the chart is the decrease is worst as compared to cement and dung individual effect. However, this does not mean that the compressive strength achieved failed as compared to the code limit. According to standard code, UBC the minimum compressive strength for Adobe block is 2.07MPa. The entire adobe blocks compressive strength excels this minimum requirement.

4.5 Effect of cement and cow dung on water resistance for constant Enset fiber content (0.4%)

Table 4.3 Water absorption, material loss and compressive strength loss of blocks, which survive 24 hour soaking having constant Enset fiber content

Sample name	W_{oven} dried sample (gm)	W_{after} soaking for 24 Hr. (gm)	Water absorption	W_{oven} dried sample after 24hr soaking	% of material loss due to soaking	Compressive strength after soak (MPa)	Decrease in compressive strength (%)
B_{C2F4}	1170			770	43		
	1230						
	1260			810			
B_{C6F4}	1230			970	21.2		
	1170			920			
B_{D5F4}	1150			1130	1.324	2.078	
	1100			1100			
	1100			1090			
B_{D10F4}	1040			1030	1.414	2.44	42.1
	1060			1040			
B_{D15F4}	1040	1500	46.6	1040	2.92	2.45	40.23
	1020	1490		1000			
	1030	1540		990			
B_{D5C2F4}	1130			1050	10.4		
	1140			940			
	1060			990			
$B_{D10C4F4}$	980	1440	47.4	1040	No material loss	1.841	47.43
	980	1450		1050			
	970	1430		1020			
$B_{D15C6F4}$	970	1380	44.11	930	2.767	1.668	21.69
	950	1400		940			
	960	1370		930			

The above table showed that for constant Enset fiber content, Adobe block containing greater than 10% sustain the soaking process. Their material loss after soaking is less than 3% of the block. Water absorption of blocks (B_{D15F4}, $B_{D10C4F4}$ and $B_{D15C6F4}$) is approximately 46%. Relation between cow dung content and water resistance of Adobe block reached in this work agree with the previous work done by Younoussan Millogo, et.al, (2016). The difference between the two works is amount of water absorbed by the blocks. Under previous work the Adobe block containing 3% cow dung recorded only about 5.63% of dry mass of the block. But in this current study water absorption for block containing maximum cow dung and maximum cement content recorded about 47% of dry mass of the block. The difference between the two studies is very significant. Soil they used (43% sand, 17.5% silt and 36% clay) for previous study is very different from the soil selected for this current study (sand content of soil is13.2% and the remaining is fine soil). Since about half percent of the soil is sand their water carrying capacity is very low as compared to the soil used for this study. So the type of soil selected for adobe block production greatly affects the water absorption property of block when subjected to water source. Adobe block constructed using high sand content absorbs less water as compared to adobe block constructed with very plastic soil.

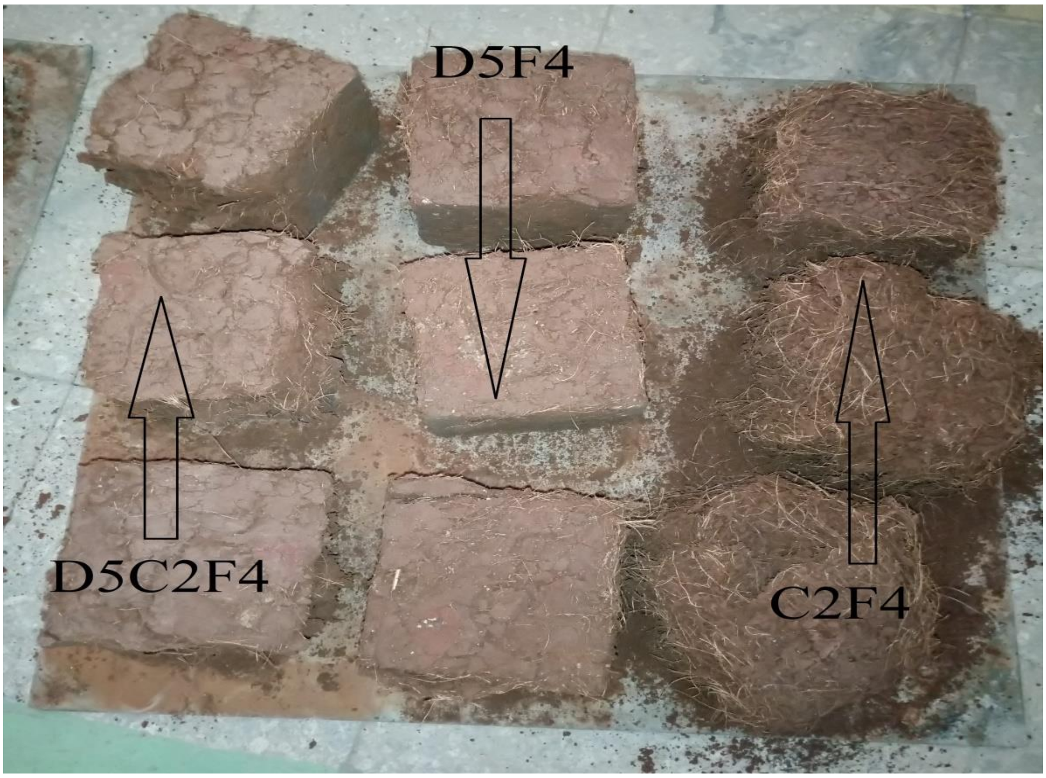


Figure 4.11: Effect of soaking on B_{C2F4}, B_{D5F4} and B_{D5C2F4}

From the above figure, it is understood that block containing 2% cement completely degraded as compared to those having 5% cow dung and those containing 2% cement and 5% cow dung. As visual investigation showed adding cement in to block, result block to have high affinity towards water and to be easily attacked by water action. Effect of soaking on Block stabilized with only 5% cow dung is not harsh as compared to on block containing 2% cement in addition to 5% cow dung. Justification for this is, material loss calculated for the two blocks after soaking. Material loss for block stabilized with 2% cement only, 5% cow dung only and block stabilized with 2% cement in addition to 5% cow dung is 21.2, 1.324 and 10.4% respectively. So form this result an understanding we develop is, without additional material which improve soil material bondage, like cow dung, adding 2% cement have no contribution to resistance of block to water action. This result complies with previous research conducted by (Younoussan Millogo, et.al, 2016) and (Gernot Minke, 2007) individually. The former conducted on effect of cow dung on adobe block and the later one conducted on effect of cement on adobe block physical and mechanical behavior. Younoussan Millogo, et.al what they determined form their study is, cow dung addition on adobe block with clay contained soil will have resistance towards water. Researchers conducted by (Gernot Minke, 2007) validate this current research result also. The past research says that adding cement up to 6 or 8% will not have support for improvement of compressive strength and water resistance of adobe block.

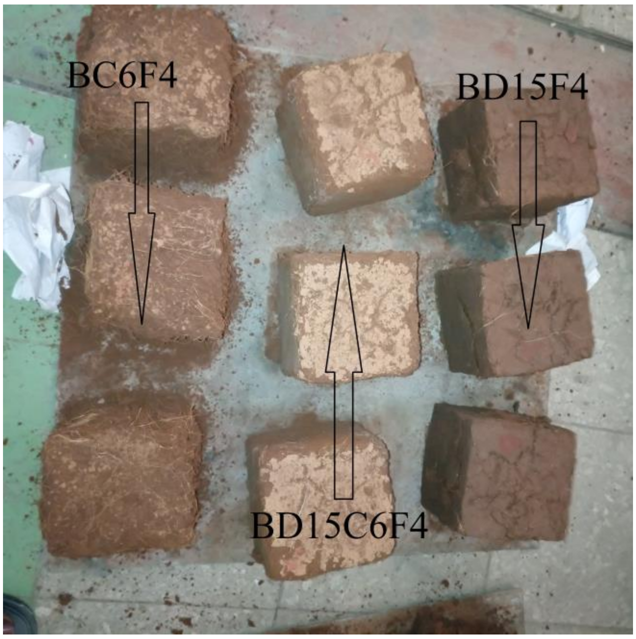


Figure 4.12: Effect of soaking on B_{C2F4}, B_{D5F4} and B_{D5C2F4}

The above figure shows block B_{C6F4}, B_{D15F4} and $B_{D15C6F4}$. To a certain degree similar thing is observed in figure (4.12). The difference here is block stabilized with 6% cement in addition to 15% cow dung have better resistance to water action as compared to block stabilized with 15% cow dung only. There is no significant difference in material loss between the two blocks. The big difference is the physical change observed after soaking. Block stabilized with only 15% cow dung shows cracks, which are wider in size and number. But in case of block added with 6% cement in addition to 15% cow dung there is no significant crack developed after soaking and oven drying. Though the compressive strength of $B_{D15C6F4}$ is less than other blocks, since it has better durability as compared to other blocks and its compressive strength as compared to UBC is enough, can be used as alternative material for walling purpose.

4.6 Effect of Fiber on Compressive Strength and Water Resistance of Adobe Block

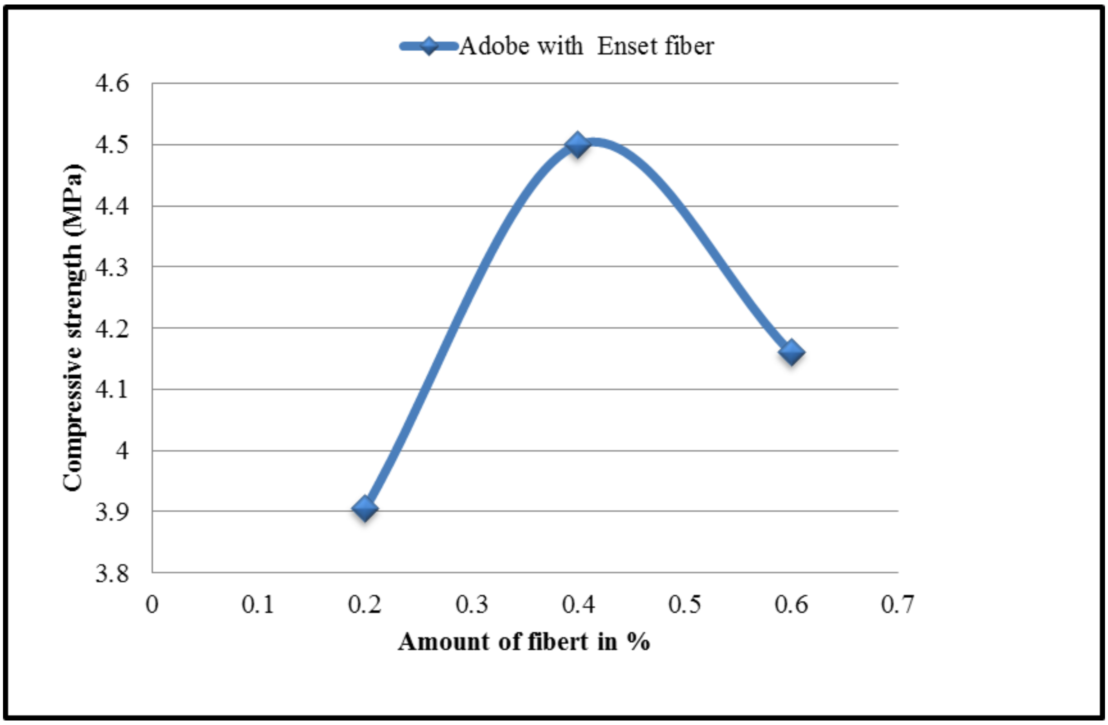


Figure 4.13: Effect of amount of fiber on compressive strength of block

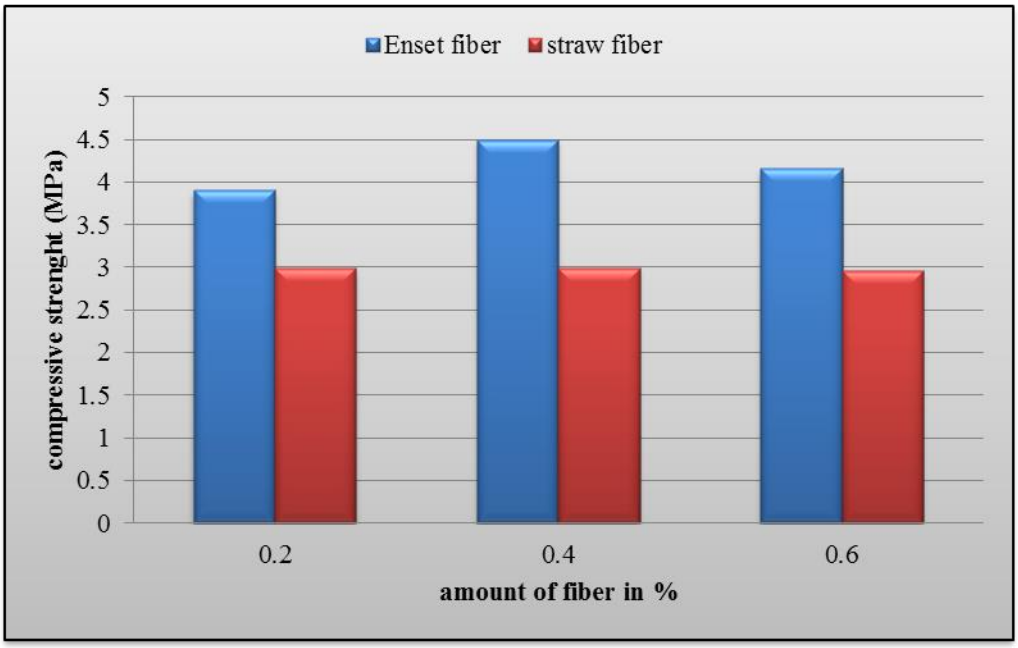


Figure 4.14: Fiber content versus compressive strength

The effect of fiber amount on the compressive strength of adobe and the difference in compressive strength between Enset fiber (false banana fiber) and straw fiber (locally named "chid") is stated on above chart. For the case of Enset (false banana) fiber, compressive strength increase as we increase fiber content from 0.2% to 0.4, but decrease as we increase from 0.4% to 0.6%. From the graph we understand that optimum amount of fiber (Enset) content to achieve maximum compressive strength is 0.4% of the dry mass of the soil. However, this result is not observed for "chid" fiber case. There is no significant difference on compressive strength among adobe containing 0.2%, 0.4% and 0.6% fiber content. For adobe with 0.4% chid fiber, there is little decrease in compressive strength. This result, about effect of Enset fiber on compressive strength, agreed with Previous studies, which have recognized that reinforced compressed earth block (CEB) with 0.4% of the Polypropylene fibers recorded the highest compressive strength; also, these studies prove that increasing fiber content more than 0.4% reduces the strength significantly. But for the chid fiber case this is not true. From this result, we understand that increasing content of chid fiber (between 0.4 and 0.6%) do not have significant effect in improving the compressive strength of Adobe block. The reason for this is fiber bonds the particle together under compression to have high resistance. Nevertheless, adding beyond optimum amount result decrease in the overall density of the matrix because fiber is lightweight and low dense material fiber. Therefore, compressive load resistance of the block will decrease.

The other thing we understand from the above result is compressive strength of adobe with chid and Enset fiber is not the same. Adobe with Enset fiber recorded highest compressive strength as compared to chid fiber for the same percentage of fiber added. For the optimum Enset fiber case (0.4%), compressive strength of adobe with Enset fiber exceeds the adobe with chid fiber by 33.4%. Chid is used as stabilizer in traditional mud house construction method, but using Enset fiber yield higher compressive load resistance. So improving the compressive strength of Adobe block using Enset fiber is more effective than using chid fiber.

Amount of fiber added also has an effect on resistance of Adobe block towards water influence. This fiber effect can be observed on $B_{D15C6F4}$ and $B_{D15C6F6}$ blocks. On block having 0.4% Enset fiber content the physical change after soaking is insignificant, with negligible crack width and crack number. However, for blocks with 0.6% Enset fiber case, after soaking the blocks experience a number of wider cracks. So using Enset fiber greater than the optimum amount yield block that are weak toward water effect. This happens because larger number of voids will develop between the fiber and the adjacent soil matrix when a number of fiber added during the fiber and soil loss their volume at drying process.

5.0 CONCLUSION AND RECOMMENDATION

5.1Conclusion

The following conclusions are drawn from this study:

- All adobe block produced in this research for investigation satisfies the compressive strength requirement set under UBC, which limits it to be 2.07MPa strength. The minimum and maximum compressive strength recorded under this research is 2.1MPa for $B_{D15C6F4}$ and 4.5MPa for B_{F4} respectively.
- Compressive strength of Adobe block is affected by type and amount of stabilizer added. Addition of both cement and cow dung significantly decrease compressive strength. The worst case is observed in case of addition of cement. This is true if amount of cement and cow dung added is up to 6 and 15% respectively.
- Water left in the Adobe block after curing process significantly affects its compressive strength.
- Soaking Adobe block with water result physical and mechanical property change.
- Stabilizing block with cow dung better improve water resistance of capacity block as compared to stabilizing block with cement. Loss of material after soaking for adobe block B_{C6F4} and of B_{D5F4} is 21.2 and 1.3% respectively..
- Adobe block stabilized with 15% cow dung, 6% cement and 0.4% Enset fiber performs best from compressive strength and durability point of view to be selected as affordable, and alternative construction material, as compared to block stabilized with fiber (straw) only.
- As compared to straw fiber Enset fiber stabilized Adobe block have higher compressive strength and water resistance
- Using large amount of fiber content for adobe block production results weak block under water and under compression.

5.2 Recommendation

Housing is one of the basic needs of human being which provide shelter from the external varying environment. Fast growing demand of this basic need is resulting deforestation, especially in developing country. One cause for depletion of forest coverage in Ethiopia from 40 % to 2.36% is forest cutting for housing purpose. This is because of housing method in Ethiopia. Cob type of housing is the common type of housing which require timber skeleton before application of mud mixed with straw applied to fill the gap between the wood.

- To tackle deforestation problem facing our country I recommended research institution to focuses on searching for alternative construction material, and conduct study to improve the property of potential material like, Adobe block which is low cost, affordable and sustainable.
- The current cob housing construction method in Ethiopia use straw fiber for stabilizing the mud to improve the mechanical strength of the mud, but from compressive strength and water resistance point of view Enset fiber is more effective, so it is better to advocate this knowledge among the society.

5.3Future work

From different point of sight it is better to conduct research on construction material. Since it affect the cost, durability, comfort, and affect surround environment during and after housing project construction. This research try to fill little knowledge gap exist among society about mud stabilization technique. But addressing all area of study about Adobe block under this research is difficult.

So the following research areas are recommended for future studies.

- Conducting this research in different area to identify the effect of different soil type on mechanical property of block
- Investigating Effect of water added on property of block
- Researching mechanical machine for adobe block production to make easy for a society to produce block in large quantity at a time

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Appendix A: Figures which shows the effect of soaking Adobe block in to water

Figure 4.15 effec soaking on BC2F2 and BC4F4 Figure 4.16 effect of soaking on BC6F6

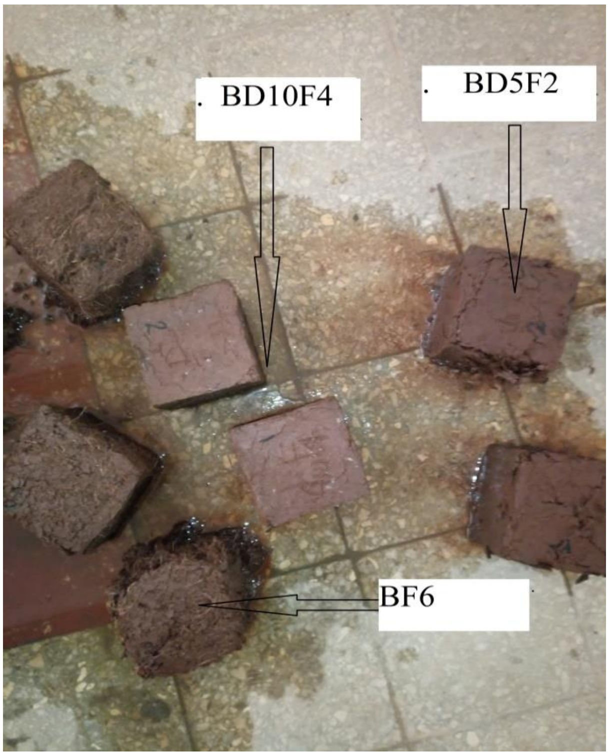

Figure 4.17 effect of soaking on BD5F2, BD10F4 and BF4 Figure 4.18 effect of soaking on BD15F6

Figure 4.19 effect of soaking on BF4 and BF2 Figure 4.20 effect of soaking on BD5C2F2

Figure 4.21 effect of soakign on BD10C4F4 Figure 4.22 effect of soaking on BD15C6F6

Appendix B: Compressive strength result of Adobe blocks

Compressive strength of the Adobe block is get from the compression testing machine. Since the testing machine is digital it gives both the maximum load and the corresponding maximum compressive strength. At the start of load the size of the specimen(10x10cm contact area) is given to the machine.

Compressive strength is calculated as

Compressive strength= P/A where p= load

A= contact area

So if it is necessary the corresponding load can be determined using the above formula

Table 4.4 weight and compressive strength of Adobe block sample cured for 28 day

Sample name	no	Sample weight at 28 day	Sample weight oven dry (for compressive strength)	Sample weight oven dry (for absorption)	Compressive strength (28 day)	Average compressive strength (MPa)
BC2F2	1	1280	1200	1160	3.217	3.212
	2	1230	1150	1140	2.963	
	3	1290	1200	1140	3.457	
BC4F4	1	1190	1160	1200	3.358	2.927
	2	1190	1200	1210	2.853	
	3	1210	1200	1210	2.57	
BC6F6	1	1260	1160		2.982	2.628
	2	1290	1170		2.233	
	3	1240	1200		2.670	
BD5F2	1	1190	1090	1100	3.568	3.611
	2	1140	1100	1150	3.709	
	3	1140	1080		3.339	
	4	1200			3.829	
BD10F4	1	1080	1060	1040	3.506	3.408
	2	1100	1020	1060	3.540	
	3	1080	1050	1030	3.213	
BD15F6	1	970	960	940	3.146	3.619
	2	970	880	900	3.756	
	3	930	940	930	3.947	
BF2	1	1180	1130	1140	3.734	3.905
	2	1150	1170	1130	3.643	

	3	1170	1120	1130	4.212	
BF4	1	1180	1140	1200	4.410	4.5
	2	1250	1150	1190	4.657	
	3	1250	1200	1190	4.433	
BF6	1	1230	1110	1160	4.064	4.160
	2	1200	1160	1120	4.877	
	3	1180	1180	1140	4.513	
BD5C2F2	1	1110	1060	1050	3.441	**3.526**
	2	1110	1060	1050	3.768	
	3	1130	1050	1050	3.369	
BD10C4F4	1	1010	980	980	2.408	2.543
	2	1020	1010	980	2.651	
	3	1080	1010	970	2.560	
BD15C6F6	1	1000	980	930	2.454	2.242
	2	1030	970	960	2.146	
	3	1010	930	990	2.127	
BS2	1	1270	1190	1240	2.902	2.987
	2	1280	1220	1320	3.073	
BS4	1	1200	1140	1170	3.077	2.996
	2	1200	1160	1210	3.502	
	3	1240	1160	1220	2.408	
BS6	1	1180	1170	1170	3.274	2.961
	2	1220	1130	1170	2.648	
	3		1150	1190		

Table 4.5 weights and compressive strength of Adobe block oven dried for 24 hours after cured for 28 days

	No	Sample weight oven dry (for compressive strength)	Compressive strength (oven dry)	Average compressive strength (MPa)
B_{C2F2}	1	1200	3.882	3.982
	2	1150	4.049	
	3	1200	4.015	
B_{C4F4}	1	1160	4.311	4.331
	2	1200	4.22	
	3	1200	4.463	
B_{C6F6}	1	1160	2.704	2.896
	2	1170	2.807	
	3	1200	3.179	
B_{D5F2}	1	1090	4.121	4.12
	2	1100	3.756	
	3	1080	4.482	
	4			
B_{D10F4}	1	1060	4.581	4.217
	2	1020	3.601	
	3	1050	4.470	
B_{D15F6}	1	960	4.391	4.461
	2	880	4.539	
	3	940	4.452	
B_{F2}	1	1130	4.566	4.166
	2	1170	3.684	
	3	1120	4.247	
B_{F4}	1	1140	5.120	5.368
	2	1150	5.705	
	3	1200	5.280	
B_{F6}	1	1110	4.756	4.520
	2	1160	4.152	
	3	1180	4.653	
B_{D5C2F2}	1	1060	4.566	4.273
	2	1060	3.684	
	3	1050	4.570	
$B_{D10C4F4}$	1	980	3.327	3.502
	2	1010	3.628	

	3	1010	3.552	
$B_{D15C6F6}$	1	980	2.648	2.459
	2	970	2.271	
	3	930	2.458	
B_{S2}	1	1190	2.898	3.647
	2	1220	3.628	
	3	1260	4.414	
B_{S4}	1	1140	2.882	3.341
	2	1160	4.144	
	3	1160	2.997	
B_{S6}	1	1170	3.86	3.670
	2	1130	3.483	
	3	1150	3.669	