ISSN No.: 2454- 2024 (online)
International Journal of Technical Research & Science

PREPARATION OF ADOBE BRICK BY MIXING WITH RICE HUSH ASH

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Abstract- Adobe bricks are prepared by mixing with rice husk ash (RHA) and soil for using in construction of low cost housing. The soil samples are taken from Shan Taè Gyi village, South Dagon Township and Danyingone Township in Yangon Division. Firstly, the physical and chemical properties of these soil samples and RHA are studied. And then, SEM is also used for studying morphology of these samples and RHA. For making adobe brick by using Shan Taè Gyi soil sample and RHA, RHA is added by 0, 3, 9 and 15% by total weight. In addition, water amount is added by 40 to 65 percentage of weight of the dry soil and the weight of straw 50 g for a brick. In testing process, adobe bricks are dried by means of solar energy and using dryer at a temperature of 40°C. The testing results are measured at 2 months for sun drying and 5 hr per day for 25 days in dryer drying according to weather conditions. In this study, 3% RHA content is also observed to be the appropriate content for compressive strength of adobe bricks. The compressive strength value of sun-dried adobe brick is 32 kg/cm^2. Both linear shrinkage and unit weight of adobe bricks decreased with increase in the percentage of RHA content. The further study is carried out to make adobe brick by using Shan Taè Gyi soil and Danyingone soil samples mixing with RHA. In the present work, small cubic blocks and bars are made by adding various proportions of RHA; 3, 6, 9, 12 and 15% by total dry weight of required sample. Then, cold crushing strength (CCS), flexural strength, linear shrinkage, bulk density and water absorption are investigated. The test results indicate that the optimum conditions are found at 3% RHA content for Shan Taè Gyi and at 9% RHA content for Danyingone soil sample in adobe brick preparation. The cold crushing strength of Danyingone soil sample is 112 kg/cm^2. This adobe brick can be used in non-load bearing wall.

Keywords: adobe brick, cold crushing strength, flexural strength, linear shrinkage, rick hush ash

1. INTRODUCTION

The provision of affordable housing for its citizens is one of the cardinal programmes of every government, especially in the developing countries [1]. Nowadays the technological developments in all fields of construction have created demand for special materials, which are cheap and available in the locality abundance. These developments took certain advantages of transportation charges. Utilization of agriculture residues in housing and construction limited commercial success.

The houses in rural area are built with bamboo and thatches. These dwellings are unable to withstand the effect of weather and insect's destruction. On the other hand, the walling and partitions of dwelling with manufacturing bricks and various kinds of timber are very expensive for basic people. Moreover, the existing unburnt bricks are manufactured in the place, where occurrence of raw materials is at hand. So it is required to produce the unburnt bricks which materials are available in local [2].

A survey done by raw materials research and development Council of Nigeria on available local building materials reveals that certain building materials deserve serious consideration as substitute for imported ones. Few of these materials includes: cement / lime stabilized bricks / blocks, sundried (Adobe) soil blocks, burnt clay bricks / blocks, sandcrete blocks, soilcrete blocks, cast in-situ walls, rice husk ash (RHA), mud and straw, lime and stonecrete blocks [3].

Adobe bricks are one of the first building materials used by humans. Adobes are large, sun-baked unburnt bricks used in some tropical and semi-arid countries for building construction [4]. A distinction is sometimes made between the smaller adobes, which are about the size of ordinary baked bricks, and the larger adobes, some of which may be one to two yards (2m) long [5]. Of course, adobes are not as strong as the sandcrete or soilcrete blocks with extra bonds provided by the cementing agents, nor are they as strong as the burnt bricks which, as a result of the heat to which they are usually subjected (about 800-1100°C) become homogeneous, harder and stronger from the ceramic bond produced through the fusion of the silica and alumina constituents. Therefore, another material is used to support the strength of adobe bricks [6]. The use of adobe bricks in the construction of shelters in developing countries is mainly dependent on their mechanical resistance, water absorption and chemical behaviors. To improve the physical properties of these building materials, straw debris, fly ash, rice husk ash and small amounts of cement or lime are commonly introduced [7].

Rice husk is an agricultural waste obtained from milling of rice. About 10^8 tons of rice husks are generated annually in the world [8]. The use or disposal of rice husks has frequently proved difficult because of the tough, woody, abrasive nature of the husks, their low nutritive properties, and resistance to weathering, great bulk and ash content. In fact in South-east Asia there are areas where accumulating heaps of rice husks are a significant problem. Therefore, the burning of rice husks and utilizing rice husk ash in construction could protect the environment from contamination [9]. Burning the husk under controlled temperature below 800°C can produce ash with silica mainly in amorphous form. A state-of-the-art report on rice husk ash (RHA) was published by Mehta 1992, and contains a review of physical and chemical properties of RHA, the effect of incineration

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conditions on the pozzolanic characteristics of the ash, and a summary of the research findings from several countries on the use of RHA as a supplementary cementing pozzolanic material. Pozzolan- a siliceous or alumino-siliceous material that in itself possesses little or no cementitious value but that in finely divided form and in the presence of moisture will chemically react with alkali and alkaline earth hydroxides at ordinary temperatures to form or assist in forming compounds possessing cementitious properties [10].
For this study the rice husk ash from brick kiln is mixed in the adobe bricks to support the property of strength and to improve the physical properties so that the results of this study will be used to develop for low cost housing constructions. In this study, two methods are used to prepare adobe bricks. The first method is that RHA and straw are mixed in adobe bricks. In laboratory scale, the second method is used. In this method, RHA is only mixed in cube and bar specimens to form stable calcium silicates which have cementitious properties.

2. MATERIAL

2.1 Collection of Soil Samples

Soil samples are collected from Shan Taè Gyi village, South Dagon Township and Danyingone Township in Yangon. These samples have been obtained from several places distributed over the whole selected area in Shan Taè Gyi and Danyingone regions. These samples have been obtained from several holes are dug in the area that is big enough to supply all the required soil. First, the topsoil containing vegetable matter and living organisms is usually removed less than 2ft. Then, a pit is dug to a depth 5ft for manual excavation and collected soil for the sample at various depths between 2.5ft and 5ft. The soil samples are collected and kept in woven (PVC) bags.

2.2 Collection of Rice Husk Ash Sample

Rice husk ash is collected from brick kiln of Shan Taè Gyi village, South Dagon Township in Yangon Division. The color of rice husk ash is grey color.

2.3 Collection of Straw Sample

Straw sample is taken from paddy field in Thilawa.

3. METHOD

3.1 Determination of Physical Properties of Soil Samples

The physical properties of soil are specific gravity, atterberg limits and grain size distribution of soil. These properties are important to investigate the characteristics and engineering properties of the soil. The resulting data are described in Table 4.1.

3.2 Grain Size Analysis of Soil Samples

Grain size analysis is the determination of the size range of particles present in a soil, expressed as a percentage of the total dry weight. Complete particle size analysis requires two tests, a sieve analysis and a hydrometer analysis.

- Sieve analysis is used for particle sizes larger than 0.075 mm in diameter.
- Hydrometer analysis is used for particle sizes smaller than 0.075 mm in diameter.

3.2.1 Sieve Analysis

Sieve Analysis is used to determine grain size analysis. From this test, percent finer must be calculated and plotted on the graph. The experimental procedure of sieve analysis is mentioned in Appendix A.1.

3.2.2 Hydrometer Analysis

Soil passing U.S sieve No.200 is tested by using hydrometer to determine grain size analysis. The experimental and detailed procedure of hydrometer analysis is presented in Appendix A.2.

3.3 Specific Gravity Test

Specific gravity (G_S) is defined as the ratio of the unit weight of a given material to the unit weight of water. The specific gravity of soil solids is often needed for various calculations in soil mechanics. The experimental procedure of specific gravity test is shown in Appendix A.3.

3.4 Atterberg Limit Tests

The water content levels at which the soil changes from one state to the other is the Atterberg limits. They are plastic limit (PL), liquid limit (LL) and plasticity index (PI). The liquid and plastic limits have been widely used for soil identification and classification.

3.4.1 Liquid Limit Test

Liquid limit (LL) is the moisture content below which the soil behaves as a plastic material. The laboratory procedure of liquid limit test is described in Appendix A.4.

3.4.2 Plastic Limit Test

Plastic Limit (PL) is the moisture content below which the soil is non plastic. The laboratory procedure of plastic limit test is presented in Appendix A.5.

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3.4.3 Plasticity Index (PI)

Plasticity index (PI) is the difference between the liquid limit and plastic limit.

$$PI = LL - PL$$

where, PI = plasticity index
LL= liquid limit
PL= plastic limit

3.5 Chemical Analysis of Soil and Rice Husk Ash (RHA) Samples

Collected soil and suitable RHA samples to prepare adobe brick are also determined their composition. X-Ray Spectrometer is used to identify the major and minor oxide elements present in the samples of soil and rice husk ash. The results of X-ray Spectrometer analysis are discussed in section D and Table 4.2.

3.6 Determination of Morphology of Soil and Rice Husk Ash Samples

The morphology of these soil and RHA samples are determined by Scanning Electron Microscope (SEM). It is discussed in section 4.5 and shown in Appendix C-Figures C1, C2 and C3.

3.7 Preparation of Soil and Rice Husk Ash Samples

The soil samples are mixed thoroughly and dried in the sun. Soil lumps are broken up and then ground for one hour in a ball mill. The prepared soil powder, which passes through a 35 mesh screen (0.417 mm diameter), is kept in air-tight plastic bags to test this experiment. Rice husk ash sample is dried in the sun for two days. After drying, rice husk ash sample is finely ground for one hour in a ball mill. The prepared rice husk ash is kept in plastic bags. The prepared soil and rice husk ash samples are described in Fig. 3.1.

Fig. 3.1 Prepared Soil and Rice Husk Ash Samples

3.8 Preparation of Adobe Bricks by Using Shan Taè Gyi Soil Sample, Rice Husk Ash (RHA) and Straw

The soil sample (Shan Taè Gyi) is mixed with enough water to bring them to near suitable moisture content and thoroughly mixed to get to a state of uniform consistency. The suitable soil paste for making adobe brick has to contain a certain amount of water usually between 40 to 65 percentage of weight of the dry soil. And then this mixture is last about 24 hours for saturating in air-tight plastic bag. Next, cut straw as additive is mixed with saturated soil paste. In this work, the weight of straw 50 g is fixed for a brick. After that, rice husk ash is mixed in ratio of 3, 9 and 15% by total dry weight. The mixed soil paste is kneaded well under foot till it becomes a homogeneous mass. Consequently, homogeneous soil paste is molded in wrought iron mould with size 9.6"×4.6"×3.1" fully with clear on the surface and then released from the mould. To prevent bricks from sticking to the mould, the mould is sprinkled over with sand each time it is used. Then the bricks are air-dried in the room for a total period of 48 hours, with their being turned on edge after 24 hours. In this study, the process is carried out during rainy season. So the bricks are separated into two batches. The first batch is dried by means of solar energy for two months. The second batch is dried for 5 hr per day in drier at 40°C. The total drying period is 25 days. After drying, adobe brick size is found to be 9"×4"×3" due to shrinkage. Adobe bricks are produced

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ISSN No.: 2454- 2024 (online)

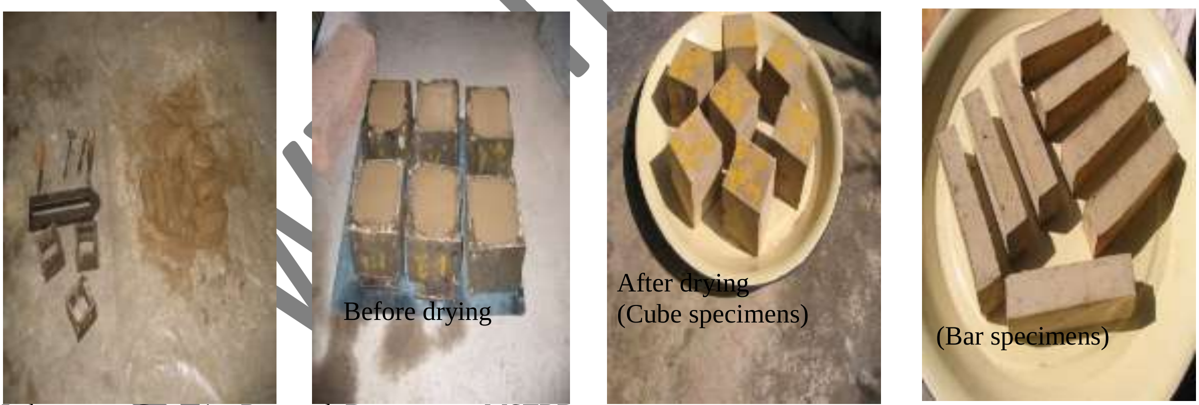
International Journal of Technical Research & Science

for measuring properties and obtaining the suitable rice husk ash ratio that gives the highest strength of adobe brick. The whole adobe brick preparation process is shown in Figure 3.2.

Fig. 3.2 Preparation Steps of Adobe Brick

3.9 Preparation of Small Cube and Bar Specimens

Small cube and bar specimens are prepared by using Shan Taè Gyi and Danyingone soil samples. Firstly, soil samples and rice husk ash are thoroughly mixed by using quartering method and screening to obtain homogeneous mixture. These specimens are made from RHA-Soil mixtures (Soil: RHA = 100:0, 97:3, 94:6, 91:9, 88:12 and 85:15) based on the total dry weight of the required sample. It is observed that the optimum water amount for making the batch composition in workable condition increases as the quantity of rice husk ash was increased. The wet mixing of water and RHA-soil mixture are made by pounding to attain homogeneous paste. The workable condition of soil paste for preparing cube and bar specimens has to contain a certain amount of water ranging from 20 to 40% by weight of dry soil. This paste mixture is kept in air-tight plastic bag for 24 hours saturation to reach uniform consistency. Bar specimens of 4"×1"×1" size for testing flexural strength and cube specimens of 2.75"×2.75"×2.75" size for determining cold crushing strength (compressive strength) are prepared by hand moulding. After that, these specimens are air-dried for 24 hours. And then, these specimens are dried in the sun for 14 and 28 days. After drying period, mechanical strength and physical properties of specimens are measured. The specimens preparation process is shown in Figure 3.3.



Laboratory: Ceramics Research Department, MSTRD

Fig. 3.3 Preparation of Small Cube and Bar Specimens

3.10 Determination of Mechanical Properties

3.10.1 Determination of Compressive Strength (flat-wise) of Adobe Bricks

Ideally, the aim of compression testing is to determine the crushing strength of material and thus to obtain data that can be used as a basic for the design of actual building structure.

In this study, the compression testing machine of capacity 200 tons is used for the compression test together with a spherical bearing block large enough to cover the specimen entirely. The test specimen is a whole brick. The frogs of brick are filled with sand. Then the brick is placed between sheets of thin plywood between the plates of the testing machine, and the upper plate is screwed down into contact with it by means of the handwheel on the top of the machine. The load is applied by pumping oil to an hydraulic ram beneath the lower plate, and its amount is shown on the dial on the right of the machine. The speed of the moving head of testing machine, during application of the load is 1.5 mm per minute. The used 200 tons hydraulic compression machine is presented in Fig. 3.4. The resultant data from testing are shown in Table 4.3, Table 4.4 and discussed in section F. The calculation of compressive strength of adobe brick is described in Appendix B.1.

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Laboratory: Building Research Station, Thuwuna

Fig. 3.4 Hydraulic Compression Machine

3.10.2 Determination of Cold Crushing Strength (Compressive Strength) of Cube Specimens

The capacity of the testing machine will be so adjusted that the load tested is within 15 to 85% of that of the testing machine. The dimensions of pressed surfaces will have been measured preliminarily to the nearest 0.5 mm for each test piece, and as required, a piece of paper shall be inserted on the pressed surface to equalize the pressure. In testing, the pressed surfaces of the test piece will be correctly placed at the center of the spherical seat. The rate of application of load will be 1.0 to 1.5 MPa {10 to 15 kg_f/cm^2} as standard and determine the maximum load {N (kg_f)} when the test piece is crushed.

In this study, the compression testing machine is capable of applying loads up to 200 kg_f/cm^2. For cube specimen (2.75"×2.75"×2.75"), the application load of (20 kg_f/cm^2) is applied and determined the maximum load when the cube specimen is crushed. The used compression testing machine is shown in Figure 3.5. The resultant data from testing are presented in section 4.8. The calculation of cold crushing strength (compressive strength) of cube specimen is shown in Appendix B.2.

Laboratory: Ceramics Research Department, MSTRD

Fig. 3.5 Compression Testing Machine

3.10.3 Determination of Flexural Strength (Modulus of Rupture) of Bar Specimens

Any suitable testing machine may be used, provided uniform rates of direct loading can be maintained. The bar specimens are supported on knife edges over a suitable span and a direct load is applied at the midpoint between the supports at a uniform rate until breakage occurs.

The load is uniformly applied at the rate of 1000 ± 150 lb (454 ± 68 kg)/min, until failure occurs. The width and thickness is measured at the break to the nearest 0.001 in (0.0254 mm). The used bending tensile strength tester is shown in Figure 3.6. The resultant data from measuring are presented in section I. The calculation of flexural strength of bar specimens is presented in Appendix B.3.

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Fig. 3.6 Bending Tensile Strength Tester

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3.11 Determination of Physical Properties of Adobe Brick and Test Specimen

3.11.1 Determination of Linear Shrinkage and Unit Weight of Adobe Brick

The dimension of adobe bricks is measured and linear shrinkage of these bricks is determined by the following formula.

$$\text{Linear shrinkage ratio} = \frac{\text{wet length - dry length}}{\text{wet length}} \times 100\%$$

The resulting data of linear shrinkage and unit weight are described in section G.

3.11.2 Determination of Water Absorption, Bulk Density and Linear Shrinkage of Bar Specimen

Water absorption and bulk density tests are carried out in accordance with JIS 1992. These testing methods and calculation of linear shrinkage are described in Appendix B.4 and B.5. The resulting data from testing are described in section J and K.

4. RESULTS AND DISCUSSIONS

4.1 Selection of Soil Samples

Soils which contain far too much clay are not well-suited to adobe brick making. Such soils tend to shrink and crack severely as they dry. Desirable soils for adobe brick-making are those texturally classified as loamy sands, sandy loams or sandy clay loams.

It is observed that soils for adobe brick making generally contain sand (50 to 85%), silt (0 to 30%) and clay (0 to 30%). However, in this study soils which contain not only high percentage of clay but also low percentage of sand are selected for making adobe brick mixing with rice husk ash that contains mainly silica. Silt is physically and chemically the same as sand but particle size is smaller than that of sand. Although Shan Taè Gyi sample contains low percentage of clay, total amount of sand and silt is 74%. In Danyingone soil sample, it contains high percentage of clay and low percentage of sand.

4.2 Selection of Rice Husk Ash Sample

In this experiment, rice husk ash (RHA) which contains at least carbon is selected. RHA is a good super-pozzolan. According to composition and chemistry of pozzolanas, loss on ignition of pozzolanas is not more than 15 percent. The RHA used in this study has 2.24% weight loss on ignition. It is observed that amorphous silica is formed at 500°C-800°C and at greater temperatures, crystalline silica is formed. Crystalline silica loses a degree of reactivity. So the RHA used in adobe brick making has to be amorphous silica form.

4.3 Physical Properties of Soil Samples

The soil samples are tested for their grain size, specific gravity, moisture content, liquid limit, plastic limit and plasticity index. The results are shown in Table 4.1.

Table-4.1 Physical Properties of Soil Samples

Physical Property Description	Location	
	Shan Taè Gyi	Danyingone
Gravel (%)	0	1
Sand (%)	1	17
Silt (%)	73	36
Clay (%)	26	46
Specific Gravity	2.72	2.65
Liquid limit (%)	51.40	40.20
Plastic limit (%)	26.03	21.08
Plasticity Index (%)	25.37	19.12
Moisture Content (%)	8.23	20.90

From the results, it is observed that Shan Taè Gyi soil sample contains 1% sand, 73% silt and 26% clay. The soil textural name of Shan Taè Gyi sample is silty clay loam. For Danyingone soil sample, it contains 1% gravel, 17% sand, 36% silt and 46% clay. The soil textural name of Danyingone sample is clay loam. Danyingone soil contains a little gravel but Shan Taè Gyi soil is not present. Although sand and clay content in Danyingone is greater than Shan Taè Gyi sample, silt content is lower than Shan Taè Gyi soil. In comparison with specific gravity, Danyingone soil is lighter than Shan Taè Gyi soil because clay content is highest in Danyingone soil. Both Danyingone and Shan Taè Gyi soil samples contain a little sand. Moisture content of Danyingone soil is

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two and half times greater than that of Shan Taè Gyi soil. So, liquid limit of Shan Taè Gyi soil sample is more than liquid limit of Danyingone soil sample. In addition, plasticity index of Shan Taè Gyi soil is high due to more liquid limit.

4.4 Chemical Analysis Results for Soil Samples and Rice Husk Ash Sample

The soil samples obtained from Shan Taè Gyi and Danyingone areas and rice husk ash sample from brick kiln in Shan Taè Gyi village are analyzed by XRS to determine their chemical compositions. The resulting data are shown in Table 2.

Table-4.2 Chemical Composition of Soil Samples and Rice Husk Ash Sample

Constituents	Composition (%)		
	Shan Taè Gyi soil sample	Danyingone soil sample	Rice husk ash sample
$Si\ O_2$	77.32	68.27	91.44
$Al_2\ O_3$	9.88	15.17	1.50
$Fe_2\ O_3$	3.82	5.51	0.37
$Ti\ O_2$	0.64	0.95	0.06
CaO	0.39	0.09	0.72
MgO	1.28	0.68	0.39
Na_2O	1.29	0.30	0.13
K_2O	1.79	1.67	2.22
MnO	0.14	0.07	0.07
P_2O_5	-	-	0.72
SO_3	-	-	0.08
Cl	-	-	0.02
CuO	-	-	0.01
ZnO	-	-	0.01
PbO_2	-	-	0.01
ZrO_2	-	-	0.004
PdO	-	-	0.003
Loss on ignition(LOI)	3.45	7.30	2.24

Chemical compositions of soil samples and rice husk ash sample are shown in Table 4.2. Major oxide elements of Shan Taè Gyi soil sample are SiO_2 (77.32%) and Al_2O_3 (9.88%). Minor oxide elements are Fe_2O_3 (3.82%), TiO_2 (0.64%), CaO (0.39%), MgO (1.28%), Na_2O (1.29%), K_2O (1.79%) and MnO (0.14%). Loss on ignition (3.45%). Chemical composition of Danyingone soil sample contains: SiO_2 (68.27%), Al_2O_3 (15.17%), Fe_2O_3 (5.51%), TiO_2 (0.95%), CaO (0.09%), MgO (0.68%), Na_2O (0.30%), K_2O (1.67%) and MnO (0.07%). Loss on ignition is 7.30%. When compared all these results to Shan Taè Gyi soil sample, percentages of Al_2O_3, Fe_2O_3 and TiO_2 of Danyingone soil sample are higher than Shan Taè Gyi soil sample. According to grain size distribution curve, clay content of Danyingone soil is higher than that of Shan Taè Gyi soil. In addition percentage of SiO_2 is lower than Shan Taè Gyi soil sample.

The RHA used in this study contains: SiO_2(91.44%), Al_2O_3(1.50%), Fe_2O_3(0.37%), TiO_2 (0.06%), CaO (0.72%), MgO (0.39%), Na_2O (0.13%), K_2O (2.22%), MnO (0.07%), P_2O_5 (0.72%), SO_3 (0.08%), Cl (0.02%), CuO (0.01%), ZnO (0.01%), PbO_2 (0.01%), ZrO_2 (0.004%) and PdO (0.003%). The total percentage composition value of silicon dioxide, iron oxide and alumina is not less than 70% for pozzolanic property[35]. In RHA used in this experiment, the total percentage composition of silicon dioxide (SiO_2 = 91.44%), iron oxide (Fe_2O_3 = 0.37%) and (Al_2O_3 = 1.50%) is found to be 93.31%. This value is greater than the required value of 70% minimum for pozzolanas. The loss on ignition is 2.24%. It means that the RHA contains little unburn carbon and this reduces the pozzolanic activity of the ash. It is evident that RHA contains mainly silica.

4.5 SEM Analysis Results for Soil Samples and RHA Sample

According to SEM image, the nature of pore sizes of soil samples can be observed as shown in Appendix C-Figure C1 and C2. It is found that porous nature of Danyigone soil sample is smaller than Shan Taè Gyi soil sample. Danyingone soil sample has plate-like structures on its surface. Shan Taè Gyi soil sample has a little plate-like structures on its surface. So Danyingone soil sample has high clay content.

SEM photograph of rice husk ash sample reveals the siliceous nature of the ash. Rice husk ash is highly porous in nature. The porous nature of RHA is responsible for its high surface area and makes it suitable for making brick. SEM image of RHA is shown in Appendix C-Figure C3. It is found that silica in RHA has amorphous form.

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4.6 Determination of Compressive Strength of Adobe Brick

Compressive Strength of Adobe brick is measured by 200 tons hydraulic compression machine. The calculated flat-wise compressive strengths of adobe brick can be found in Table 4.3 and Table 4.4.

Table-4.3 Average Dry Compressive Strength (flat-wise) of Sun-dried Adobe Brick

Percent of rice husk ash by total dry weight	Average dry compressive strength of sun-dried adobe brick (two months drying), (kg/cm^2)
0%	28.1
3%	32
9%	24.3
15%	25.8

Table-4.4 Average Dry Compressive Strength (flat-wise) of Dryer-dried Adobe Brick

Percent of rice husk ash by total dry weight	Average dry compressive strength of dryer-dried adobe brick (25 days drying, 5hr/day), (kg/cm^2)
0%	43.7
3%	60.71
9%	41.5
15%	44.8

From above the tables, it can be found that the graph line shows the highest compressive strengths (kg/cm^2) at 3% RHA content and the values of compressive strength are 60.71 kg/cm^2 for dryer-dried adobe brick and 32 kg/cm^2 for sun-dried one. Both dryer-dried and sun-dried adobe brick have the lowest compressive strength at 9% RHA content. The values of compressive strength at 9% RHA content are 41.5 kg/cm^2 and 24.3 kg/cm^2, respectively. Compressive strength of sun-dried adobe brick is lower than strength of dryer-dried adobe brick at 3% RHA content due to weather conditions. The rate of strength gain is of course dependent on the rate of drying (in this case the amount of sunshine available) and the care taken of the specimens during the curing period. The 3% RHA content is the appropriate condition in adobe brick preparation. Many national standards (Nigerian, British, American) specify a minimum value for the compressive strength of bricks of 5.2 MNm^{-2} (53.025kg/cm^2) for load bearing walls and 1.4 MNm^{-2} (14.276kg/cm^2) for non-load bearing walls [1]. By comparison with many national standards [1], adobe brick at 3% RHA for Shan Taè Gyi soil sample can be used in non-load bearing walls.

In this process, adobe bricks are prepared from Shan Taè Gyi soil sample. This process is carried out in rainy season. Adobe bricks are too brittle due to more silica content. So, compressive strength of adobe bricks decreases with increase in the percentage of RHA content. The strength of adobe brick is fluctuated when proportion of RHA increases due to weather condition, type of soil, manufacturing process and human error.

4.7 Determination of Linear Shrinkage and Unit Weight of Adobe Birck

The calculated results of linear shrinkage and unit weight for adobe brick can be found in Table 5.

Table-4.5 Linear Shrinkage and Unit Weight of Adobe brick (Shan Taè Gyi Soil Sample)

Percent of rice husk ash by total dry weight	Linear Shrinkage (%)		Unit Weight (kg)	
	25 days drying (Dryer-dried) (5hr/day)	Two months drying (Sun-dried)	25 days drying (Dryer-dried) (5hr/day)	Two months drying (Sun-dried)
0%	10.1	9.4	2.713	2.69
3%	9.7	8.7	2.516	2.65
9%	6.6	6.9	2.442	2.60
15%	6.6	6.9	2.367	2.52

In Table 4.5, linear shrinkage of dryer-dried adobe brick decrease from 10.1% to 6.6% with increase in RHA content from 0% to 15%. Linear shrinkage of sun-dried adobe brick decreases from 9.4% to 6.9% with increase in RHA content. This may be attributed to the usual replacement of the soil fines by RHA. The later is less in

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activity with changes in moisture content and therefore, reduced the linear shrinkage of adobe brick. And then, the result shows that unit weights of sun-dried and dryer-dried adobe bricks decreased according to the increase in the percentage of RHA content. The main reason is that the rice husk ash has a lower specific weight than Shan Taè Gyi soil sample.

4.8 Determination of Cold Crushing Strength (Compressive Strength) of Cube Specimens

In this test, cube specimens are prepared from two soil samples (Shan Taè Gyi and Danyingone), which are mixed with rice husk ash. Cold crushing strength of cube specimens is determined by 200 kg_f/cm^2 compression testing machine. The resulting data are mentioned in Tables 4.6 and 4.7.

Table-4.6 Cold Crushing Strength of Cube Specimens (Shan Taè Gyi Soil Sample)

Soil (%)	RHA (%)	Cold Crushing Strength, kg/cm^2	
		14 days	28 days
Control	0	47.83	52.09
97	3	64.35	67.05
94	6	59.46	63.75
91	9	52	54.16
88	12	46.19	47.68

In Table 4.6 shows the highest cold crushing strength (kg/cm^2) at 3% RHA content. The values of cold crushing strength are 64.35 kg/cm^2 at 14 days and 67.05 kg/cm^2 at 28 days. Above 3% RHA content, cold crushing strength of cube specimens decreased as the percentage of RHA content increases. In compared with control, the cold crushing strengths at 6% RHA content and 9% RHA content are higher than cold crushing strength of control. By testing result at 28 days, cold crushing strength (47.68 kg/cm^2) at 12% RHA content is lower than that of control (52.09 kg/cm^2). Thus, 3% RHA content would appear to be the suitable RHA content for Shan Taè Gyi soil sample in adobe brick preparation.

Table-4.7 Cold Crushing Strength of Cube Specimens (Danyingone Soil Sample)

Soil (%)	**RHA (%)**	**Cold Crushing Strength, kg/cm^2**	
		14 days	**28 days**
Control	0	70	76
97	3	89	107
94	6	107	94
91	9	109.6	112
88	12	120	114
85	15	100.3	100.6

In Table 4.7 shows the relationship between cold crushing strength and RHA content. By testing results at 28 days, cold crushing strength at 12% RHA content is the highest in all percentage of RHA content and the value is 114 kg/cm^2. Cold crushing strength at 9% RHA content is the second highest in other percentage of RHA content and the value is 112 kg/cm^2.

Overall result shows that the cold crushing strength increased from 70 kg/cm^2 to 120 kg/cm^2 at drying period of 14 days with increase in RHA content from 0% to 12% respectively and from 76 kg/cm^2 to 114 kg/cm^2 at drying period of 28 days except 6% RHA content. But cold crushing strength subsequently reduced with further addition of RHA. The reason for increment in cold crushing strength (CCS) may be because of the gradual formation of cementitious compounds in the soil by the reaction between the silica which contains in RHA and some amounts of CaOH present in the soil. The decrease in CCS above 12% RHA content may be due to extra RHA that could not be mobilized for the reaction which consequently occupies spaces within the sample. This reduced the bond in the soil-RHA mixture.

Crushing strength of specimens at various percentage of RHA content is greater than control. The value of cold crushing strength at 12% RHA content is higher than value of cold crushing strength at 9% RHA content a little. The incremental proportion between 9% RHA content and 12% RHA content is also 3%. In addition, working ability at 9% RHA content is better than working ability at 12% RHA content. Therefore, 9% RHA content is chosen as optimum condition for Danyingone soil sample in adobe brick preparation.

4.9 Determination of Flexural Strength of Bar Specimens

Flexural Strength of bar specimen is measured by bending tensile strength tester (TONINDUSTRIE). The resulting data are mentioned in Table 4.8 and Table 4.9.

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Table-4.8Flexural Strength of Bar Specimen (Shan Taè Gyi Soil Sample)

Soil (%)	RHA (%)	Flexural Strength, kg/cm^2	
		14 days	28 days
control	0	7.11	6.56
97	3	7.95	8.00
94	6	3.90	4.24
91	9	2.89	3.45

In Table shows the highest flexural strength at 3% RHA content. The values of flexural strength are 7.95 kg/cm^2 at 14 days and 8 kg/cm^2 at 28 days, respectively. At 28 days, flexural strength of control is higher than flexural strengths at 6% RHA content and 9% RHA. In this study, flexural strength of bar specimen decreased according to the increase in percentage of RHA above 3% RHA content. The values of flexural strength are not much different between 14 days and 28 days. When Shan Taè Gyi soil sample is mixed with 9% RHA content, this soil sample is gritty. Furthermore, working ability at 9% RHA is not good. Thus, flexural strength testing of bar specimen is not carried out. The quantity of rice husk ash at 3% is the appropriate admixture for Shan Taè Gyi soil sample.

Table-4.9 Flexural Strength of Bar Specimen (Danyingone Soil Sample)

Soil (%)	RHA (%)	Flexural Strength, kg/cm^2	
		14 days	28 days
control	0	34.23	38.79
97	3	28.71	36.37
94	6	37.1	38.75
91	9	39.1	41.43
88	12	30.55	31.69
85	15	32	28.29

In Table 4.9 describes the relationship between flexural strength and RHA content. By testing results at 28 days, flexural strength at 9% RHA content is the highest in all percentage of RHA content and the value is 41.43 kg/cm^2. Although flexural strength at 9% RHA is higher than control, the value at 9% RHA content is not much different. Thus, the quantity of RHA at 9% is the best admixture for Danyingone soil sample in adobe brick preparation.

4.10 Determination of Linear Shrinkage of Test Specimens

The calculated results of linear shrinkage for specimens of two soil samples are described in Table 10.

Table-4.10 Linear Shrinkage of Test Specimens

Soil (%)	RHA (%)	Linear shrinkage (%)	
		(Danyingone)	(Shan Taè Gyi)
control	0	9.4	3.73
97	3	9.1	3.41
94	6	8.8	3.22
91	9	8.1	2.69
88	12	7.48	ND
85	15	7.48	ND

In Tables 4.10 and 4.11, it is observed that linear shrinkage of specimens decreased as the percentage of RHA content increases. The reason is that RHA reduces the movements (shrinkage and swelling) of the soil when its moisture content varies due to weather conditions. By comparison with Shan Taè Gyi soil sample, linear shrinkage of specimens (Danyingone soil sample) is higher than linear shrinkage of specimens (Shan Taè Gyi soil sample) because Danyingone soil sample contains high percentage of clay. According to described data in section 4.3, the percentage of clay content is almost two times greater than percentage of clay content in Shan Taè Gyi soil sample. These figures can be applied in making adobe brick mould.

4.11 Determination of Water Absorption and Bulk Density of Test Specimens

Water absorption and bulk density data of specimens which are made by using Danyingone soil sample are presented in Table 4.11. These are not tested in Shan Taè Gyi soil sample because of workability condition.

Table -4.11 Physical Properties of RHA-Danyingone Soil Specimen

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Soil (%)	RHA (%)	Water absorption (%)	Bulk density (g/cm^3)
control	0	7.75	1.95
97	3	9.35	1.89
94	6	9.55	1.86
91	9	11.8	1.82
88	12	13.65	1.79
85	15	18.2	1.74

From above the tables, as the proportion of RHA increases a gradual decrease in bulk density whereas, an increase in water absorption is observed. This may be attributed to the usual replacement of the soil fines by RHA. RHA has high porous nature. So, water absorption capacity increased with increase in the percentage of RHA. The cause of decreasing bulk density may be due to RHA, which has a lower specific weight than sand.

4.12 The Noticeable Points in Adobe Brick Preparation by Mixing With Rice Husk Ash

In this study, the following points are observed in rice husk ash- adobe brick making.

- Clayey soil and rice husk ash, which has little carbon should be selected. According to compositon and chemistry of pozzolanas [35], carbon content in rice husk ash should be as low as possible, below 12 percent is normally recommended. Soil suitable for adobe brick should have a high enough clay content to help the brick resist moisture and provide strength to the brick.
- Rice husk ash used in adobe brick should be finely ground.
- Soil powder is thoroughly mixed with rice husk ash to obtain homogeneous mixture.
- And then, water is added only enough in homogeneous soil mixture to create a workable consistency and to become plasticity, uniformity and homoginity.
- It is important to the right blend of soil and water. A trial and error method is sometimes required to achieve the right blend.
- Soil paste should be saturated for long time in air-tight plastic bag.
- The longer saturation time of soil paste mixture in air-tight plastic bag, the better strength of adobe brick.
- In brick molding, soil paste in bulk is thrown in the brick mould and then scraped off the excess soil to smooth the surface.
- It is necessary to consider the shrinkage of adobe brick for making brick mould.
- To avoid the development of cracks that might result from a fast and high rate of dehydration, adobe bricks are kept under the shade for 2 days and then placed in the sun to gain strength.
- In sun drying, drying rate should be uniform.
- Adobe brick preparation process is more suitable in dry climates.
- Adobe brick should be used after drying in the sun for up to 30 days.

4.13 Applications of Adobe brick Mixing with Rice Husk Ash

In this study, the compressive strength of sun-dried adobe brick at 3% RHA for Shan Taè Gyi soil sample is 32 kg/cm^2 (3.13 MNm^{-2}). Many national standards (Nigerian, British, American) specify a minimum value for the compressive strength of bricks of 5.2 MNm^{-2} (53.025kg/cm^2) for load bearing walls and 1.4 MNm^{-2} (14.276kg/cm^2) for non-load bearing walls [1]. Thus, the sun-dried adobe bricks at 3% RHA for Shan Taè Gyi soil sample satisfy the condition and are suitable for short non-load bearing walls (dwarf walls, partition walls, parapet walls, etc). In addition these bricks are used in temporary buildings such as briefing halls and the building for storage of crops such as silo. Ola (1983) has reported that a compressive strength of only about 0.207 MNm^{-2} (2.1108 kg/cm^2) is required for a one-storeyed structure with light roofing [1]. Therefore the RHA-adobe bricks are being used mainly for bungalows and one-storeyed buildings with light roofing.

CONCLUSION

Adobe bricks are prepared by using two soil samples (Shan Taè Gyi soil and Danyingone soil). In the first method, Shan Taè Gyi soil sample is mixed with straw and rice husk ash in adobe brick preparation. The proportions of mixed rice husk ash are 3%, 9% and 15% by total dry weight. In the compressive load test, 200 tons hydraulic compression machine is used. Compressive strength of adobe brick with size (9"×4"×3") is highest at 3% RHA content. The values of compressive strength at 3% RHA content are 60.71 kg/cm^2 (5.9 MNm^{-2}) for dryer-dried adobe brick and 32 kg/cm^2 (3.13 MNm^{-2}) for sun-dried adobe brick. As the adobe brick is unburnt brick, water absorption test cannot take place.

In the second method, two soil samples are mixed with rice husk ash in cube and bar specimens making. The ratios of soil and rice husk ash are 100:0, 97:3, 94:6, 91:9, 88:12 and 85:15, respectively. In compressive load

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test, 28-day cold crushing strength of cube specimen is highest at 3% RHA content for Shan Taè Gyi soil sample and the value is 67.05 kg/cm^2. It is observed that 28-day cold crushing strength of cube specimen is highest at 9% RHA content for Danyingone soil sample and the value is 112 kg/cm^2. When cold crushing strength of cube specimens is compared, cold crushing strength of cube specimen (Danyingone soil) is higher than that of cube specimen (Shan Taè Gyi soil).

In the flexural load test, 28-day flexural strength of bar specimen is maximum at 3% RHA content for Shan Taè Gyi soil sample and the value is 8.00 kg/cm^2. For Danyingone soil sample, 28-day flexural strength of bar specimen is highest at 9% RHA and the value is 41.43 kg/cm^2. It is observed that 3% RHA content is the appropriate condition for Shan Taè Gyi soil and the quantity of RHA at 9% is the optimum admixture for Danyingone soil in adobe brick preparation.

From the results of available strength of adobe brick and test specimens, adobe bricks (Soil-RHA mixture) should be used in one-storeyed buildings with light roofing, short non-load bearing walls (dwarf walls, partition walls, parapet walls,etc), temporary buildings such as briefing halls and the building for storage of crops such as silo.

Since the raw materials (soil and rice husk ash) required in the adobe brick are readily available in local, bricks can be made at the required place where the construction site is. Therefore, it may reduce the transportation cost. In the manufacturing of adobe brick, fuel and skill labour is not required. In addition, the production of adobe bricks mixing with RHA saves the time of burning, solves pollution problems and reduces energy consumption. Adobe brick should be used in low cost housing of rural region. Especially the brick is used in protected walls of crop storage silos and it can prevent the stored materials from the weathering effects.

RECOMMENDATIONS

[1] Soil Tests should be made to select suitable soil sample in the preparation of adobe brick mixing with RHA.

[2] Adobe brick should be prepared by mixing with other pozzolanic materials in order to use in load-bearing wall and improve strength and water resistant.

[3] Adobe brick preparation should be tested by using lateritic soils, dolomite and rice husk ash (RHA).

[4] Selection of soil sample should be noticed in RHA-adobe brick making. Dirt from old stream beds or low lying flood plains should not be used because they are usually full of fine silt and rocks and have little or no clay in them.

[5] If clayey soil is selected in adobe brick production, lime-RHA mixture should be used in adobe brick to resist weathering effect and reduce cracking of adobe brick.

[6] If adobe bricks are used in exterior walls or walls enclosing kitchens, toilets and bathrooms, portland cement mortor or other cement-based render should be used to eliminate the effect of rainwater or water from domestic use splashing on the walls.

[7] Adobe brick should not be used in damp situations and in places subjected to heavy rain.

APPENDIX

A.1. Experimental Procedure of Sieve Analysis

Take 500 gm of oven-dried soil sample and prepare sieve set in series of U.S standard sieve No.4, 8, 16, 30, 50, 100, and 200. The sieves are shaken by electrically operated sieve shaker for 15 minutes. After shaking, weigh soil retained on sieve series. A sieve analysis consists of shaking the soil through a stack of wire screens with opening of known size.

A.2. Experimental Procedure of Hydrometer Analysis

Mix a moist specimen of soil, about 50 gm dry weight, with distilled water to form a smooth thin paste. Add deflocculating agent, 1cc of sodium carbonate, and wash the mixture into the mechnical mixer. Stir the suspension in the mixer for 5 min, or until the soil is broken down into individual particles. After mixing, wash the suspension into the graduated cylinder and add enough distilled water to bring the level of 1000 cc mark. Place the palm of the hand over and turn the cylinder upside down and back for about 30 sec. Set the cylinder on a table, insert the hydrometer in the suspension and start the timer. Take hydrometer readings at elapsed times of 1/4, 1/2, 1 and 2 min without removing the hydrometer. Remix and repeat this set of four readings. Repeat until a consistent pair of sets is obtained. After the two minutes reading, remove the hydrometer, remix and restart the test. Take reading on the hydrometer at elapsed times of 2, 5, 10, 20 min etc approximately doubling the previous interval. For this series of readings the hydrometer should be stored in another cylinder of distilled water and insert the suspension just prior to the reading. The hydrometer should be wiped dry before each insertion. Note the temperature of the suspension. When the hydrometer reads around 1.001, remove the hydrometer; pour the suspension into a large evaporating dish, taking care to avoid losses. Evaporate the suspension in the oven; allow cooling in the desicators, and weigh to obtain the weight of the dry soil sample.

Calculation:

For Hydrometer Analysis,

$R_c = R_a$ - zero correction + C_T

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where,

R_a = actual hydrometer reading
R_c = corrected hydrometer reading
C_T = temperature correction factor = 3.8 at T = 30°C
(zero correction = -2)
R = R_c + Meniscus Correction

where,

R = corrected hydrometer reading for meniscus
(Meniscus Correction = 1)

$$\% \text{ Finer} = \frac{R_c(a)}{W_s} \times 100$$

where,

Ws = weight of orginal soil sample placed in suspension
a = correction factor for unit weight of solids

$$D = K\sqrt{\frac{L}{t}}$$

where,

D = diameter of soil particles
L = the distance particles fall in some time interval t
t = time
K = a factor dependent upon temperature and specific gravity of the soil particles

$$\text{Percent finer} = N\% = \frac{(\text{No.200 sieve retained \% finer x hydrometer \% finer})}{100}$$

A.3. Experimental Procedure of Specific Gravity Test

In specific gravity test, pycnometer (volumetric bottle) 500 ml at 20°C (or) specific gravity bottle, distilled water, heat source (or) hot plate, balance (0.01 g sensitivity), drying oven, thermometer (graduated to 0.1°C), evaporating dishes, pipette and U.S sieve No.40 (or) B.S sieve No.36 are required.

First, this procedure consists of obtaining at least five set of concurrent temperature and weight measurements about 4°, 5°C apart and within the temperature range of 27° to 45°C. Each set, representing the coordinates for a point on the calibration curve, is obtained as.

Second, is specific gravity test of soil. Use the pycnometer of 500 ml for test, put the distilled water into the pycnometer half of pycnometer and No.40 sieve pass soil 100 gms in it. Then boilled the pycnometer with heat source after ten minutes. Remove the pycnometer from the heat source to cool for air. Cool the bottle and suspension to some temperature with the range of the calibration for the bottle. Add water to bring the bottom of the meniscus to the calibration mark. Dry the outside of the bottle and inside of the neck above the meniscus. Weight the bottle with the water and soil in it to 0.01g. After test dry the soil in the oven, cool and weigh. The dry weight of soil grains can be obtained. The dry weight of soil is W_s.

The specific gravity of the soil G_s can be obtained from

$$G_s = \frac{W_s G_T}{W_s - W_1 + W_2}$$

where,

G_s = specific gravity of soil
G_T = specific gravity of water at T; temperature
W_s = dry weight of soil (after test)
W_1 = weight of bottle + water + soil
W_2 = weight of bottle + water (from calibration curve)

A.4. Laboratory Procedure of Liquid Limit Test

Take about 100 gm of moist soil and mix it through with distilled water to form a uniform paste. Place a portion of the paste in the cup of the liquid limit device, smooth the surface off to a maximum depth of 1/2 in and draw the grooving tool through the sample, keeping it perpendicular to the cup surface. Turn the crank at the rate of about two blows per second, and counter the number of blows required the closed the groove in the soil for a distance of 1/2 in. Repeat to obtain four more water content determination in the range 10 to 40 blows. Make a plot of water versus log of number of blows. Water content at 25 blows is liquid limit.

$$\text{Liquid limit} = \frac{\text{Weight of water}}{\text{Weight of oven dried soil}} \times 100\%$$

$$L = \frac{(W_1 - W_2)}{(W_2 - W_c)} \times 100\%$$

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where,

L = liquid limit
W_1 = weight of container + wet soil
W_2 = weight of container + dry soil
W_c = weight of container

A.5. Laboratory Procedure of Plastic Limit Test

Make a soft pat by throughly mixing about 15 gm of soil with distilled water. Roll the pat with the palm of the hand on the glass plate to form a thread about 1/8 in, in diameter. Fold the thread and press together into a lump, and then roll it out again. Repeat until the thread crumbles into a number of pieces while being rolled. Immediately place the crumbled pieces in a small container and determine its water content. Water content in the crumbled pieces is plastic limit. The plastic limit is calculated in the same way as the liquid limit.

B.1. Calculation of Compressive Strength of Adobe Brick

$$\text{Compressive strength, kg/cm}^2 = \frac{W}{A}$$

where:

W = maximum load indicated by the testing machine, in kilograms
A = average of the gross areas of the upper and lower bearing surfaces of the specimen in square centimeters.

B.2. Calculation of Cold Crushing Strength (Compressive Strength) of Cube Specimen

The cold crushing strength (kg_f/cm^2) c is calculated according to the following formula,

$$c = \frac{W}{a \times b}$$

where, W = maximum load (kg_f)
a,b = longitudinal and lateral dimensions of pressed surface (cm)

B.3. Calculation of Flexural Strength of Bar Specimen

The flexural strength of each bar specimen is calculated as follows:

$$M = \frac{3WL}{2bd^2} \times 10$$

where,

M = modulus of rupture, (kg_f/cm^2)
W = load at rupture, (kg)
L = distance between supports, (cm) = (10.16 cm)
b = width of specimen, (cm)
d = thickness of specimen, (cm)

B.4. Determination of Water Absorption and Bulk Density of Bar Specimen

(1) Dried mass : Dry the sample in the thermostatic vessel at 110 ± 5°C, and consider the mass when it has reached a constant mass to be the dried mass W_1 (g).

Method of saturation with water

(a) In the case of the boiling method, after the dried mass has been weighed, submerge the sample under the water level of the boiling tank, boil for 3 hours or more, and allow it to cool down to the room temperature. Consider this to be the sample saturated with water. In this case, it may not be impedimental to cool by addition of water.

(b) In the case of the vacuum method, after the dried mass has been weighed, place the sample on the bottom of the vacuum vessel, suck for 15 minutes under the vacuum of 2.0 kPa or under, and inject the medium liquid after the air in fine cavities has been elimanated completely. In this case, inject the medium liquid until the sample is soaked completely, then open the cock gradually, and leave standing for 30 minutes after the pressure has been lowered to the atmospheric pressure. Use white kerosine for the medium liquid.

(2) Mass in water of sample saturated with water : Weight the sample saturated with water as suspended in water with wire of 1mm or under in diameter, and consider the substracted value of the mass of the wire to be the mass in water W_2 (g).

(3) Mass of sample saturated with water : Take out the sample saturated with water from the water, wipe the surface with wet cloth rapidly, weigh after water drops have been removed, and consider this to be the mass saturated with water W_3 (g). In the case the white kerosine has been used for the medium liquid in the operations of (2) and (3), operation shall be carried out by substituting white kerosine for water. In addition, the wet cloth used shall be wringed out after it has been submerged well in the medium liquid. Weigh the mass accurately to the unit of 1 g or 0.1 g.

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Calculation:

Water absorption : The water absorption A_w (%) shall be calculated from the following formula, and be rounded off to one place of decimal in accordance with JIS Z 8401.

$$A_w = \frac{W_3 - W_1}{W_1} \times \frac{1}{S} \times 100$$

Bulk specific gravity (= Bulk density) : The bulk specific gravity D_b shall be calculated from the following formula, and be rounded off to two places of decimals in accordance with JIS Z 8401.

$$D_b = \frac{W_1}{W_3 - W_2} \times S$$

where, W_1 : mass of dried sample

W_2 : mass in water of sample saturated with water

W_3 : mass of sample saturated with water

S : specific gravity of medium liquid (for kerosine, S = 0.79)

B.5. Determination of Linear Shrinkage of Bar Specimen

Linear shrinkage is determined by preparing rectangular bar (4"×1"×1") from control (100% soil) and RHA-soil mixtures (100:0, 97:3, 94:6, 91:9, 88:12, and 85:15). The test sample is mixed with optimum water just to moisten it and placed in a mould. As soon as the bar is made, a straight line is drawn on the surface of the test specimen. It is then air-dried and finally dried in the sun for 28 days to get constant mass. The difference in the linear indicates linear shrinkage.

$$\text{Linear shrinkage ratio} = \frac{\text{wet length} - \text{dry length}}{\text{wet length}} \times 100\,\%$$

Figure C1. SEM Photograph For Shan Tae J Gyi Soil Particle

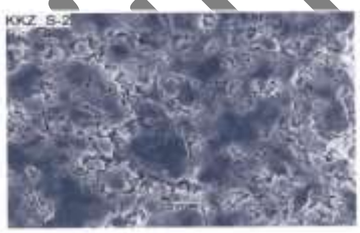

Figure C2. SEM Photograph For Danyingone Soil Particle

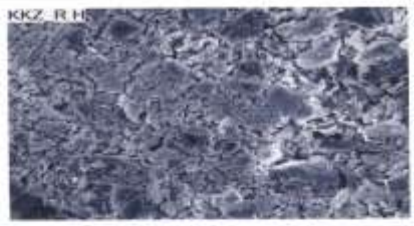

Figure C3. SEM Photograph For Rice Husk Ash Particle

ACKNOWLEDGMENTS

The author is also grateful to her supervisor Daw Khin Mya Thwin, Lecturer, Department of Chemical Engineering, Technological University (Thanlyin), for giving invaluable advice and support.

The most grateful acknowledgement is extended to Kyi Kyi Zin for her idea approaching to the practical and theoretical methods useful discussions, hardwork and invaluable suggestions for this journal.

The author is also greatly thankful to Daw Thwe Thwe Oo, Associate Professor and Head of Department of English, Technological University (Thanlyin), and all of the teachers at the Department of English, Technological University (Thanlyin), for their willing and effective contribution in her research work during the study period.

Special thanks are also extended to Daw Aye Aye Than, Executive Engineer, Building Research Station, Thuwuna and Daw Swe Swe Than, Research Engineer, Building Research Station, Thuwuna for their helpfulness in testing strength propertie of adobe brick samples.

Moreover, her sincere thanks go to Dr. Thida Swe, Deputy Director, Ceramics Research Department, MSTRD and all of the staffs from Ceramics Research Department of MSTRD for their helpful support in this work.

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