CONCRETE EVALUATION METHODOLOGY TO SOIL BLOCKS FOR SUSTAINABILITY

Pawan Vijay[1], B Bhattacharjee[2]

1. IIT Delhi, India

ABSTRACT. The construction practices of today demand use of alternative building materials which consume less energy. One such material is the adobe bricks. In the present work, the adobes are prepared using the locally available soil (Basgo clay) in Ladakh. Since blocks purely made of soil are prone to shrinkage it is required to stabilize these blocks with straw. Hence, an attempt is made to study the adobe blocks prepared using Basgo clay and natural agricultural straw from scientific point of view. The variation in properties like Compressive strength, Tensile strength, Flexural strength, Shrinkage and water absorption are studied and compared for different variable parameters such as water-clay ratio and percentage of straw. The main objective of this project is to analyze the various engineering properties of adobe bricks by conducting tests similar to that for cement so as to check the potential of these bricks as an alternative to traditional bricks.

Keywords: Adobe, Straw, XRD, Shrinkage, Aspect Ratio.

Pawan Vijay is a B.Tech (2014 batch) graduate in Civil Engineering from National Institute of Technology Surat; Holds M.Tech (2017 batch) in Construction Engineering and Management from Indian Institute of Technology Delhi. He has worked in a Navratna PSU MTNL, India as JTO-Civil and is currently working as MT-Civil in a Maharatna PSU Coal India. His areas of interest are in concrete technology, exploring use of new construction materials and contract management.

Professor Bishwajit Bhattacharjee is working with the Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi (India). His research interests pertain to the domains of cement and concrete technology, building science, sustainable construction, and health monitoring of structures. His publications in these areas are well cited. He is also a recipient of the Indian Concrete Institute's Life Time Achievement Award.

INTRODUCTION

Adobe is a very old construction material in the form of mud blocks, typically prepared with firmly compacted earth, clay, and straw, moulded into bricks or blocks and dried in the sun heat.
Adobe is a word which has many different definitions to different people. A word of Arab origin, it literally means "earth from which unburnt bricks are made." Technically speaking, it is a balanced mixture of clay and straw - enough straw to keep the dried clay from cracking and enough clay to give the dried mixture strength.

Adobe around the world

The technique of shaping earth into bricks was brought to the United States, particularly to the states of New Mexico, Arizona, Colorado and California, by the Spaniards. They in turn learned it from the Arabs, who, through innumerable intermediaries, got it from ancient Mesopotamia.
It has been recorded that the earliest clay huts of the fifth millenium B.C. at Hassuna, Iraq, were built of clay lumps in which fine straw or pounded scrub was incorporated. In Iraq thousands of years ago earth was the most plentiful building material and was used in unbaked form. Iraq and Iran, while using local earth extensively, have generated building forms such as the arch, the vault, and the dome which today we do not necessarily associate with adobe. These may be thought of as the contributions of adobe to the classical building technique. (Subhash Mishra, 2013)
Buildings made of sun-dried earth are common throughout the world (south western North America, South America, Spain, Eastern Europe, North Africa, Middle East Asia, and Western Asia). Its extensive practice can be credited to its simplicity of design and production, and economics. In below figure one can see the typical stages of adobe construction.

Adobe soil collection Moulding into bricks Sun-drying of bricks Adobe house

Figure 1 Various stages in Adobe construction (Bhartat B1,2014)

Advantages and Disadvanantages associated with use of adobe material

Advantages

- The most important advantage of adobe is that it is not costly as it does not require extra energy to fire the bricks or cement thus reducing costs and damage to the environment.
- Thermal Mass & ECO Friendliness, Thermal mass is a term used to describe the ability of building materials to store heat (thermal storage capacity). The basic

characteristic of materials with thermal mass is their ability to absorb heat, store it, and at a later time release it. Thus, it also reduces the heating and cooling costs.

- Mud brick is a natural material that can create a more environmentally friendly building.
- The mixture of mud brick is available in abundance and the only source of energy needed is solar energy. If it is maintained properly, it is durable and many old buildings have been standing perfectly even after many years.
- Adobe soils also possess good acoustic properties.
- Earth building can be so very simple that (with adobe at least) a beginner can attempt and successfully build his own home.
- Aesthetics: Earth buildings have an appearance which is very unique. Many people build out of mud simply because they like the look of it.

Disadvantages

- Water related problems (rain water and then drying may cause cracks in the wall)
- Structural Damage Problems (poor foundation)
- Poor seismic performance.
- Erosion of walls at level by splashing of water from ground surfaces.
- Attack by termites and pests.
- High maintenance requirements (Sangeeta Roy1, 2013)

MATERIALS

Fibre (Straw)

For this project, Wheat straw is collected from Punjab and Rice straw is collected from local market of Delhi. For the study the fibre (straw) contents of 0%, 1.5%, 3% and 5% by weight are considered for preparing mix with Basgo soil.

Basgo Soil

The Soil is local soil of Ladakh, known as Basgo clay. The coordinates of source of Basgo soil is : 34°13′12″N 77°16′48″E.

EXPERIMENTS' LAYOUT AND TEST RESULTS

The various tests on adobe soil are done in analogues to cement. So tests required for cement to check it as a building material shall be done on adobe soil as well to check its potential as a building material.

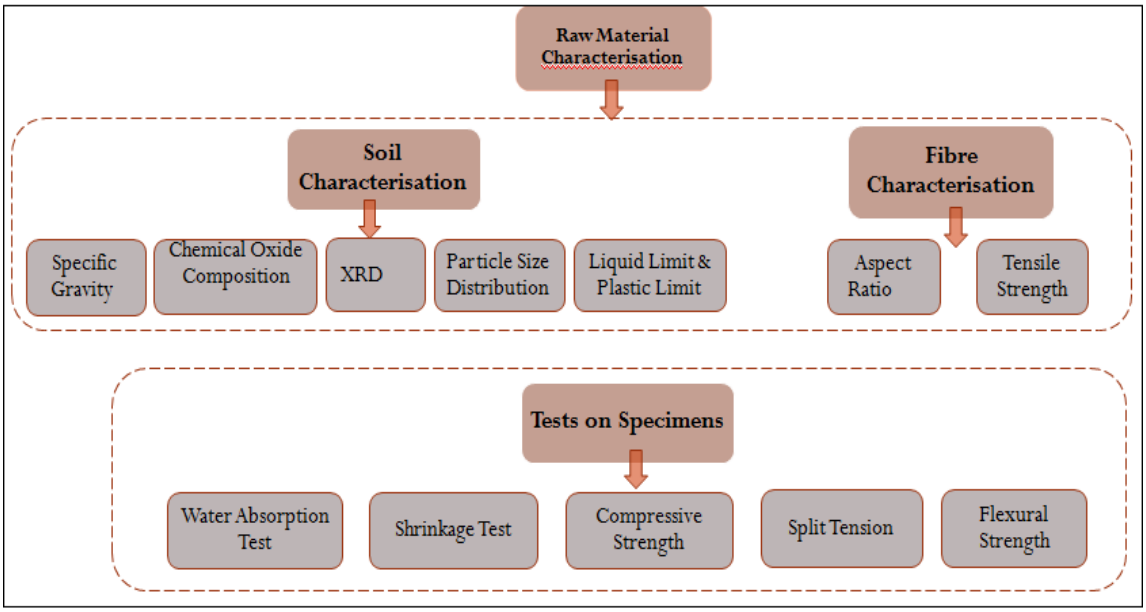

Figure 2 Experiments' Layout

Raw Material Characterisation

Basgo Clay

Specific Gravity

Specific gravity test is done to find out the weight of the soil sample for a given unit volume. The test is carried out as per I.S. 1727-1967. "Le Chaterlier's Flask" is used to determine the specific gravity.

Table 1 Specific Gravity Test

SAMPLE NO.	WEIGHT OF SOIL (GM)	DISPERSED VOLUME IN FLASK (ML)	SPECIFIC GRAVITY
1	63	24.6-0.4 = 24.2	2.60
2	71	25.1-0.7 = 24.4	2.91

So, average s.g = 2.76

Particle Size Distribution

This test depends upon analysis of the "halo" of diffracted light produced when a laser beam passes through a dispersion of particles in air or in a liquid. The angle of diffraction increases as particle size decreases, so that this method is particularly good for measuring sizes between 0.1 and 3,000 μm.
Results are shown in the below graph:

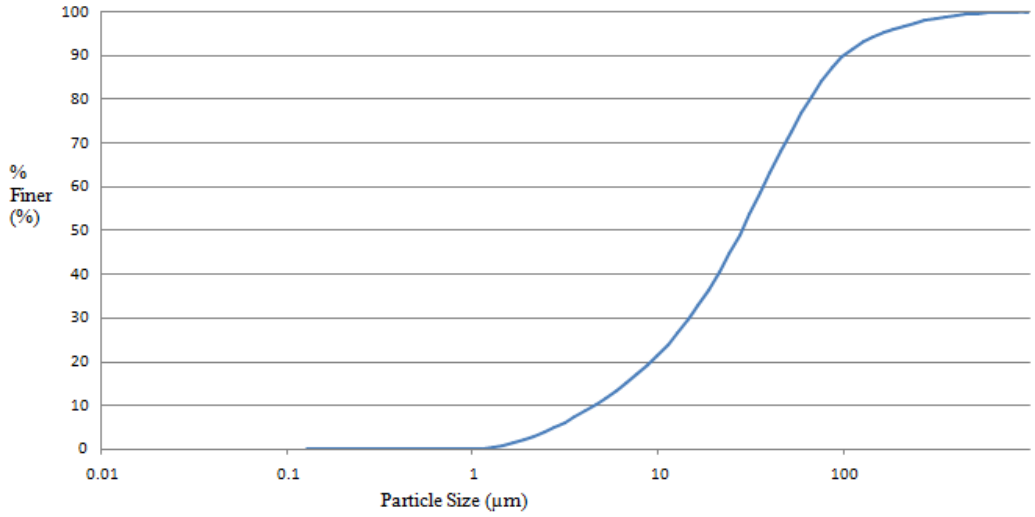

Figure 3 Particle Size Distribution

The results show that size of particles are varying from 0.1µm to more than 100 µm.

X-Ray Diffraction Test

X-ray diffraction is a technique that provides detailed information about the atomic structure of crystalline substances. It is a powerful tool in the identification of minerals in rocks and soils. The bulk of the clay fraction of many soils is crystalline, but clay particles are too small for optical crystallographic methods to be applied. Therefore, XRD has long been a mainstay in the identification of clay-sized minerals in soils. X-ray diffraction analysis can be conducted on single crystals or powders.

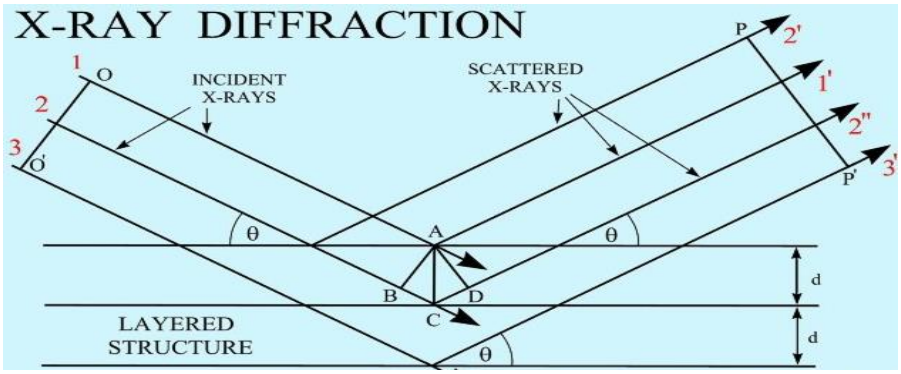

Figure 4 X-ray Diffraction principal (Ref-14)

X-ray diffraction occurs when X-rays are scattered by atoms arranged in an orderly array in crystals. A simplifying way to intuitively comprehend the relatively complex phenomenon of XRD is to envision regularly spaced planes of atoms in mineral structures (Fig. 4-3). The distance between a given set of planes is termed d-spacing. The d-spacing, although on a scale of Angstroms, can be determined quite accurately using XRD. The principles under-lying this determination are elegantly expressed by the Bragg equation:

The results showed that Predominant crystals are Quartz and Calcine which also comply with the results of Chemical Oxide Test as shown in below graph.

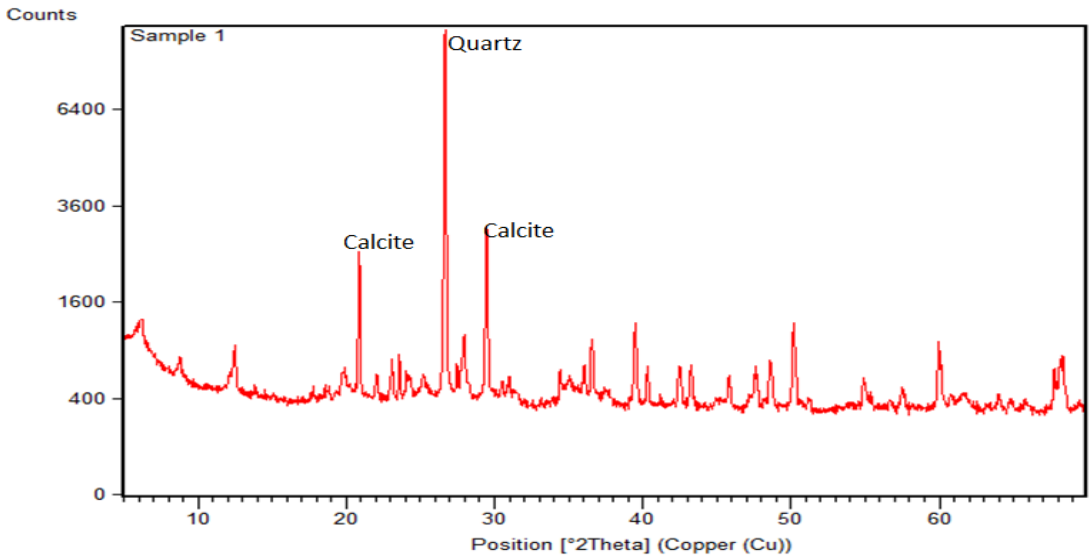

Figure 5 XRD Result of Basgo soil

Plastic Limit & Liquid Limit

The liquid and plastic limits of soils are both dependent. on the amount and type of clay in a soil and form the basis for the soil classification system for cohesive soils based on the plasticity tests. Besides their use for identification, the plasticity tests give information concerning the cohesion properties of soil and the amount of capillary water which it can hold. The plasticity limit of soil gives idea of what should be minimum water content to have standard consistency in the mix.

Liquid Limit

Liquid Limit of soil is defined as the value of moisture content corresponding to 25 no. of blows which is found by plotting graph water content and no of blows (in log scale) as shown below-

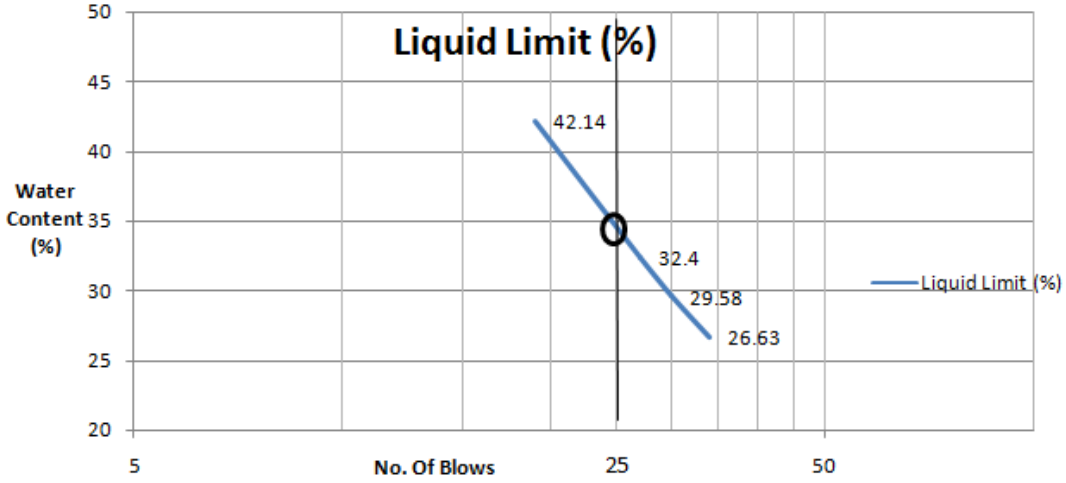

Figure 6 Graph for Liquid Limit Test

Hence Liquid Limit = 34.17%

Plastic Limit

Table 2 Plastic Limit

Determination No.	PL-1	PL-2	PL-3
Container Empty Weight W_o (gm)	9.4	10.91	10.86
(Weight of Container + wet soil) W_1 (gm)	10.98	14.71	14.32
(Weight of Container + Oven dry soil) W_2 (gm)	10.73	14.02	13.73
Weight of water $W_w = W_1 - W_2$ (gm)	0.25	0.69	0.59
Weight of Oven dry soil $W_d = W_2 - W_o$ (gm)	1.3	3.11	2.87
Water Content $w = \frac{Ww}{Wd} x100$	19.65	22.18	20.56

So, the average Plastic limit value for the Basgo soil is = 20.79 %

Plastic limit of clay soil is helpful to have idea of what should be standard consistency to prepare adobe mix designs.

Fibre (Straw)

Aspect Ratio (l/d) of fibres straw

Based on the geometric specification of approximate 100 fibres of rice and wheat the aspect ratio is calculated. The length of fibre is measured using plain geometric scale and diameter is measured using screw gauge.

Rice straw Wheat straw

Figure 7 Random samples of Rice straw and Wheat straw

-For rice straw the aspect ratio ranged from 20 to 50

-For wheat straw this value ranged from 30 to 70

Tensile Strength test of straw

Few random samples of wheat and rice straw are taken and have been placed in the instrument shown in the figure to measure the tensile strength of fibres alone.

Figure 8 Setup for tensile strength test of fibre

Rice straw

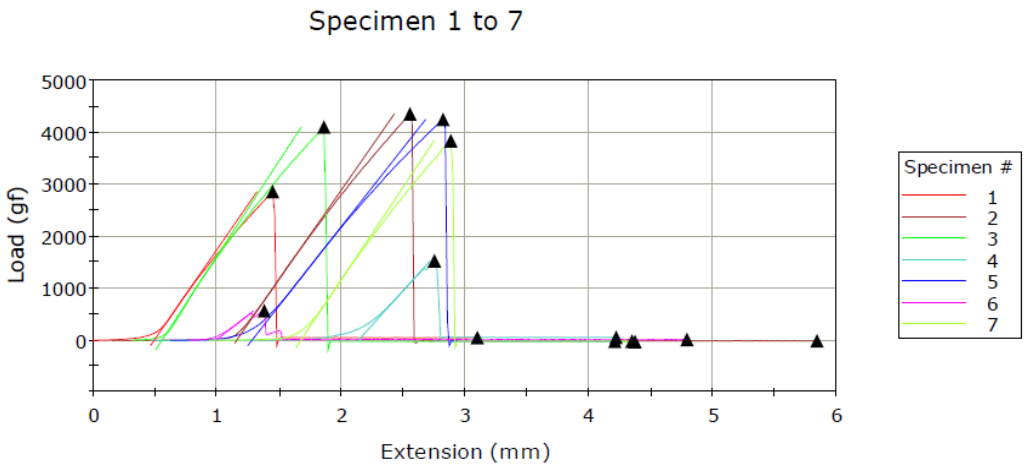

Figure 9 Load vs Extension graph for Rice straw

Wheat straw

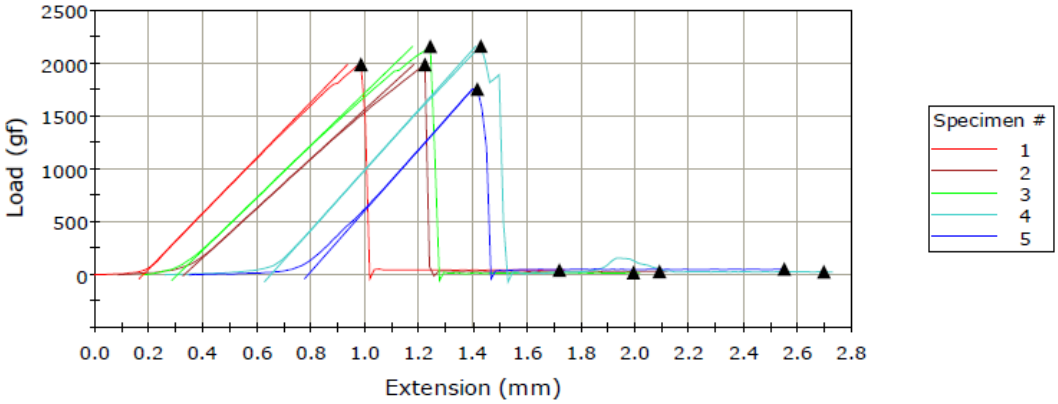

Figure 10 Load vs Extension graph for Wheat straw

The Tensile strength of Rice straw is more as compared to Wheat straw and therefore in present work, rice straw is used to stabilize the adobe blocks.

Drying of Cubes (Observation)

Drying of cubes, cylinders and beams were observed to be very slowly. The cubes were kept in closed room at constant R.H., but not in the open sun due to fear of bed weather. This may be the reason for slow drying of cubes and beams.

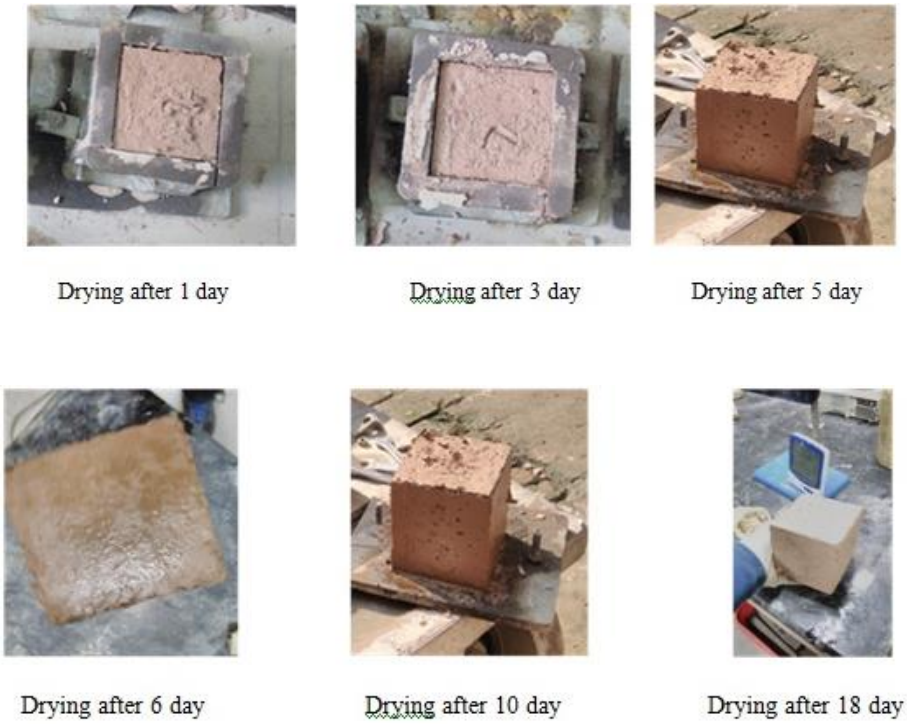

Figure 11 Drying of cubes with time

Compressive Strength test results

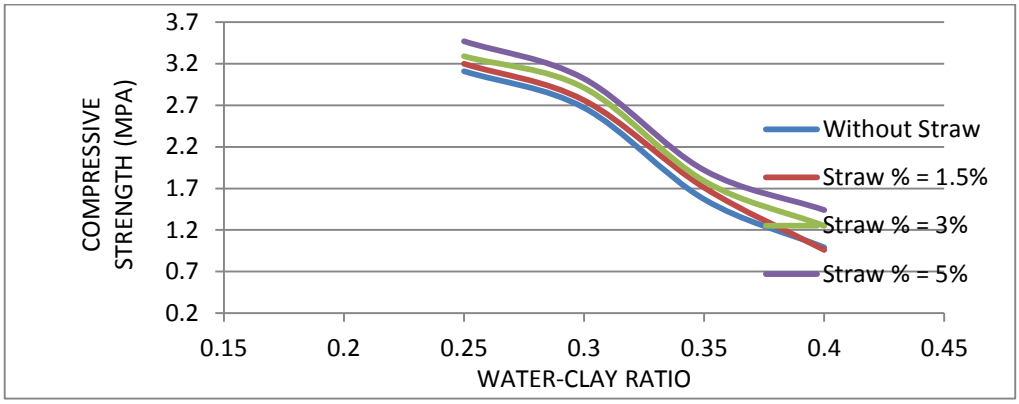

Figure 12 Compressive strength vs Water-Clay ratio graph for different % of straw

The compressive strength values of adobe cubes are less as compared to normal burnt bricks but can be improved by stabilising the adobe with lime, fly-ash or cement as stated in various literatures. But a common pattern of decrease in compressive strength with increase in water-clay ratio has been observed for particular percentage of straw as shown above.

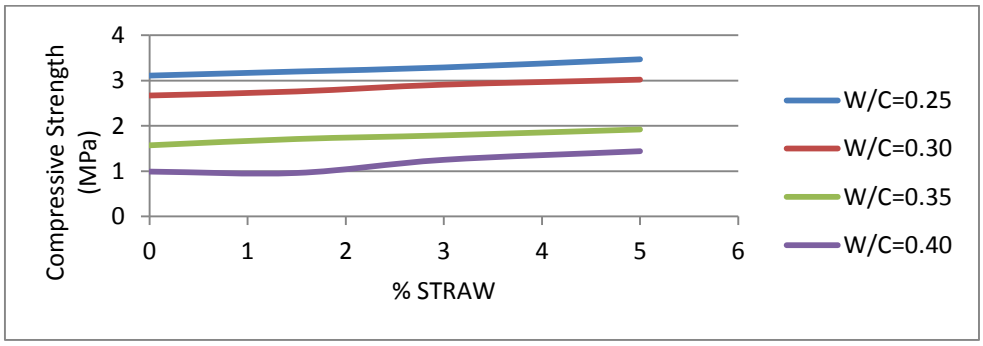

Figure 13 Compressive strength vs % straw for different water-clay ratio

The compressive strength of adobe cubes increase with increase in percentage of rice straw for constant W/C as shown above.

Tensile Strength test results

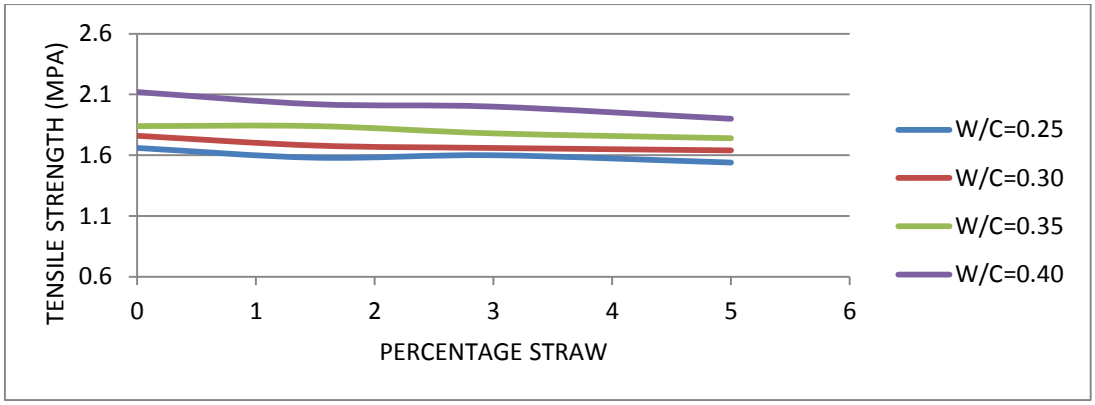

Figure 14 Tensile strength vs Water-Clay ratio graph for different percentage of straw

The Tensile strength of adobe cubes increases with increase in percentage of rice straw for constant percentage of water-clay ratio as shown above while it decreases with increase in water-clay ratio for constant percentage of straw as shown below.

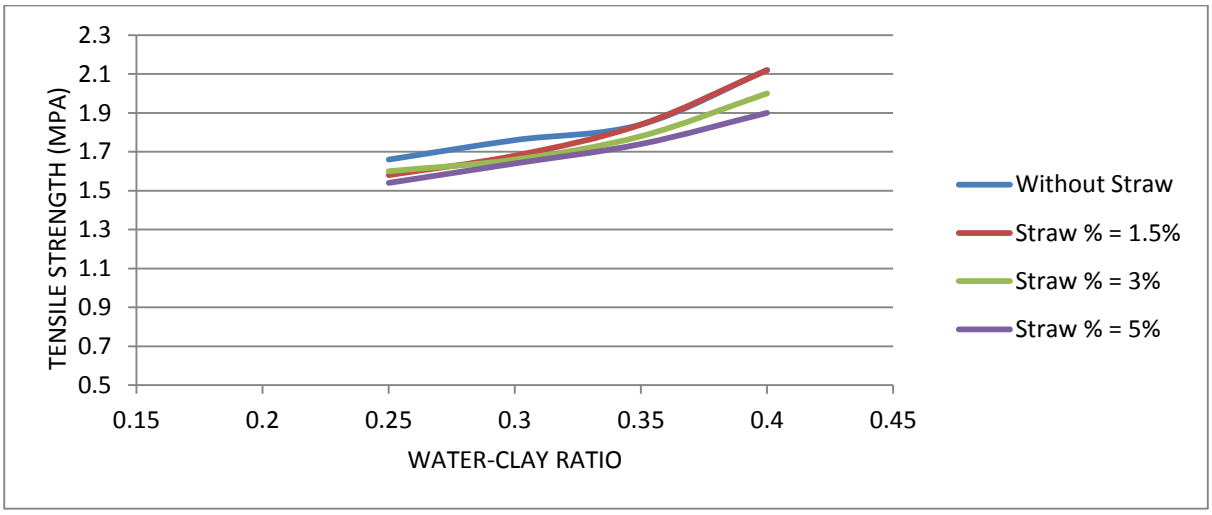

Figure 15 Tensile strength vs percentage straw graph for different Water-Clay ratio

Flexural Strength test results

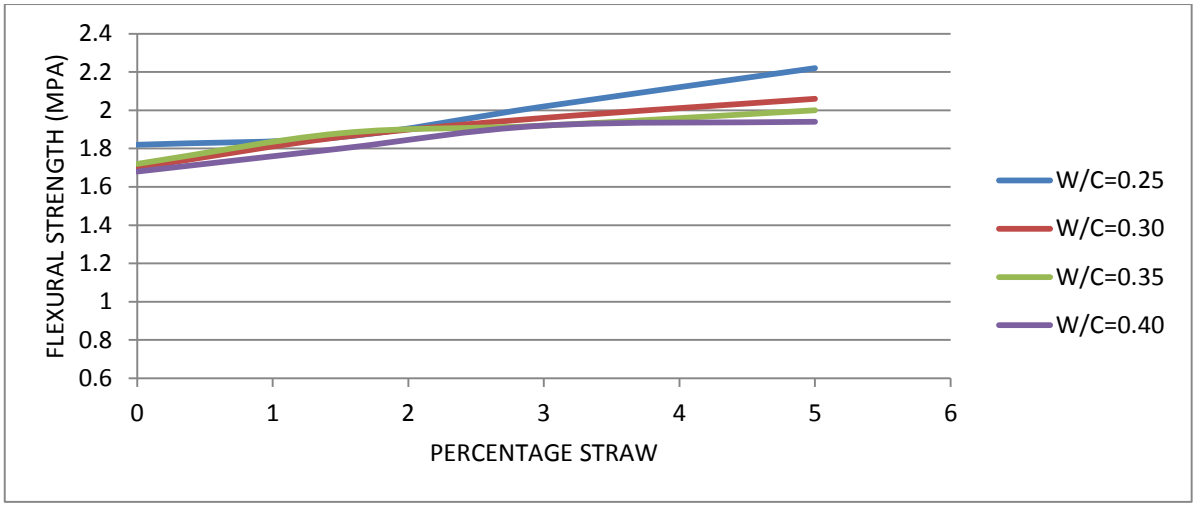

Figure 16 Flexural strength vs Water-Clay ratio graph for different percentage of straw

The Flexural strength of adobe cubes increases with increase in percentage of rice straw for constant percentage of water-clay ratio as shown above while it decreases with increase in water-clay ratio for constant percentage of straw as shown below.

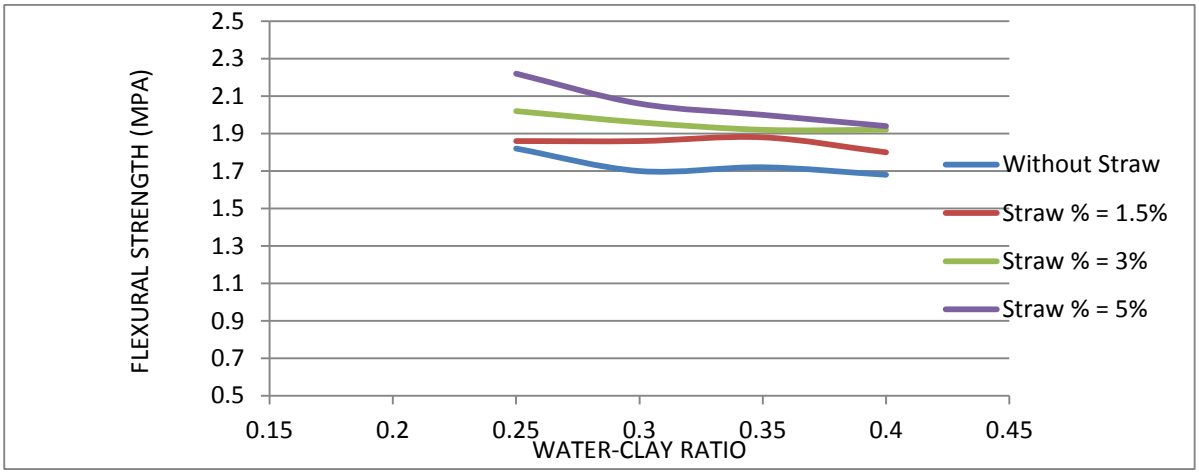

Figure 17 Flexural strength vs percentage straw for different Water-Clay ratio

Shrinkage Test

After sufficiently drying cubes were observed to be shrunk in size but the shrinkage got reduced with increase in percentage of straw.

The percentage shrinkage is observed to be increased with increase in water-clay ratio for constant percentage of straw while percentage shrinkage reduced with increase in percentage of straw for constant water-clay ratio as shown in below graphs.

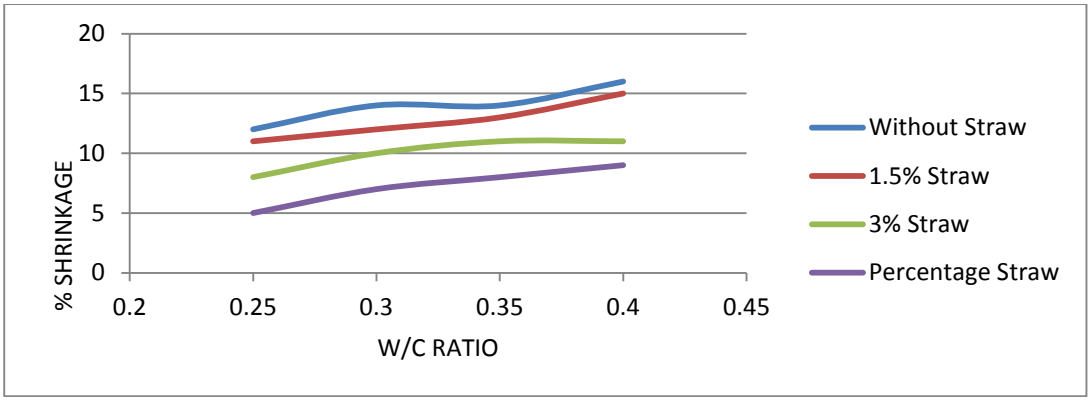

Figure 18 Percentage Shrinkage vs W/C Ratio

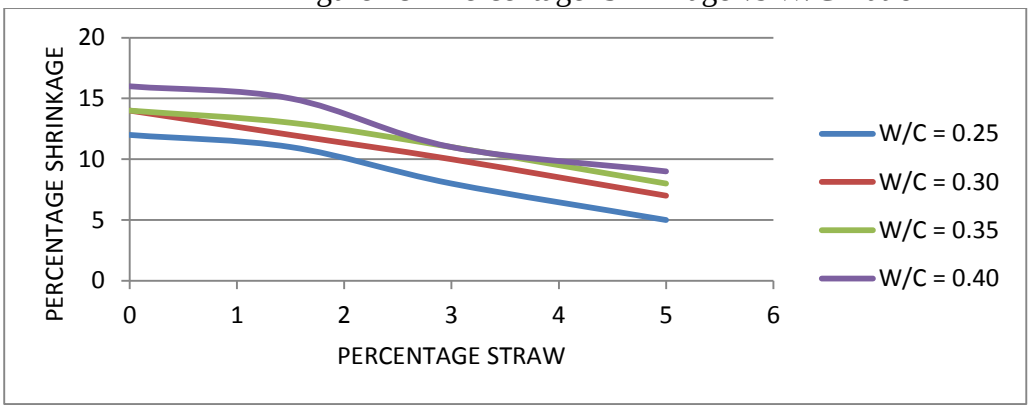

Figure 19 Percentage Shrinkage vs Percentage straw

Summary

Initially the characterisation of soil is done by performing some tests like Chemical Oxide Composition, Specific Gravity test, Particle Size Distribution, X Ray Diffraction test (XRD). Then the different mix designs have been casted by varying percentage Straw and Water-Clay Ratio. Further tests similar to that of cement cubes have been performed on the prepared adobe blocks.

Basgo soil is clayed soil which contained enough silica and calcine to be used as adobe soil. Tensile strength of Rice straw is found to be superior to tensile strength of wheat straw. Hence Mix designs are casted using Basgo soil along with different percentage of Rice straw.

CONCLUSION

The important findings of the thesis are as follow:

- The Compressive strength values are around or below 3MPa but they showed a pattern of increasing compressive strength on increasing percentage of straw and trend of decreasing compressive strength on increasing water-clay ratio.
- The flexural strength of adobe beams decreased with increase in water-claay ratio while it increased with increase in percentage straw

- The tensile strength of rice straw is found to be more than tensile strength of wheat straw which may be due to their more uniform structure and orientation of micro fibres in rice straw.
- As stated in various literature that adobe soils have the problem of shrinkage, the same is observed here as well. But the percentage shrinkage got reduced when we increased the percentage straw content. So one has to use minimum percentage of straw so as to avoid any significant shrinkage later on in case of adobe blocks.
- The drying of cubes is also observed to be very slow the reason of which may be that we did not keep the blocks in open sun as generally the case with adobe blocks due to risk form weather.

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