EVALUATION OF SOME PHYSICAL AND MECHANICAL PROPERTIES OF SELECTED WALLING MATERIALS

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DEDICATION

This thesis is wholeheartedly dedicated to:

- God, trusting Him to fulfill all the beautiful covenants He has for me and my family.
- Pa Haruna A. Olorunwuyi:- My Father who gave all he had for my education.
- Mama Maryam A. Haruna for her moral, financial and motherly support.
- My Wife – E.A.A. Haruna and the children.

CERTIFICATION

This is to certify that this work on Evaluation of some physical and mechanical properties of selected walling materials was carried out by HARUNA Ibrahim. Olusegun MEE/96/8538 in the Department of Mechanical Engineering, School of Engineering and Engineering Technology Federal University of Technology Akure

It is adjudged as meeting the requirements in partial fulfillment of the award of the degree of Master of Engineering (M. Eng.) in Mechanical Engineering (Building Services Option) of the Federal University of Technology, Akure.

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ABSTRACT

Current high cost of conventional walling materials, the desire for reasonable thermal comfort and problems involved in the analysis of heating and cooling systems call for the search for alternative walling materials. In this work, some physical and mechanical properties namely: compressive strength, moisture content and shrinkage were evaluated for selected mixes of sawdust concrete and Electric Arc Furnace (EAF) slag cement blocks.

The samples were prepared by grinding, sieving and mixing with water to ensure cohesion and firmness. The blocks derived were fired in muffle furnace to 1200^0C and then allowed to dry in still air. Their properties were evaluated/measured, The values obtained were subjected to statistical analysis using the general linear model. Particular attention was given to the EAF slag-cement blocks where gradual replacement of cement by EAF slag of 10%, 15% and 25% were carried out. Control cubes used for comparison of compressive strength were made from cement-sand of 1:8 mix ratio. EAF slag-cement blocks had higher cohesion, higher compressive strength, low moisture content and negligible level of shrinkage. This encourages building with less cement thus assisting in obtaining relatively low cost, durable and functional buildings. Building with blocks made by replacing cement with EAF slag to 25% level reduced cost.

CHAPTER ONE

1.0 INTRODUCTION

Hardly can any developing nation make serious or meaningful progress if her sourcing of the basic walling or building materials is solely dependent on importation. Minerals used as raw materials for walling are very vital in the development of indigenous walling materials industry, relevant to the economy of the nation and comfort of human beings. In Nigeria, for example, all our cement factories were built considering the availability of large deposits of limestone and marble, clay and shale at their respective sites; materials for walling are ready sources of revenue that in no small measure boost our economy. The astronomical increase in prices of conventional walling materials makes them become out of reach for most Nigerians.

Okiwe and Onwelu (1998) confirm that this is evident in the number of people who are unable to own houses. To some extent, the presence of foreign based companies, the very high taste of well-to-do Nigerians and their huge investments in multi-nationals have blind-folded our front-liners as to seeing the need for developing indigenous technology to improve on works already done towards finding alternatives to foreign walling materials. Ufaruna,(1996) reported that the multi-nationals solely depend on research results emanating from their parent companies and hence are not interested either in funding research into local materials or even encouraging such research work by way of using results from such researches constructively.

Nigeria is naturally endowed with many materials in abundance. Such materials tested in this investigation are clay, mud or base sand, Electric Arc Furnace slag, and sawdust. This research is a sort of further investigation on the alternatives to conventional walling materials. For a material to be selected for walling purposes, it must meet certain physical and mechanical qualities. These qualities and the methods of determining them are discussed in this work.

1.1 OBJECTIVES OF THE RESEARCH

The major objectives of the work is to investigate some physical and mechanical properties of some varied mixes from Omi-oye sand, cement, sawdust and Electric Arc Furnace (EAF) slag for block making as substitutes to conventional walling materials.

The specific objectives of the study are to:

(a) Determine the moisture content, compressive strength and shrinkage of sawdust concrete and Electric Arc Furnace slag-cement concrete of mix-ratio 1:3:6 and 2:3:6

(b) Determine compressive strength of derived blocks by gradual replacement of cement with Electric Arc Furnace (EAF) slag in relation to curing age.

1.2 JUSTIFICATION FOR THE PROJECT

This project is to contribute, very considerably, towards gingering the average Nigerian to develop the culture of using local walling materials. This will greatly reduce cost, project indigenous technology and enhance living in conducive environment that is temperature – friendly.

1.3 RESEARCH METHODLOGY

Sample sand was obtained from Omi-oye River near Aiyetoro Gbede in Ijumu Local government Area of Kogi State.

The cement material was obtained from West Africa Portland Cement Company, the sawdust from local sawmills and the Electric Arc Furnace slag from Ajaokuta slag yard. The samples were collected in their natural form towards the end of the rainy season as it is customary of the people of the area to build their houses at the beginning of the dry season each year. The samples were prepared by grinding, sieving before being mixed with water to ensure cohesion and firmness. In view of the wide range of proportions to be tried, a complete work experimental design was used with a baseline of 1:3:6 of cement; sawdust; sand.

The blocks were fired in muffle furnace to 1200^{0}C and then allowed to dry in still air. The shrinkage was then measured using a block venire calliper. The mixes were laid on a flat wooden table, covered with polythene bag and the physical and mechanical properties were measured after 10, 15, 20, and 30 days each to determine the effects of curing on the compressive strength, shrinkage and moisture content. The data obtained were subjected to statistical analysis using the general linear model.

CHAPTER TWO

2.0 LITERATURE REVIEW

Afolayan and Marona (1988), Ndububa and Ndububa (1998) reported some work on sawdust concrete. The specimen sawdust used was from "soft" and "Hard" woods derived from common Nigerian timber species. They used water cement ratios of 1:8 for their investigation, which they arrived at after several trials on moisture free materials. Lambrapoulas (1989) used thermal comparator for measuring thermal conductivity of non – metallic solids. He was of the opinion the thermal conductivity increases in direct proportion to increase in temperature.

David et al (1989) reported that the thermal conductivity of non-metallic solids is strongly related to density and greatly modulated by presence of moisture. They used "adobe" – a building material as their example for trial mixes. It is of note that they did not introduce the use of additives. The linear and volumetric shrinkages of the mixes investigated were presented, as 0.86% and 0.21% respectively. Guma, (1998) determined the moisture content of base sand using the Speedy moisture tester. He sampled Kaduna river and specimens of diameter 5.08cm and height 5.08cm. The permeability of the sample was measured using permeability testing equipment.

Diagbonya, 1987 in his research work done on the strength properties of slag concrete found that concrete (water/cement ratio and mix) made with the EAF slag aggregate obtained from Delta Steel Company Aladja was found to be between 1.2 and 1.6 times stronger in both compression and tension than the equivalent concrete made with natural river sand. The work further described a procedure of gradual practical replacement of cement with EAF slag in block- making aimed primarily at finding out the behaviour of slag/cement blocks in terms of strength and economic significance in the building industry.

2.1 Thermal Comfort

The essence of thermal comfort covers the effects of the thermal environment on people, processes, materials, livestock and even plants. The main focus of this research will be human beings. An essentially comfortable environment is one in which the occupants experience no heat stress or strain.

A comfortable condition is said to be in the neutral zone where a body needs to take no particular action to maintain its proper heat balance. Man's manual, intellectual and perceptual performance is in general highest when he is in a state of thermal comfort. The sensation of warmth or cold is registered by the nerve-endings when the skin temperature is above or below body temperature. The principal factors affecting this sensation are: mean radiant temperature, air velocity and relative humidity.

2.1.1 Mean Radiant Temperature

Mean radiant temperature is the wet radiation exchange on the actual surfaces. The uniform black body temperature of an imaginary enclosure with which man, also assumed to be a black body, will exchange the same heat by radiation alone as he would exchange by radiation in the actual complex environment. The surface temperatures of a uniform enclosure, which will give the same net radiation exchange as the actual surfaces and their associated temperatures.

2.1.2 Air Velocity

Air velocity is the rate of air movement. This is measured using Kata thermometer or hot wire anemometer.

2.1.3 Relative Humidity

This is the ratio of the partial pressure of water vapour to the saturation pressure $\phi_a = \frac{P_{dp}}{P_{sat}}$ (2.1)

Where;
ϕ_a = relative humidity
P_{dp} = partial pressure
P_{sat} = saturation pressure

This is the ratio of water vapour actually present in the air per unit volume to that which air would contain if saturated at the same temperature.

Other desirable properties of walling materials to enhance thermal comfort are also discussed below;

2.2 Good Thermal Insulation property

Insulating the system is to reduce transmission losses and so reduce the change over temperature. Insulated structures designed to collect and store solar energy may run the risk of becoming fire hazards, unless proper precautions are taken at the design stage (Adegoke and Bolaji: 2000). Also accurate behavioural predictions of materials are necessary to locate these problems and to develop solutions to them.

2.3 Resistance to Vapour Migration and Condensation

Rates of water vapour transport between two psychometric environments through a partition depend upon the partial vapour pressure differences across the partition. The partial pressure of an air-water vapour mixture is calculated from the product of the relative humidity and saturation vapour pressure, P_{sat} at the prevailing dry-bulb temperature. Thus the higher the air temperature and the higher the relative humidity, the greater the vapour pressure. Steam or water addition to an air environment at constant atmospheric pressure and at a constant temperature increases the specific humidity of the environment and hence the relative humidity. It should, however, be noted that vapour migration and condensation cause deterioration in buildings, hence the need for application of vapour barrier.

All forms of thermal insulation applied to buildings, rises inside temperatures and humidity and also make the outer parts of the structure colder and more prone to condensation. The prevention of condensation hinges on adequate ventilation, adequate structural heating, incorporation of vapour barriers and thermal insulation where necessary. When an insulant absorbs moisture its thermal conductivity rises very significantly. The moisture contained can also increase the rate of corrosion, mould growth and deterioration of the structural materials. Radiation shielding can be rendered useless by the deposition of very thin liquid films on the surface because the emmissivity of most liquids are very high. Condensation conditions can only be avoided by modifying constructional details, provision of an internal barrier on the warmer side of the structure or increasing the permeance of outlet regions by, for example, introducing ventilating centres or roof spaces or by varying the internal environmental condition.

Vapour cannot be completely relied upon in the long term if and when continuous high humidity is present. The main safe and practical solution is the prevention of condensation by proper thermal design or by proper choice of structural materials considered suitable for the local temperature of designated areas or by air-conditioning the building.

2.4 Excellent Spalling Resistance

Spalling resistance or thermal fatigue resistance is a measure of the resistance of a walling material to sudden changes in temperature. Thermal stability is very necessary in walling materials as sharp changes in rates of heating and cooling lead to spalling, cracking or crumbling. Materials with less thermal coefficient of expansion and coarse textures have increased resistance to sudden changes in temperature. Materials having high mechanical strength have lower spalling tendency than weaker materials because the property to yield under stress is major in its resistance to spalling.

2.5 Volume Stability

Volume changes with respect to changes in temperature are not necessarily noticeable in walling materials. Temperature changes coupled with resultant change in volume results in cracking or crumbling. Volume changes are not easily noticeable because the temperature difference is usually over a time lag and is usually not sharp. Volume stability is a desirable property of walling materials, for it ensures non-appearance of additional stresses which could weaken the structural strength. (Arumala and Akpokodge, 1997).

Generally foundation of structures from non-porous walling materials should be stronger than those made from porous materials in anticipation to allow for easy bearing of the load coming on it, when it is a load bearing wall. The response, to heat and load, of walling materials is of paramount importance. Long time exposure to heat results in failure of the material under comparatively low temperature and load conditions (Edoro et. al; 1991). Many parameters are considered about various materials to aid in determining the level of value for use or otherwise for walling.

2.6 Under Load: (Resistance to Temperature below Fusion Point)

This is a measure of the resistance that a walling material imparts to the combined effects of heat and load. It is also the softening temperature indicated either by complete sloughing down or breaking of the specimen when a load of 1.608N is applied. Materials, generally, being bodies of more than two constituent compounds fail under load conditions at temperatures much lower than the fusion point of the highest melting point of the predominant constituent. Failure in any material is also influenced by its time duration of exposure to heat and load. Long time of exposure results in failure of materials even under comparatively low temperature and load conditions. (Okiwe and Onwelu 1998).

2.7 High Permeability and Flowability

Base sand or mud with higher permeability is referred to as 'Open sand' while the one with low permeability is referred to as 'Close sand'; Permeability is therefore, proportional to the number and size of the spaces that are available between the individual particles of sand. Flowability of base sand on the other hand is its ability to be compacted effectively to a uniform mass. Higher compaction force is needed for sand with poor flowability. Generally, flowability depends on factors such as frictional forces that assist the bonding action of clays but opposes free movement of sand grains.

2.8 High Deformation and Toughness Property.

Deformation or plasticity is indicated by the increase in length of sand specimen during its compressive strength test. High deformation value of sand relates to better capacity of the moulds to tolerate hydrostatic pressure as also to volumetric contraction. Toughness relates deformation with compressive strength. It also gives an idea about the quality of sand mixture.

2.9 Moderate Plasticity of Sand

Plasticity is an important parameter in the evaluation of sand for walling works. Walling materials, definitely, should be sufficiently mouldable and perpetuate the desired shape. Plasticity depends on mobility, stickiness, binding strength, extrudability and others. Deductions concerning plasticity depend on the plastic limit and the liquid limit of particular clay. Plastic limit is the moisture content when a clay/water mixture rolled in thread – like shape ceases to flow under its own weight. Therefore, the range of moisture content between the plastic and liquid limits is the range of water to form plastic clay useful for building. The plastic index is hence the optimum moisture percentage needed to form a plastic paste. Generally, clays with plastic limit below 15% are said to be non-plastic or of low plasticity, while clays with plastic limit between 20-35% are considered moderately plastic. (Afolayan and Marona, 1988).

2.10 The Time Constant of a Building

Considering $H = H_o e^{-kt}$ being heat loss at any time t.

Integrating $H = H_o e^{-kt}$ with respect to time between zero and infinity, we arrive at $H_o k^{-1}$. This means that if all the heat stored in the building structure is lost because it has cooled down to the same temperature as the outside, the amount of heat involved is

H_o/K – the product of the design heat loss rate and the reciprocal of the time constant (usually expressed in hours) by dividing the heat stored in the building structure by the design loss rate.

2.11 Clays

Ordinary, one thinks of clay as the material for the potter, a gardener will as well call it the most important part of heavy soil. A building engineer sees it as the material from which bricks are made to build houses or line furnaces. (Ndububa and Ndububa, 1998). To some other people it is the material that is used to stop leaks in canal embankments (Gidigasu 1976).

Clays has been studied from different points of view by the Geologist, the Mineral Resources Engineer, Mechanical Engineer, the Chemist, Ceramic Technologist, Soil Scientist, Civil Engineer and recently Building Service Engineers. Assuming the granite is tropical, these are types of the mineral: Alkali, Quartz, Plagiocalse Feldspar and Olivie Crystallized out adjoint to each other in different proportions in the surface of the rock.

Each is attacked at different rate by the weathering agents and all are attacked very slowly by the periods of time available for geological processes are so great that huge amounts of rocks may be transformed. Alkali feldspar-orthoclase is a compound of potash, $K_2OAl_2O_26iO_2$. It is gradually attacked by water containing carbon dioxide in solution, which leaches away the potash and some of the silica, leaving the aluminium silicate, kaolinite.

In the course of time, the feldspar in granite is transformed by percolating waters into clay. (Okeke, 1991).

$$K_2OAl_2O_22SiO_2+K_2A1_2O_26SiO_2+2H_2O+Co_2=$$

$$Al_2O_22SiO_22H_2O+4SiO_2+K_2CO_2 \qquad (2.2)$$

The plagioclases feldspar, anorthite, which is typical of this group, is written as $CaO.Al_2O_2$. $2SiO_2$. It is probably converted to clay by a reaction very similar to that by which orthoclase is decomposed.

$$CaO.Al_2O_2.2SiO_2 + 2COc + 2H_2O = Ca(HCO_3)_2+$$

$$Al_2O_22SIO_22H_2O \qquad (2.3)$$

Another form derived from above is by removing Percolating water from the solution.

2.11.1 Primary or residual Clays:

These are clays that are not transported too far away from the site of the original rock by flowing water or other means. These clays have the chance of retaining not only unchanged fragments of the original rock but also reaction products characteristic of the parent rock. Between these two limits, clay is in the plastic state. (Adegoke, 1989) and can be moulded by hand or machine. Clays differ in the case with which they can be moulded.

The plastic clays usually have a wide difference between the upper and lower plastic limits. Clays of low plasticity have a relatively small difference between the two limits. In the plastic condition, applying a little more than minimum force can alter its shape and when the force is removed the new shape is maintained. This is known as the qualitative condition of plasticity in clays.

2.11.2 Action of heat on clay

In the plastic state, small forces deform clay. When a clay particle is dried, it is rigid by comparatively fragile. It is also readily broken down by action of water. Firing at a bright red heat; usually renders the clay article hard and durable. At about 150°C, residual water not completely removed by the process of drying is expelled. From temperature 450°C to 600°C, chemical decomposition of the Kaolinite clay takes place and the combining water is driven off. (Guma, 1998). For pure clays this can amount to 4% of the weight of the dry clay. This reaction is represented thus:

$$(OH))_8 Al_2Si_4O_{10} = Al_2O_2 + 4SiO_3 + 4H_2O \qquad (2.4)$$

Industrial clays are liable to contain organic compounds. These are decomposed and the residual carbonaceous matter is burnt away over a larger range of temperature about 350°C-850°C, provided the clay is open to free oxygen. At this stage of heating the clay has become resistant to the slaking action of water but has become porous and still relatively fragile. This temperature range is known as the oxidizing range (Okeke, 1991).

A clay article does not develop its strength until it has vitrified. The verification range starts at about 900°C and extends up to the highest temperature the clay can withstand without melting. This as well depends on the kinds of clay mineral and the impurities present. The upper temperature may vary from 1000°C to over 1500°C (Guma, 1998). During verification period, the porosity of the mass of clay decreases and its strength and hardness increase. There is notable firing –shrinkage. Provided the clay article is heated uniformly and not subjected to external forces strong enough to be detrimental, this firing – shrinkage is not accompanied by distortion but loss of shape becomes increasingly difficult to prevent as the firing temperature increases. The properties of drying – shrinkage and firing – shrinkage shown by clays cause manufacturing difficulties with all classes of clay wares, whether table ware, wall tiles, electrical porcelain, fire clay products, bricks, roofing tiles or salt glazed wares.

2.11.3 Properties of Clay

Clay – water relationship:

If clay and water are agitated together for sometime and then allowed to rest some of the clay particles stay in suspension for a considerable time. The coarse particles, which settle comparatively rapidly, often do not consist of any clay mineral at all but particles of sand, mica, feldspar and Iron pyrites present as impurities. Finer particles take longer to settle and the very finest stay in suspension for days and even weeks.

2.11.4 Clay in the plastic state:

When clay is thoroughly mixed with less water than is actually needed to make a fluid slip, it acquires a pasty consistency. A mix of such consistency can be made either by mixing ground dry clay with sufficient water or by removing some water from clay slip:

(i) By filtering

(ii) By evaporation

(iii) Or by pouring it on to a porous plaster slab

It is usually possible to distinguish two proportions of water at which there is a definite, glaring and observable change in the properties of the clay paste.

2.12 Need for Consideration of Thermo – Mechanical Properties

The thermo-mechanical properties need more attention now than ever before to facilitate properties choice or sourcing alternative walling materials. (Oshinubi and Katte 1991) investigated the effect of 0 to 3 hours elapse time after mixing on the grain size and plasticity characteristics of soil – cement mixes in road construction. Road Construction and walling purposes are interrelated. The aim of the investigation to them was to adopt the soil classification indices method to validate the use of soil – cement mixes for pavement construction. The effects of cement content on the maximum dry density (MDD) and optimum moisture content of soil/cement mixture were tested.

This is of paramount importance to the Building Engineer. These test results validly support the linear shrinkage, hence failure of most highway pavement, though non-load bearing, points to the need for further research for soil cement mixes for load bearing walls. Values of physical and mechanical properties of walling materials are available in various forms in published works in journals, of renowned research giants in Building Services Engineering (Kethandran and Eckert; 1978) & (Frank and Mark, 1988).

A lot of research works are in progress. Works on heat flow and temperature are as well considered in view of the physical and mechanical properties measured or determined. (Summer 1966) described precision instruments for temperature measurement in the National Engineering Laboratory Report.

2.13 Synthetic Sands:

These, basically, are silica sand that contains little or no binder in their natural state. Their strength is developed be adding clay and other additive separately, thus moulding properties are efficiently controlled. However, moulding sands are comprised mainly of silica, grains and clay.

2.13.1 Silica and grains

Silica and grains are very important in moulding sands for their outstanding properties. The provide permeability for the sand. they also impart chemical resistively to the sand. They are specified according to their size and shape. Hence the fine the grains, the more intimate the contact, the higher the compactness and the lower the permeability. Fine grains tend to fortify the mould and reduce the tendencies for it to get distorted. Their shapes are classified as below:

(i) **Compounded grains:** These grains are cemented together and fail to separate under screening. It is comprised of rounded, sub-angular or angular grains or a combination of the three. They are highly desirable for waling works due to breakdown only at very high temperature.

(ii) **Rounded grains:** These grains have the least contact with one another in a rammed structure; thereby making the sand with rounded grains lacks strength.

(iii) **Sub-angular grains:** they have comparatively lower permeability and hence greater strength than the rounded grains.

(iv) **Angular grains:** these are grains that have fine edges with almost – flat surface. They produce higher strength and lower permeability than angular grains.

When sand is rammed in a mould, the sand grains are forced together. The clay coating on each grain is so placed that it locks the grains in position and also makes them retain that position. Though if the amount of water added is exact to form the film, the bonding action is best. Excess water reduces strength and weakens the structure. Therefore, permeability is proportional to the number size of the spaces that are available between the individual particles of sand.

2.13.2 Binders Agents

The main purpose of binders is to influence the bonding properties of sand. Binders are either in liquid form or in a much finer state of setting than the sand grains. In compactness, the binder coatings form lens-shaped masses at the point of contact of the grains. In actual sense, the strength of the bond so produced is a function of number and area of these contacts. Increasing the binder content makes the layer becomes continuously and progressively thicker. Common binders are molasses, animal dings, starch, oil and dextrin (David, et. al. 1989). Fibrous materials commonly used are wood, straw, flour, dried grasses, sawdust and coconut fibres, manure etc. These are used to prevent scabbing. They are also used to improve collapsibility. They are as well useful in providing resistance to expansion defects.

Several investigations have been carried out using coconut shells, palm kernel shells, base sand, laterite etc. Pre-colonial days, people used palm kernel, coconut shells, grasses and others as binders. A lot also had been done on sawdust concrete and EAF slag blocks for use in embankments and drainage passageways.

CHAPTER THREE

3.0 MATERIALS AND METHODS

Properties tested were moisture content, compressive strength and shrinkage of sawdust and EAF slag-cement blocks of different mixes. Compressive strength of derived blocks with gradual replacement of cement with EAF slag, also shrinkage, moisture content and compressive strength of sawdust mixed concrete blocks in relation to curing age were measured.

3.1 Material Preparation

3.1.1 Sawdust Concrete

The mixes of sawdust concrete of 2: 3: 6 and 1:3:6 were carried out complying with British Building Standard 882. The 2:3:6 mix was made up of one part of Sawdust to two parts of cement and mixed with water finely enough to avoid segregation. The moulding was done and cubes defined as X_1, X_2, X_3, X_4 and X_5 for sawdust cubes. The specimens were removed from the mould after 30 hours. Covering the cubes with polythene sheets for the first 10 days. The 1:3:6 mix is made up of one part of sawdust to one part of sand to one part of cement, also finely mixed with water to equally ascertain that there was no segregation.

3.1.2 Omi – Oye Sand

Omi-Oye sand is in bountiful deposits immediately off an ox-bow lake just some metres off Ilorin- Kabba road near Ayetoro Gbede, Kogi State. The Natural Omi-Oye sand is fine, has very good surface characteristics and of uniform grain size. It serves as very cheap source of raw materials for block making factories around. Sieved to remove stones, granites and other impurities, it mixes fixedly (without segregation) with the usual WAPCO cement.

3.1.3 Electric Arc Furnace Slag

Some quantities of EAF Slag were collected from Ajaokuta Slag yard from which through sieving, metallic and other form of lumps, were sorted out and disposed of. The pure slag was then ground into very fine powder. Pure natural sand and common Portland cement was used in this work. After thoroughly mixing the materials in the used ratio or proportion on a flat clean surface, experimental cubes labelled C_1, C_2, C_3, C_4 and C_5 using gravimetric ratio of 1:8 (Cement/sand) control test pieces. Thereafter other test pieces were cast, gradually reducing the amount of cement proportionally to equivalent of Slag by 15%, 25%, 35%, 45% and 50% respectively. Each set (10 pieces) of the test pieces was allowed to dry for periods ranging from 10 to 50 days.

3.1.4 Slag-sand cement Concrete

The EAF slag-cement blocks. Slag-cement blocks were produced using varied mixes of slag and cement with Omi-oye sand in a proportion to slag and cement. Also slag-cement with sand. These mixes were categorised 1:3:6, 2:3:6 and by gradual replacement of cement by slag to 10%, 15% and 25%. Emphasis, here, was on the gradual replacement vis-à-vis the compressive strength of derived blocks.

3.1.5 Cement-Sand Blocks

The materials were mixed manually on a board. Experimental cubes were moulded using 1: 8 mix ratio. The cubes made of 1 part of cement plus 8 parts of sand were used as control pieces. They were exposed to the atmosphere for a curing period of 30 days. The compressive strength of the cubes was evaluated at stages of curing. i.e 5 days, 10days, 15 days, 20 days, 25 days and 30 days.

3.2.0 Firing Procedure

3.2.1 Electric Arc Furnace (EAF) Slag Block

Drying Procedure was by exposing the cast-cubes to the atmosphere for a period of 10 to 90 days. The drying period varied from 10 to 30, 30 to 50, 50 to 90 days.

3.2.2 Sawdust Concrete Block

The Specimens were soaked for 6hours, later removed and placed in an open space for drying. The lengths of respective sides and the length of corresponding sides were recorded for the first 30 days. Weights of specimen cubes were taken at 10,20 and 30days of curing. All these were carried out to British Building standards 882.

3.2.3. Omi – Oye Sand Block

Firing was done in the Muffle and Vesteer Furnaces. It was done at a fairly slow rate for complete drying. Though slow the firing was steady to prevent stream formation within. Heating ranged from 80^{0}C to 100^{0}C and was done for about 2 hours.

3.2.4 The Physical and Mechanical Properties Evaluated

a. **Compressive Strength:** Compressive Strength that is the "Strength" of the blocks was considered. The factors that affect compressive strength affect the strength of the wall. Hence, compressive strength is the main thing to consider in a wall.

b. **Shrinkage:** Volumetric shrinkage is the reduction in volume of concrete due to varying factors. A major symptom of shrinkage is cracking, which is a sign of poor quality that could be reduced using suitable materials and mix ratios.

c. **Moisture Content:** Moisture content is the amount of water in form of vapour in a body. This is expressed using the mass of water present in relation to the mass of the body, which is expressed as a percentage, especially, in a body formed using some quantity of water. Determining moisture content of a body is simply determining the amount of condensed water vapour in the body.

3.3.0 APPARATUS DESCRIPTION

3.3.1 Tensile and Compressive Strength Testing Machine

The universal materials Testing machine as shown in Fig 3.1 is a hydraulically operated unit providing facilities for compression and tensile tests at loads of up to 100kN. It has these components

i. Compression platens

ii. A digital load-meter

iii. A dial gauge system for basic deflection measurements. Ending Wedge chucks for holding tensile tests work pieces.

The Basic machine:

The basic machine consists of a rigid four-column frame, which support a hydraulic ram. A cross member fitted to the top of the ram-carrier and loading platform supported on two trebars. These trebars are connected at each end by ball joints so that the loading platform is completely self-aligning and loading is axial. A strain-gauged load-link is fitted midway up each trebar and the two links provide an output for the digital load meter. Loading platform is used for compression tests while that below is for tensile tests. The machine is supported on four study horizontal legs, which spread the load and provide adequate stability.

The hydraulic ram has a self-sealing coupling and can be connected either to the manual or motorised pump. The hydraulic ram, manual pump, motorised pump and connecting hose are all rated for operation up to 200kN and therefore have a good margin of safety when operating over the load range of the machine.

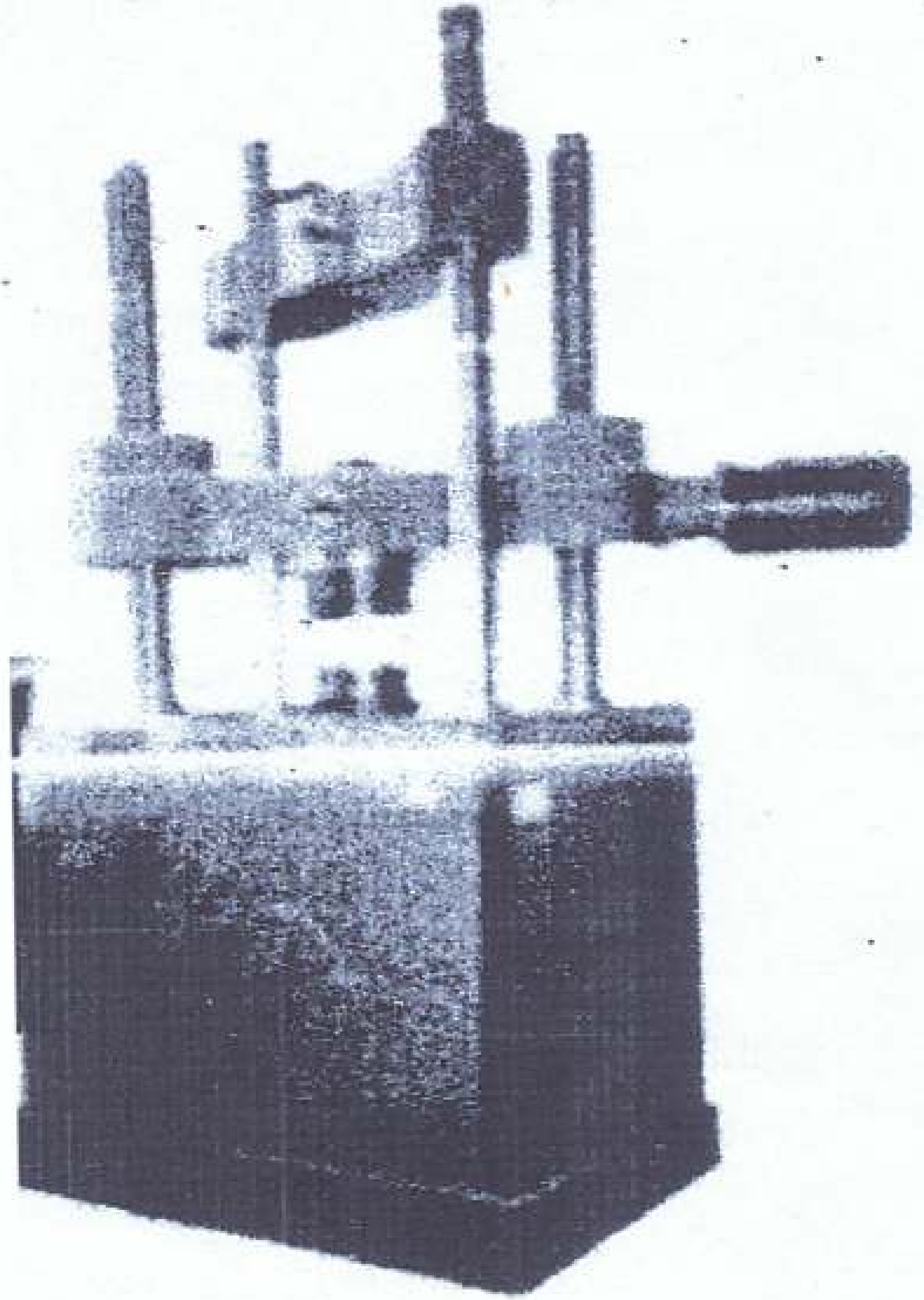

Fig. 3.1: Tensile and Compressive Strength Testing Machine

3.3.2 MOISTURE CONTENT TESTING MACHINE

The speedy moisture tester (normally referred to as "Speedy") is a device for testing the moisture content of materials. It comprises of a body with a body with a hole and the lid is made up of a dial and the calibrated cap. It has two metal balls as pulverisers for testing moisture content of coarse materials e.g. clays.

The Process:

The speedy was cleared to ensure that it was free from residues: A chip of sample was ground before weighing and loaded into the body of the speedy. Two full measure of speedy absorbent were added to ensure adequate coverage in each trial. The speedy was then sealed, and shaken with the dial facing up. The readings were then taken, placing the speedy horizontally, directly allowing the readings to be facing the dial gauge at eye level to enhance accuracy. For clay blocks, the ground chip is loaded with two steel ball pulverisers into the speedy body with sample held horizontally and rotated for about 30seconds to put the steel ball pulverisers into orbit inside the speedy body. The speedy is then held for about 20seconds and the cycle is repeated for three minutes before the readings were taken for each trial. Turning the speedy quickly ensures that the heat given off by the reaction is confined and liberated all the moisture in the material. Turning was done twice or thrice to get near accurate results.

3.3.3 Muffle Furnace

Muffle furnace, as shown in Fig. 3.2, is calibrated from $0^{0}C$ to $1100^{0}C$ and has maximum power rating of 1.5 kW. Its internal volume is 24 litres with digital temperature display and refractory muffle with steel outer case. Graded asbestos – free insulation with air gap provides safe outer case temperature. It has integral chimney with adjustable vane for draught control plus counter poised swing – up plug door with switch, which isolates power from element when door is opened.

The internal safety thermal fuse is to prevent over-heating.

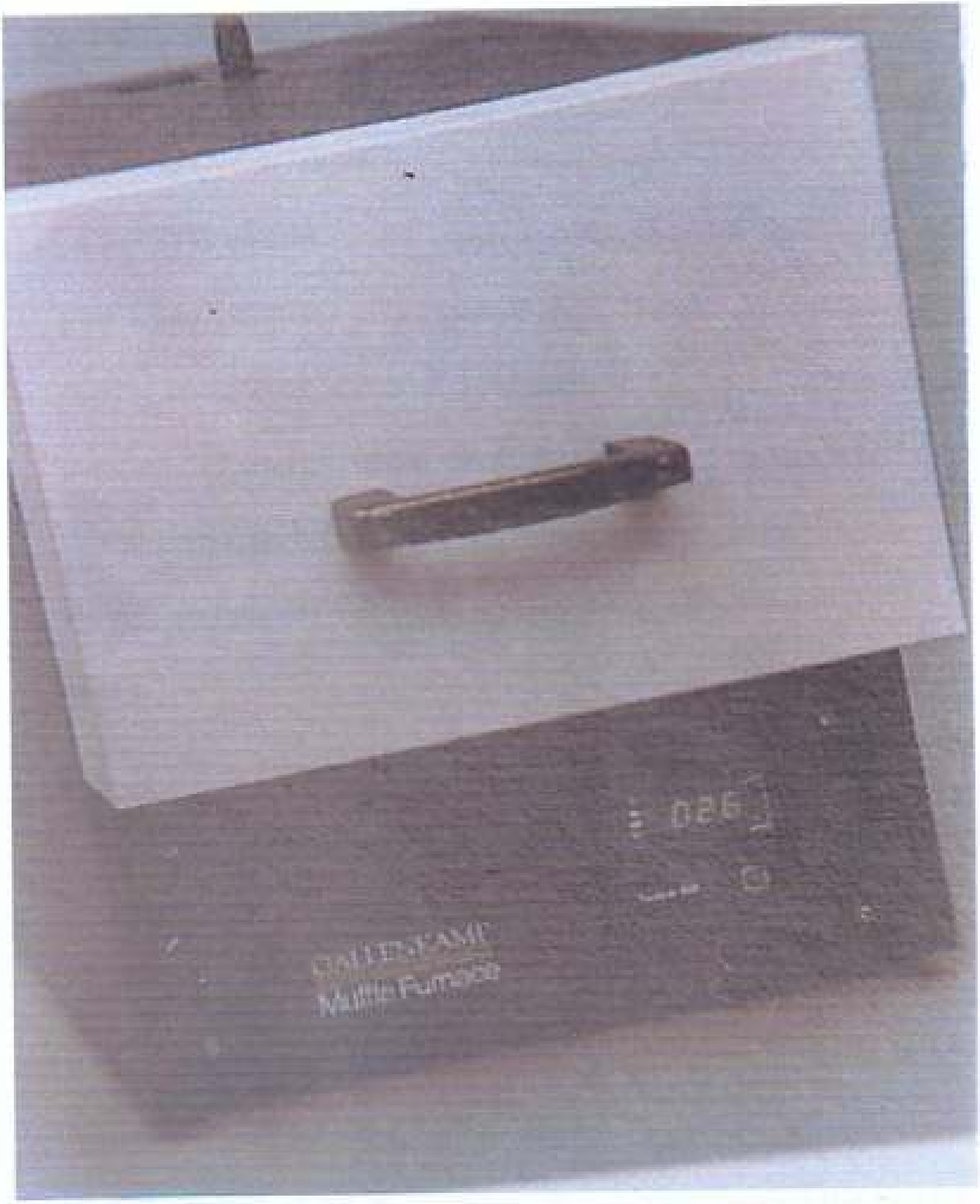

Fig. 3.2: Muffle Furnace

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The physical and mechanical properties considered are compressive strength, shrinkage and moisture content.

4.1 Sawdust Mixed Concrete Block

4.1.1 Compressive Strength for 1:3:6 Mix Ratio

The sawdust mixed concrete block is made up of sawdust plus 1 part of cement plus 1 part of sand. The compressive strength of the considered mixes is presented in Fig. 4.1. The average compressive strength of the mix is 5.28 N/mm^2. The longer the age of the block, the higher the compressive strength. After 25 days of curing, compressive strength ranges from 5.22 N/mm^2 to 5.61 N/mm^2.

It was also observed that with increasing curing age, the compressive strength of the blocks used for the experiment was closing up. i.e. the range of the compressive strength of the set of blocks considered was becoming smaller. At curing age of 15 days it ranged from 3.98 N/mm^2 to 4.72 N/mm^2. The increase is more noticeable from curing age of 10 days to 15 days than from curing age of 15 days to 25 days. This is due to the fact that the rate of radiation, conduction and convection on the blocks when newly moulded was higher than after a period of exposure. It can be as a result of the fact that compressive strength depends on a combination of moisture content, amount and type of binder.

The mix ratio has a lot of effect on the compressive strength. The mass of block, ratio of mix and curing age increase the compressive strength. The range of compressive strength increase with curing age as clearly shown in Fig. 4.1

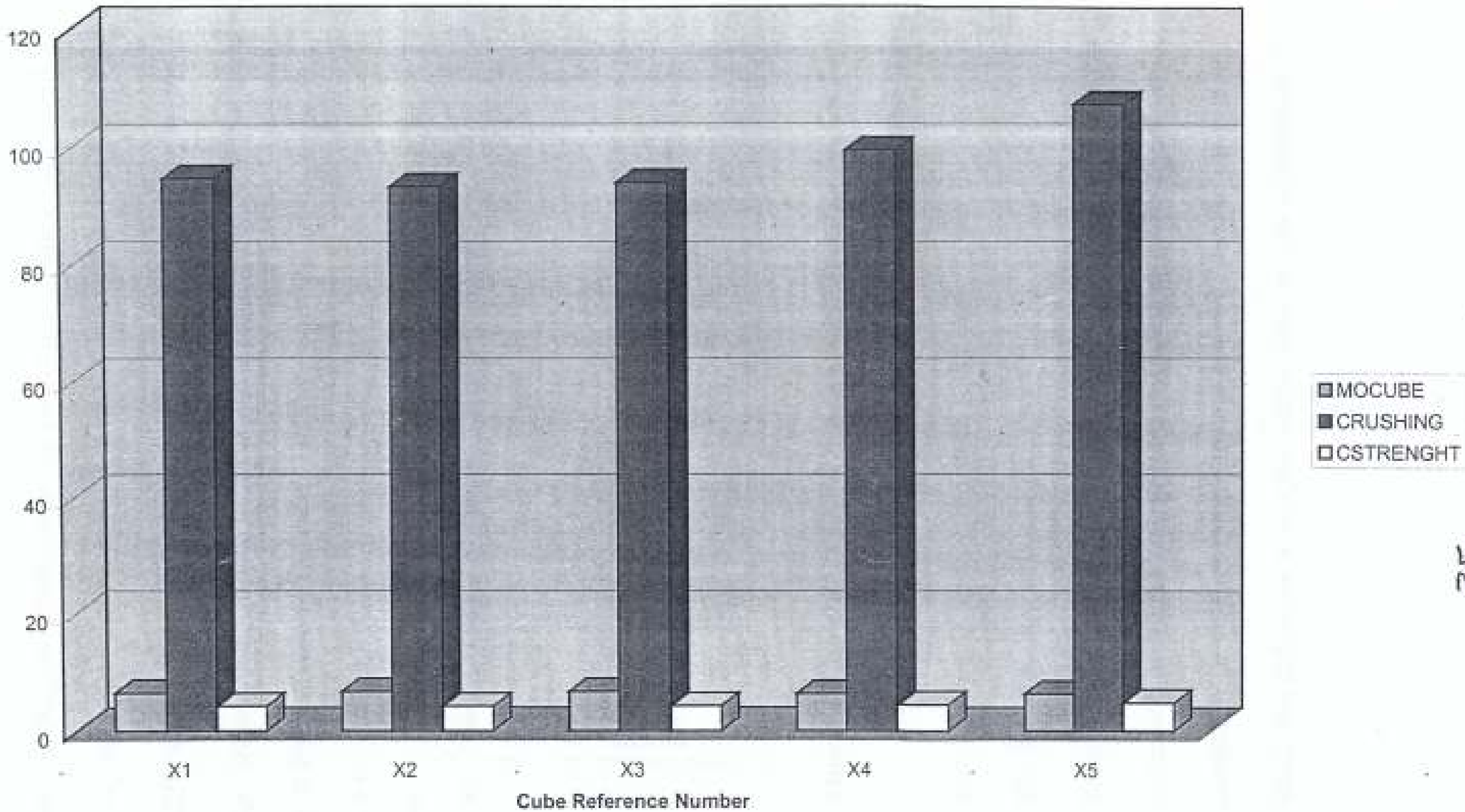

Fig 4.1 The Chart of the Compressive Tests on Sawdust Concrete of 1:3:6 Mix Ratio (30 Days)

4.1.2 Shrinkage

Table 4.1 shows shrinkage almost at the placing of the blocks. Further shrinkage was reduced by the prevention of drastic water loss by covering the blocks with polythene. Linear shrinkage varied from 0.15% to 0.22% while volumetric shrinkage varied from 0.19% to 0.23%. Thus average linear shrinkage was 0.188% and average volumetric shrinkage was 0.214% as shown in Table 4.1.

Table 4.1: Result of Shrinkage Measurement for 30day Sawdust Concrete of 1:3:6

CUBE REF NO	CUBE DIMENSION IN MM			SHRINKAGE (%)	
	Side 1	Side 2	Side 3	Linear Shrinkage	Volumetric Shrinkage
X_1	149.8	150.0	150	0.15	0.22
X_2	149.6	150.0	149.9	0.17	0.19
X_3	150.0	149.8	149.8	0.19	0,21
X_4	149.9	149.6	150.0	0.22	0.22
X_5	150.0	149.8	150.0	0.21	0.23

4.1.3 Moisture Content

The moisture content of each of the specimen used was measured using speedy moisture tester and shown in Table 4.2. The initial weight of the blocks varies from 1.791 kg to 2.1543 kg. Their weights on ignition varied from 1.756 kg to 2.105 kg. The difference in weight ranged from 0.026 kg to 0.176 kg. Moisture content by percentage ranged from 1.2% to 8.2%. For each sample block, the difference in weight, which is the weight of moisture, is expressed as a percentage of the initial weight to depict % moisture content as presented in Table 4.2

Table 4.2 Results from Experiments on Moisture Content of Sawdust Concrete of 1:3: 6 Mix Ratio (Results of Moisture Content at 110°C)

Sample No.	Initial Mass (kg) (m_w)	Mass on Ignition (kg) (m_d)	Difference in Mass (kg) (Shrinkage)	% Moisture content = $\frac{(m_w-m_d)}{m_d} \times 100\%$
S_1	2.1543	1.9776	0.1767	8.2
S_2	2.1318	2.1053	0.0265	1.2
S_3	1.791	1.756	0.0150	1.9
S_4	1.898	1.852	0.0460	2.4
S_5	2.059	2.023	0.0360	1.7

S_1, S_2, S_3, $S_4$and S_5 are references numbers of cubes used.

Source: Field survey

4.2 Sawdust Concrete Blocks

4.2.1 Compressive Strength of Sawdust Concrete of 2:3:6 Mix Ratio

This set of concrete blocks was made with 1 part of sawdust to 2 parts of cement and sand. This amount of sand is for high cohesion. The compressive strength of the blocks is presented in Table 4.3. For the first 10days of curing the mass of the cubes and the compressive strength varied from 4.25 kg to 4.80 kg and from 1.71 N/mm^2 to 2.22 N/mm^2 respectively. At 15 days of curing the compressive strength varied from 3.98 N/mm^2 to 4.61 N/mm^2. The compressive strength had appreciable increase at curing age of 25 days varying from 5.22 N/mm^2 to 5.61 N/mm^2.

The 2:3:6 mix compares reasonably with the usual values of lightweight concrete blocks. The mixes gave values that are reasonably presentable.

Table 4.3: Results of Compressive Strength of Sawdust Concrete of 2:3: 6 Mix Ratio

Cube Ref No	Age of cube (Days)	Mass of Cube (kg)	Crushing Load (kN)	Compressive Strength (N/mm^2)
C_1	10	4.80	48.8	2.20
C_2		4.75	38.0	1.71
C_3		4.50	40.0	1.80
C_4		4.60	38.0	1.88
C_5		4.25	49.3	2.22
C_1	15	4.80	99.7	4.50
C_2		4.85	98.4	4.44
C_3		4.75	88.2	3.98
C_4		4.85	100.6	4.54
C_5		4.70	102.1	4.61
C_1	25	5.20	117.1	5.32
C_2		4.95	124.1	5.61
C_3		5.00	115.5	5.22
C_4		4.90	120.4	5.44
C_5		5.00	121.7	5.50

4.2.2 Shrinkage of Sawdust Concrete of 2: 3:6 Mix Ratio

Source: Field Survey

Table 4.4 shows the results of shrinkage measurement for sawdust concrete of 2:3:6 mix ratio. Volumetric and Linear Shrinkage were observed almost immediately the cubes were placed. Further immediate drastic loss of water had to be prevented to avoid cracking. Linear shrinkage varied from 0.33% for cube X_1 to 0.53% on cube X_3. Volumetric shrinkage 0.80% to 0.91% on cube X_4. It was observed that cubes X_1, X_2, X_3 and X_5 had equal linear and volumetric shrinkage.

Table 4.4: Results of Shrinkage Measurements for 30day Sawdust Concrete of 2:3: 6 Mix Ratio

CUBE REF NO	CUBE DIMENSION IN (mm)			PERCENTAGE SHRINKAGE	
	SIDE 1	SIDE 2	SIDE 3	LINEAR SHRINKAGE	VOLUMETRIC SHRINKAGE
S_1	150.0	149.9	150.0	0.07	0.07
S_2	150.0	149.5	150.0	0.33	0.33
S_3	150.0	150.0	149.9	0.07	0.07
S_4	149.6	150.0	149.8	0.27	0.40
S_5	150	150.0	149.7	0.20	0.20
Average				0.19	0.21

Source: Field Survey

4.2.3 Moisture Content

Fig 4.2 shows that the results of moisture content for this mix was a bit uniformly high. The 2 parts of cement must have caused that, since cement has higher rate of water retention than sawdust. The moisture content varied from 7.8% to 8.8%, majorly clustering between 8.4% and 8.5%. The average moisture content for the set is 8.32% which is reasonably high.

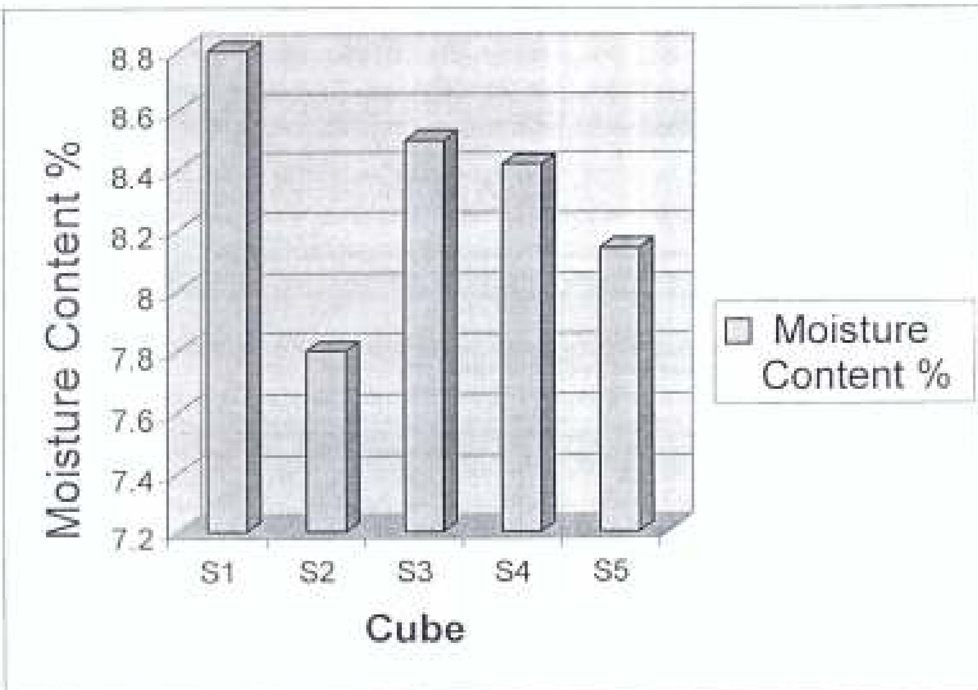

Fig. 4.2 Results of test on moisture content for sawdust concrete of 2:3:6 mix ratio

Source: Field Survey

4.3 Slag-Cement Concrete Blocks

4.3.1 Compressive Strength of Slag-Cement Concrete Block of 1:3:6 mix ratio

Slag-cement of 1:3:6 mix ratio was made of 1 part of slag to 1 part of cement and 1 part of sand. Table 4.6 shows the compressive strength of the test pieces as determined at various curing ages using the Universal Cold Crushing Machine available in National Iron Ore Mining Project Laboratory, Itakpe. The compressive strength of the test specimen remained almost constant.

As the cement hydrates, lime ($CaCOH_2$) is produced. The compressive strength varied form 1.71N/mm^2 to 2.22N/mm^2 for the first 10days but stabilizes within the fifteen days at 4.5 N/mm^2. It increased to 5.61N/mm^2 about the 25th day.

Table 4.6: Results of Compressive Strength of Slag-cement Concrete of 1:3: 6 Mix Ratio

Cube Ref No	Age of cube (Days)	Mass of Cube (kg)	Crushing Load (kN)	Compressive Strength (N/mm^2)
C_1	10	6.80	96.5	1.71
C_2		6.70	98.3	1.78
C_3		6.90	97.0	2.09
C_4		7.00	99.8	1.72
C_5		6.70	100.2	2.22
C_1	15	6.60	129.6	4.50
C_2		6.50	129.1	4.49
C_3		6.70	128.0	4.49
C_4		6.80	128.0	4.50
C_5		6.40	199.5	4.50
C_1	25	6.40	190.2	4.80
C_2		6.20	198.0	4.92
C_3		6.50	188.0	4.89
C_4		6.60	200.0	5.61
C_5		6.60	202.2	5.58

Source: Field Survey

4.3.2 Shrinkage

Table 4.7 shows that shrinkage was observed almost immediately the concrete were placed on the table. However further shrinkage was reduced by preventing drastic water loss through covering the blocks with polythene spread. Shrinkage also occurred by the withdrawal of water from the concrete. Shrinkage of concrete increased with time. The most noticeable increases occurring at the early ages.

Table 4.7: Results of Shrinkage Measurements for 28day EAF Slag Concrete of 1:3: 6 Mix Ratio

CUBE REF NO	CUBE DIMENSION IN (mm)			PERCENTAGE SHRINKAGE	
	SIDE 1	SIDE 2	SIDE 3	LINEAR SHRINKAGE	VOLUMETRIC SHRINKAGE
C_1	149.7	149.5	149.6	0.33	0.80
C_2	149.6	149.7	149.5	0.33	0.80
C_3	149.2	149.9	149.5	0.53	0.93
C_4	149.5	149.8	149.4	0.40	0.86
C_5	149.5	149.7	149.3	0.47	0.91
Average				0.41	0.86

Source: Field Survey

4.3.3 Moisture Content

Fig 4.4 shows the moisture content of each specimen used and was measured. The variation in moisture content is relatively low and very constant for the set. The moisture content varied from 7.9% to 8.8%. The graphical representation is in Fig. 4.3.

Table 4.8: Results of Test on Moisture Content for Slag-Cement Concrete of 1:3:6 Mix Ratio

Sample No	Initial Mass m_w (kg)	Mass on ignition m_d (kg)	Difference in mass (kg) $m_w - m_d$	% moisture content = $(\frac{m_w - m_d}{m_d} \times 100)\%$
C_1	3.06	2.82	0.24	8.5
C_2	3.04	2.80	0.22	7.9
C_3	3.05	2.82	0.23	8.8
C_4	2.98	2.80	0.18	8.6
C_5	3.06	2.83	0.23	8.8

Source: Field Survey

4.4 Slag-cement Concrete Blocks of 2:3:6 mix ratio

4.4.1 Compressive-Strength

The Slag-cement concrete of 2:3:6 mix ratio is made of 1 part of cement to 2 parts of slag. The compressive strength of the test specimen decreased with increase in slag content. The ratio of decrease in compressive strength to increase in slag content reduces with increase in curing age. The alkali soluble silica (SiO_2) and Alumina (Al_2O_3) available in the slag reacts with the lime to form calcium silicate and aluminum hydrates that reduces the porosity of the concrete, which in turn increases the compressive strength of the concrete. It is also noteworthy that no appreciable loss, in compressive strength was noticed when cement was replaced to the level of 25% slag.

Table 4 . 8: Results of Compressive Strength Test on Slag/Cement Concrete of 2:3: 6 mix ratio

Cube Ref No	Age of cube (Days)	Mass of Cube (kg)	Crushing Load (kN)	Compressive Strength (N/mm^2)
D_1	10	8.4	84.8	3.85
D_2		8.35	74.0	2.98
D_3		8.10	76.0	3.15
D_4		8.20	84.0	3.29
D_5		7.85	85.3	3.88
D_1	15	8.4	100.6	4.50
D_2		8.48	102.2	4.40
D_3		8.35	100.2	4.28
D_4		8.40	104.0	4.54
D_5		8.20	103.8	4.60
D_1	25	8.40	100.8	5.40
D_2		8.42	104.2	5.38
D_3		8.45	102.8	5.42
D_4		8.30	104.0	5.50
D_5		9.36	103.8	5.36

Source: Field Survey

4.4.2 Moisture Content

Fig 4.3 shows the moisture content for 2:3:6 for slag-cement, which varied between 5.7% and 7.2%. The mean moisture content of these specimens is 6.6%.

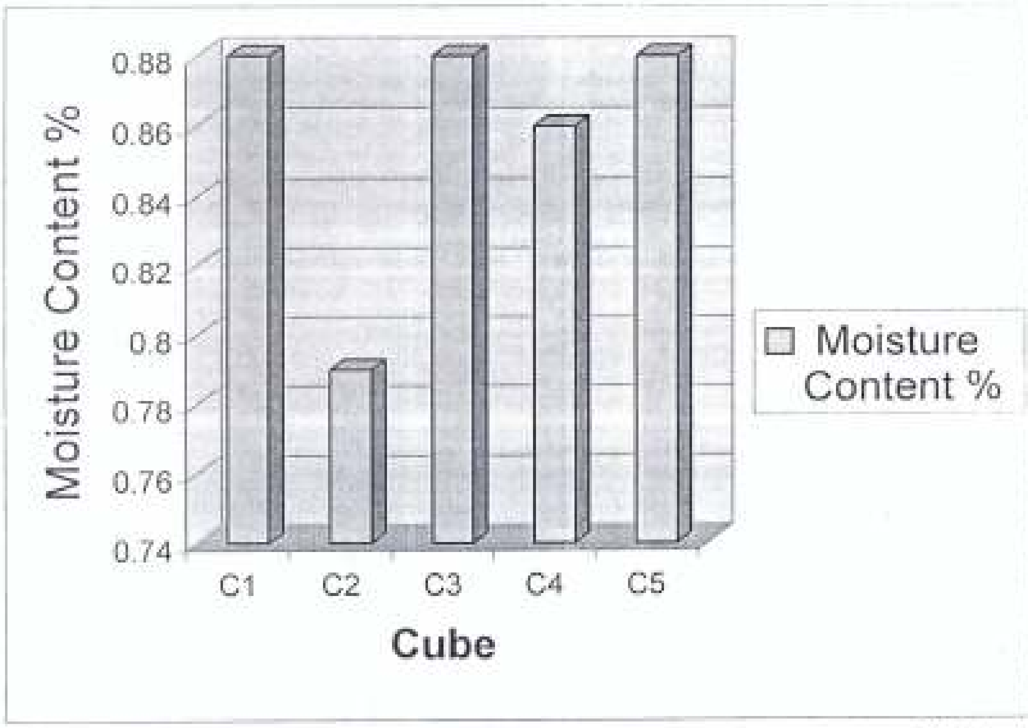

Fig. 4.3 Results of test on moisture content for slag-cement concrete of 1:3:6 mix ratio
Source: Field Survey

4.4.3 Shrinkage

Shrinkage is almost absent because the values were negligible and has no reasonable effect on the blocks.

4.5 Slag-sand Cement Blocks by gradual replacement of cement by EAF slag

Slag-sand cement blocks derived by gradual replacement of cement by EAF slag in relation to compressive strength were done in bits. It was from 10% to 15% and 25% keeping the amount of sand uniform for the three stages of cement-slag replacement. The compressive strength of blocks of 10% slag replacement were shown in Fig 4.4a while that of 15% slag replacement showed improvement on that of 10% slag replacement as shown in Fig. 4.4b. The compressive strength of 25% slag replacement blocks has moved to 7.0 N/mm^2 as shown in Fig. 4.4c. In all, the curing age of the blocks also had positive effect on the compressive strength.

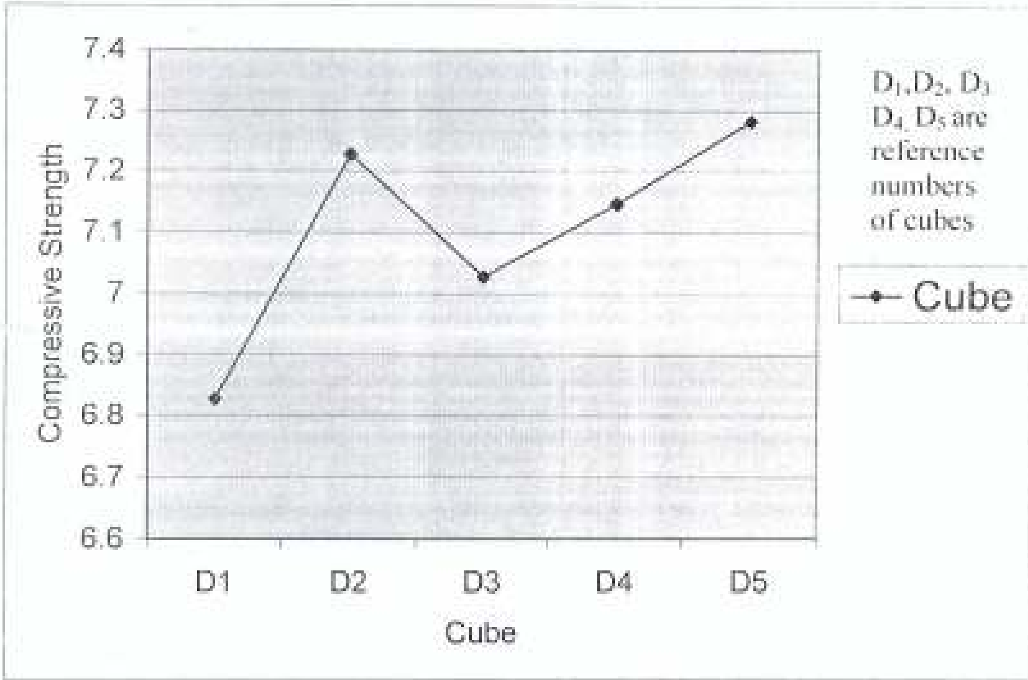

Fig. 4.4a Results of Compressive Strength tests on slag/cement concrete of 10% Slag Replacement.
Source: Field Survey

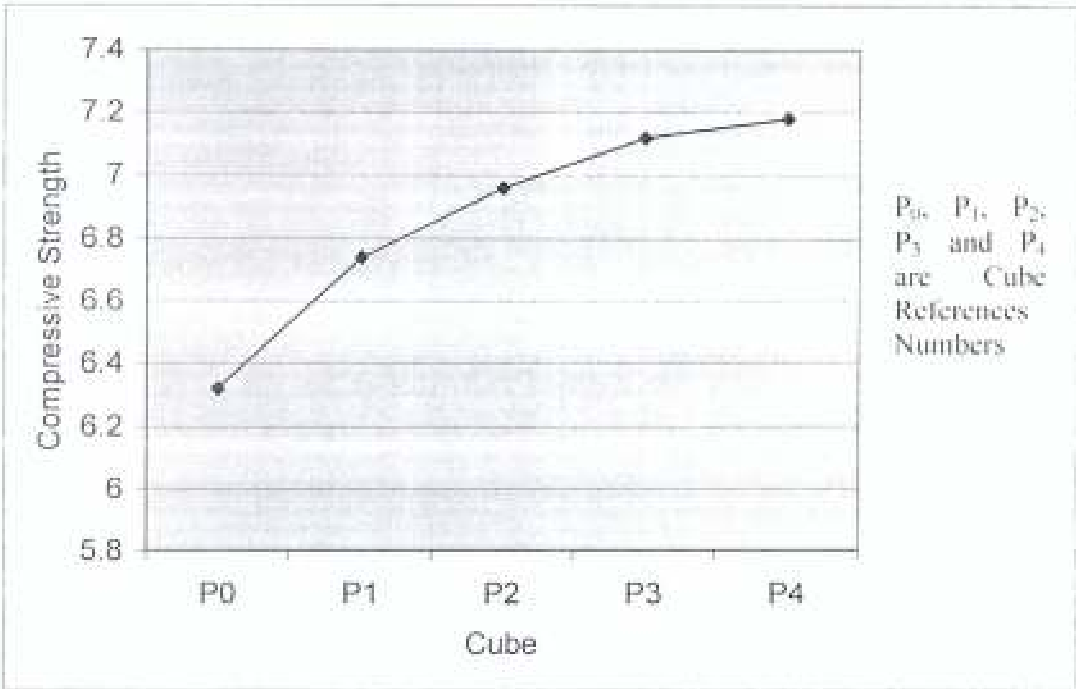

Fig. 4. 4b Results of Compressive Strength tests on slag/cement concrete of 15% Slag Replacement.
Source: Field Survey

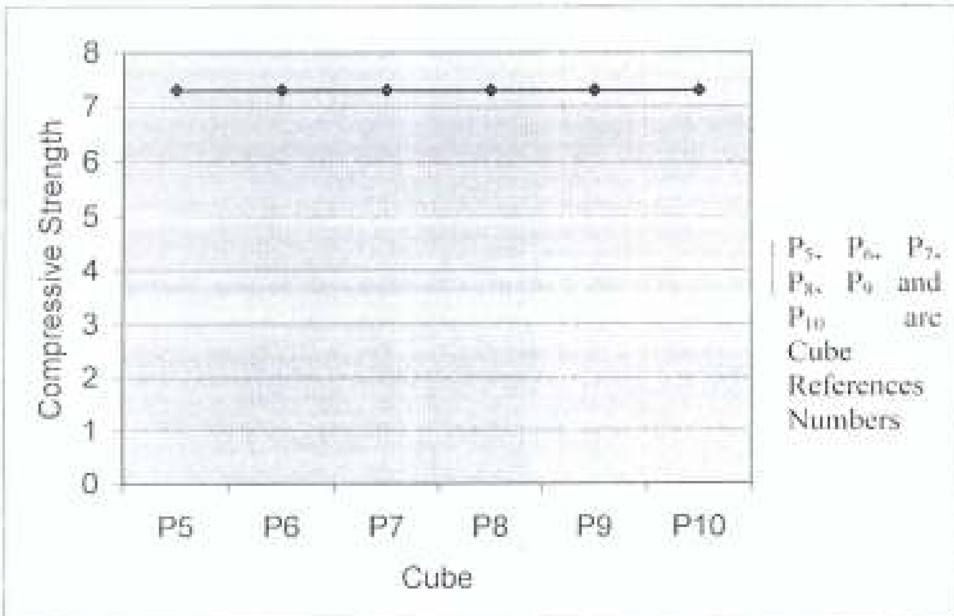

Fig. 4.4c Results of Compressive Strength tests on slag/cement concrete of 25% Slag Replacement.
Source: Field Survey

4.6 Cement-Sand Blocks

The compressive strength of the blocks were measured

The compressive strength ranged from 2.7 N/mm^2 to 4.35N/mm^2 It increased from 2.7 N/mm^2 to 3.4 N/mm^2 for the first 5 days.

The increase in compressive strength was not uniform. The increase from the 10th day to the 15th day ranged from 3.5 N/mm^2 to 4.0 N/mm^2. From the 15th day to the 30th day it ranged from 3.50 N/mm^2 to 4.35 N/mm^2 . The compressive strength improved considerably towards the 30th day of curing, as shown in Fig 4.5

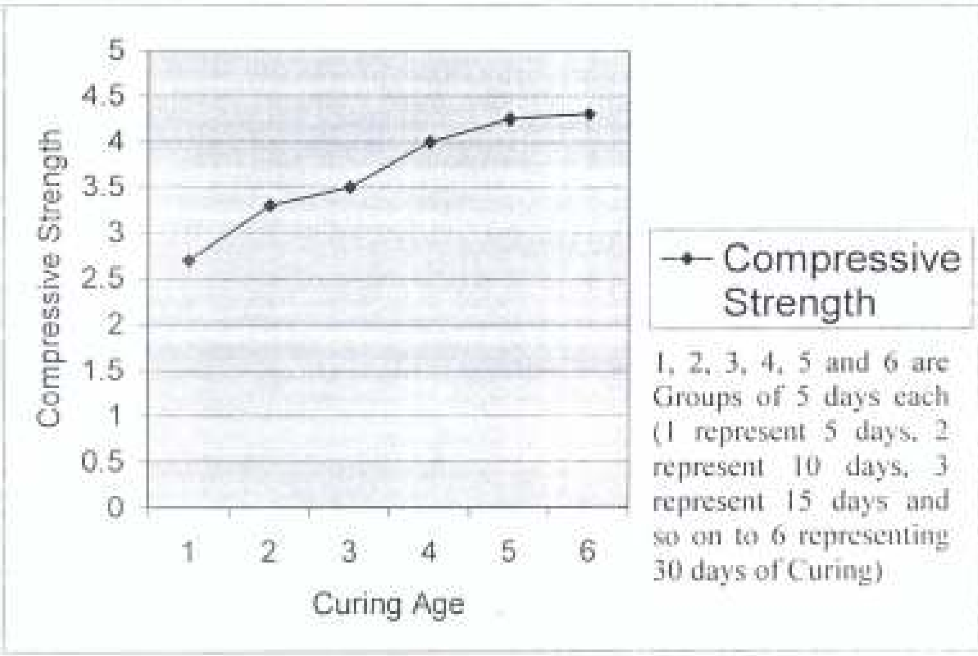

Fig 4.5: Compressive Strength of Cement Concrete of 1:8 Mix Ratio

Source: Field Survey

4.7 General Comparison/Discussion

It is generally observed that the moisture content of sawdust concrete was relatively high. Shrinkage is relatively low on slag-cement of 2:3:6 mix ratio that confirmed high cohesion. There was noticeable improvement in 2:3:6 of sawdust concrete over that of 1:3:6 mix ratio. The increase in compressive strength is also significant. The sawdust concrete of 2:3:6 shows an improvement on that of 1:3:6 for the physical properties considered, as shown in Fig 4.6

The slag-cement concrete of 2:3:6 mix ratio proved that a lot of resources have been wasted in totally depending on WAPCO cement for walling. The slag-cement concrete blocks have higher cohesion, higher compressive strength, low moisture content and negligible level of shrinkage. With the recent economic reforms we can save a lot of our meager resources by turning EAF slag – (a waste product, posing disposal problem in our iron and steel industries) to wealth with little efforts and financial input.

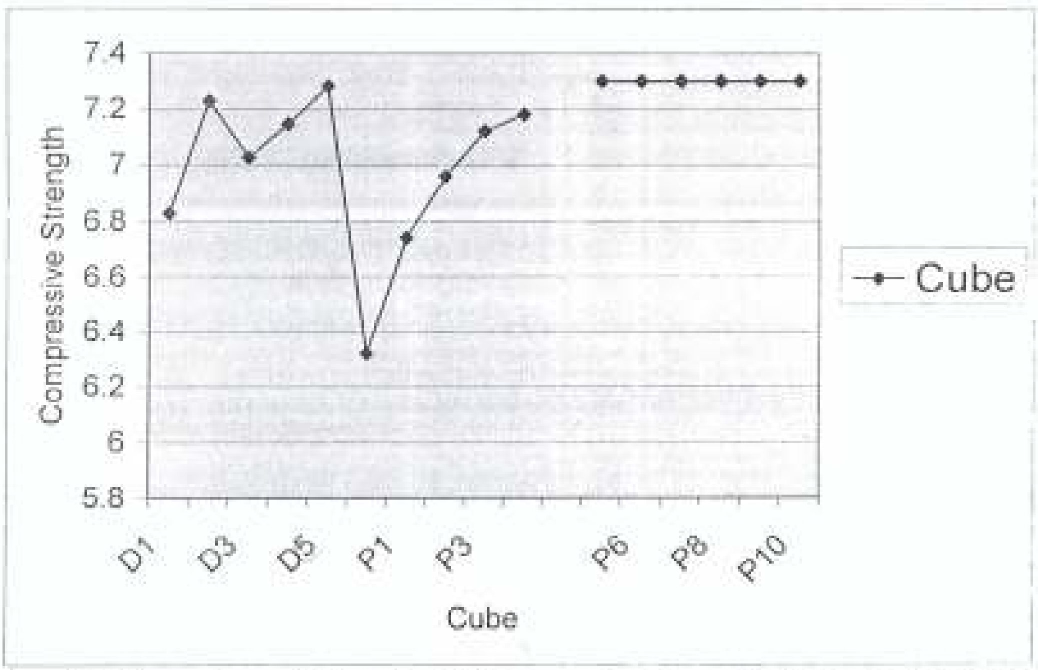

Fig. 4.6 Comparison of Results of Compressive Strength tests on slag/cement concrete of 10%, 15% and 25% Slag Replacement.
Source: Field Survey

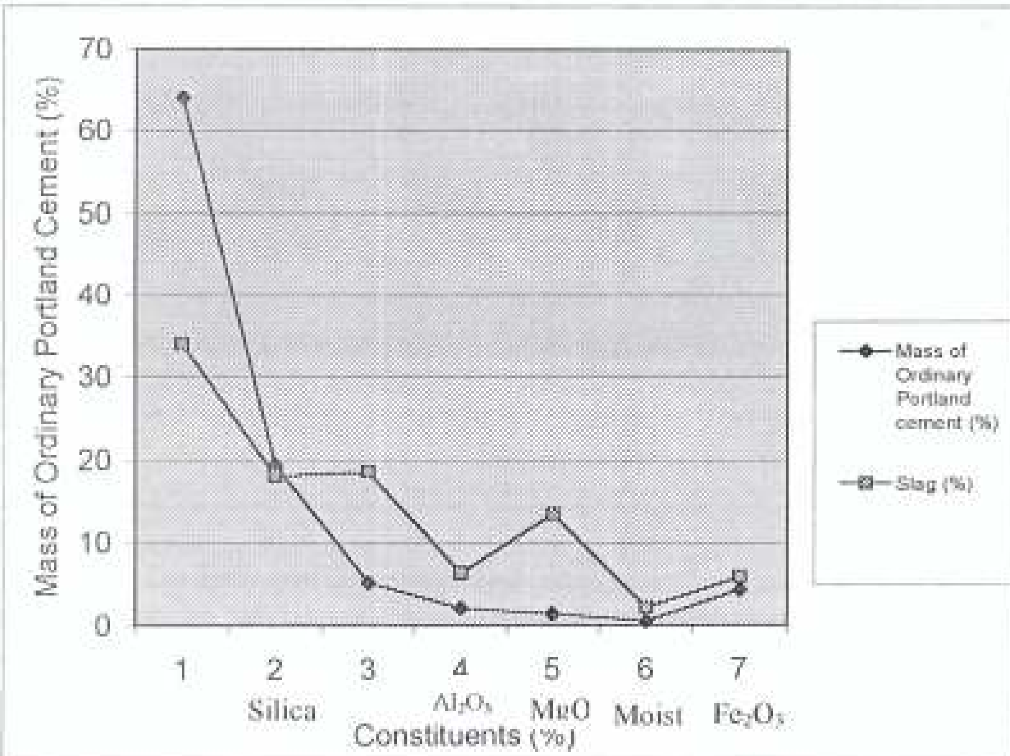

Fig. 4.7 Chemical Constituents of Cement and Slag
Source: Field Survey

4.8 Economic Consideration

The EAF slag blocks that are derived as a result of gradual replacement of cement by EAF slag showed little or no difference in compressive strength as compared to cement-sand blocks in the mixes.

From chemical constituents of cement to slag; iron oxide (Fe_2O_3, 5.20%: 8.66%); So also Alumina (Al_2O_3, 2.14%: 6.4%). Magnesia (MgO, 1.40%:13.56%). There is a slight difference in Silica content i.e. 19.5% for cement and 18.13% for slag (Fig. 4.7). Moisture content of cement is 0.18% but that of slag is 0.72%. The particle size distribution of slag 1.00mm to 0.100mm varies from 100% to 62.03% while that of cement is from 1.00mm to 0.100mm ranges from 100% to 72% hence finely as shown in Fig. 4.7

Considering the fact that 5 bags of cement plus 30 head pans of sand produces 200 blocks, at the current price of cement fluctuating between ₦1650.00 and ₦1800.00 for an averagely decently – designed 3 bedroom flat, one needs 3000 blocks. Hence at 200 blocks from 5 bags plus 15 head pans of sands. Price of cement required is 5 x ₦1650 x 15 = ₦123,750.00 less workmanship and transportation. Using 25% of EAF slag will reduce 5 bags of cement by 25% i.e using 3.75 head pans of cement plus 1.25 head pans of EAF slag with 30 head pans of sand to produce 200 blocks.

Hence 3000 blocks will cost 3.75 x 1650 x15 = 24750 x 3.75= N92,812.50. Difference = ₦123,750- ₦92,812.50 = ₦30,937.50.

From this analysis, it is noteworthy, that with 25% replacement of cement with EAF slag reduced cost of 3000 blocks by ₦30,937.50

CHAPTER FIVE

5.0 STATISTICAL ANALYSIS

The data were subjected to Anova. It shows good correlation and the regression analysis is reliable. The model used being

$$y = 6.911x_1 - 0.423x_2 + 12.518x_3 - 28.902$$

where y = age of cube (AOF cube)

x_1 = mass of cube (kg)

x_2 = crushing strength and (kN/mm^2)

x_3 = compressive strength (N/mm^2)

Correlation is significant at 0.01 levels. From the model, summary R^2 confirms reliability i.e. $R^2 = 0.845$. (Appendices B and C)

5.1 Moisture Content

The mean mass of the cubes ranged from 6.14 kg to 6.49 kg. This confirms the fear entertained by grouping the cubes as at when moulded i.e. the preparation of each set of cubes were at different stages and were categorized. The standard deviation ranged from 0.1387 to 0.223. The difference between the lower bound and the upper bound at 95% confidence interval for mass is very insignificant.

5.2 Compressive Strength

The mean compressive strength of each group ranged from 4.35 kg/cm^2 to 9.24kg/cm^2. The standard deviation ranged from 0.2597 to 0.8464. This confirms the authenticity of the values. The difference between the lower bound and the upper bound at 95% confidence interval for the compressive strength is equally insignificant.

The values were analysed statistically on the mould linear operator.

CHAPTER SIX

6.0 CONCLUSION

6.1 Sawdust - Cement Blocks

Sawdust concrete is a form of lightweight concrete that has fairly low compressive strength. The compressive strength of the blocks of 1:3:6 mix ratio was better than those of 2:3:6 mix ratio. The compressive strength of both mixes (i.e. of 1:3:6 and 2:3:6 appreciated considerably as the curing ages increased. The only visible problem was cracking which suggests that efforts could be intensified in finding ways for curtailment of the cracking. Sawdust that is the major material in Sawdust – Concrete blocks is available at minimal or no cost.

The major problem of sawdust – concrete blocks, however, is cracking. To avoid cracking, sawdust – concrete blocks are tailored for use in non- – load bearing walls. Hence the use of Sawdust in Sawdust – Concrete blocks is for cost reduction, in a way, and solution to disposal problems on the other hand.

6.2 EAF Slag-Cement Block

From the results of the mixes obtained from EAF Slag-Cement, we conclude that industrial wastes from furnaces in the iron, steel and glass industries could be used as an alternative raw material for cement in the building industry. That cement can be replaced by up to 25% of EAF slag in block making without appreciable loss in strength is a welcome development in view of the escalating cost of cement. The use of EAF slag in block making is very cheap, does not demand extra energy and is very durable. With the present prohibitive price of cement, which is obviously beyond control, part replacement of cement with EAF slag will drastically reduce cost of walling materials.

Though the compressive strength of the specimens decreased with increase in slag content, the compressive strength improves noticeably as the curing age increased towards 90days. It is, therefore, observed that with replacement of cement up to 25% slag and increasing the curing age to 100days stabilise the compressive strength.

6.3 Suggestion for Further Work

I humbly wish to suggest that:

1. Investigation into the curtailment of cracking in Sawdust-Concrete blocks should be carried out.
2. Further work is suggested on heat absorption capability of EAF slag concrete blocks in maintaining comfort condition (during the cold and hot months) in buildings.
3. All available building raw materials should be seriously researched into and appropriate steps taken by government to encourage their use in the production of walling materials adaptive to our tropical conditions.

4. Reputable scholars from recognized Universities of Technology such as FUTA should be commissioned to conduct further in-depth investigation into the relevance of our locally available raw materials for walling purposes.

5. People should be re-orientated to develop objective social attitudes towards patronizing such locally produced walling and building materials.

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APPENDIX

Appendix A: Results of Compressive Strength Tests on Sawdust Concrete of 1:3: 6 Mix Ratio

CUBE REF NO	AGE OF CUBE (DAYS)	MASS OF CUBE (kg)	CRUSHING LOAD (Kn)	COMMPRESSIVE STRENGTH (N/mm^2)
X_1		6.50	94.7	4.22
X_2		6.70	93.3	4.16
X_3	10	6.65	94.0	4.19
X_4		6.30	99.4	4.43
X_5		6.30	107.2	4.78
X_1		6.45	129.2	5.76
X_2		6.60	132.1	5.89
X_3	15	6.60	127.6	5.09
X_4		6.30	128.5	5.73
X_5		6.35	135.0	6.02
X_1		6.20	198.3	8.44
X_2		5.90	206.2	9.27
X_3	25	6.30	186.0	8.36
X_4		6.30	221.2	9.94
X_5		6.00	227.4	10.22

TABLE 4.1

X_1
X_2
X_3 are identification numbers on each cube
X_4
X_5

Appendix B: Analysis of Variance for Changes in the Weight of Sawdust before and after Ignition

Summary

Groups	Count	Sum	Average	Variance
Initial Weight	5	100.341	20.0682	2.462829
Weight on Ignition	5	97.139	19.4278	1.929705

Anova

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.02528	1	1.02528	0.466829	0.513747	5.317645
Within Groups	17.57014	8	2.196267			

Appendix C: Analysis of Variance for Compressive Strength Tests on 30days Sawdust Concrete 1:3: 6 Mix Ratio

Summary	Count	Sum	Average	Variance
D_1	11	75.1	6.827273	0.104182
D_2	11	79.5	7.227273	0.198182
D_3	11	77.3	7.027273	0.064182
D_4	11	78.6	7.145455	0.080727
D_5	11	80.1	7.281818	0.099636
P_0	5	31.6	6.32	0.027
P_1	5	33.7	6.74	0.098
P_2	5	34.8	6.96	0.033
P_3	5	35.6	7.12	0.012
P_4	5	35.9	7.18	0.032
P_5	5	36.5	7.3	0.045
P_6	5	36.5	7.3	0.045
P_7	5	36.5	7.3	0.045
P_8	5	36.5	7.3	0.045
P_9	5	36.5	7.3	0.045
P_{10}	5	36.5	7.3	0.045

Anova

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1.440727	4	0.360182	32.21138	5.04E-12	2.605972
Columns	5.021819	10	0.502182	44.91057	1.38E-18	2.07725
Error	0.447273	40	0.011182			
Total	6.909818	54				

Appendix D: Analysis of Variance for the Particle size distribution of Cement, Slag and Sand

Summary	Count	Sum	Average	Variance
1	3	299.55	99.85	0.0675
0.8	3	299.05	99.68333	0.300833
0.63	3	298.47	99.49	0.5941
0.4	3	297.47	99.15667	1.817433
0.315	3	282.67	94.22333	75.06293
0.25	3	237.67	79.13667	334.1812
0.016	3	169.48	56.49333	1415.539
0.125	3	117.52	39.17333	2277.055
0.1	3	74.28	24.76	1064.115
Cement (%)	9	631.68	70.18667	1504.568
Slag (%)	9	855.35	95.03889	157.2916
Sand (%)	9	588.87	65.43	1654.542

Anova

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	20744.59	8	2593.073	7.169831	0.000444	2.591094
Columns	4550.835	2	2275.418	6.291516	0.00964	3.633716
Error	5786.631	16	361.6645			
Total	31082.05	26				

Appendix E: Physical Properties of Cement Slag and Sand

	Cement	Slag	Sand
Bulk Density	1.37	1.58	2.48
Moisture Content	0.18	0.72	0.17

	Cement	Slag	Sand
Bulk Density	1.37	1.58	2.48

	Cement	Slag	Sand
Moisture	0.18	0.72	0.17

Appendix F: Analysis of Variance for the Chemical Constituents of Cement and Slag

Summary

Groups	Count	Sum	Average	Variance
Cement	8	99.85	12.48125	470.7551
Slag	7	99.88	14.26857	118.5771

Annova

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11.9262	1	11.9262	0.038695	0.847096	4.667186
Within Groups	4006.748	13	308.2114			
Total	4018.674	14				

Appendix G: Mechanical Grading of Base Sand

Sieve size (μm)	Grain retained (gm)	(%) retained	Multilier	Produce	Cumulative (%)
3350	0.30	0.30	3	0.90	0.30
1700	2.41	2.41	6	14.46	2.71
850	4.56	4.56	15	68.40	7.27
425	8.20	8.20	25	205.00	15.47
250	55.62	55.62	45	2502.80	17.09
180	24.18	24.18	60	1450.80	95.27
125	4.43	4.43	81	358.83	99.70
45	0.16	0.16	164	26.24	99.86
45	0.14	0.14	275	38.50	100.00
	100.00	100.00		4666.00	

Appendix H: Chemical Constituents of Cement and Slag

Compound	Mass of Ordinary Portland cement (%)	Slag (%)
Lime CaO	64.02	34.01
Silica SiO_2	19.50	18.17
Iron Oxide Fe_2O_3	5.20	18.66
Alumina Al_2O_3	2.14	6.40
Magnesia MgO	1.40	13.55
Manganese Oxide MnO	0.50	2.18
Others (SO_3, Na_2O K_2O etc)	4.37	5.91

Appendix I: Result for Moisture Content of Sawdust Concrete of 2:3:6 Mix Ratio

Sample No	Initial Mass m_w (kg)	Mass on ignition m_d (kg)	Difference in mass (kg) $m_w - m_d$	% moisture content = $\frac{m_w - m_d \times 100}{m_d}$%
S_1	2.852	2.620	0.232	8.8
S_2	2.848	2.640	0.208	7.8
S_3	2.754	2.536	0..218	8.5
S_4	2.960	2.730	0.230	8.42
S_5	2.92	2.700	0.220	8.14

Appendix J: Results of Test on Moisture Content for Slag-Cement Concrete of 2:3:6 Mix Ratio

Sample No	Initial Mass m_w (kg)	Mass on ignition m_d (kg)	Difference in mass (kg) $m_w - m_d$	% moisture content = $\frac{m_w - m_d \times 100}{m_d}$%
D_1	4.04	3.82	0.22	5.7
D_2	4.10	3.84	0.26	6.7
D_3	4.16	3.88	0.28	7.2
D_4	4.16	3.88	0.28	7.2
D_5	4.06	3.82	0.24	6.2