THE SUITABILITY OF MAIZE COBS FOR THE PRODUCTION OF PARTICLE BOARD

By

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DECLARATION

I, Ibrahim K. Zubairu hereby declare that this Thesis has been prepared by me and is solely the record of my research work. That to the best of my knowledge, it has not been presented anywhere for any degree.

All literature cited are specifically acknowledged by means of references.

15th Oct. 1989
.....
Date

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Declarant

CERTIFICATION

This thesis entitled "THE SUITABILITY OF MAIZE COBS FOR THE PRODUCTION OF PARTICLE BOARD" by Ibrahim K. Zubairu meets the regulations governing the award of the degree of Master of Science (in Construction Technology) of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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Above all, I would like to say thanks be to Almighty Allah for his divine guidance.

ABSTRACT

A study was carried out to investigate the suitability of the maize cob (Zea mays) for particle board manufacture. The purpose was to examine general limits within which a satisfactory board can be made with this agricultural residue.

The maize cob was found to consist of pith, wood-blast and cortical layer or chaff.

Samples of particle board were produced from the maize cob collected from farms around Samaru Village. A liquid resin of "Gum Arabic" was used in six concentration levels: starting from 9, 10, 11, 12, 13 and 14 percent based on the oven-dry weight of maize cob particles. Some selected physical and mechanical properties of the boards were evaluated.

The results were compared with the data available from the present standards. All samples satisfied the standard requirements except for "water absorption" and "thickness swelling" tests. This may be due to non-addition of wax during the manufacturing process. It was generally observed from the results that the maize cob is a good material for particle board manufacture and its properties were consistently dependent on the resin concentration levels and density.

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ABBREVIATIONS

BS	=	British Standards
cm	=	Centimetre
FAO	=	Food and Agriculture Organisation
gm	=	gramme
i.e.	=	that is
Kg.	=	Kilogramme
KN	=	Kilo Newton
m	=	Metre
mm	=	millimetre
N	=	Newton
%	=	Percent
μm	=	Micro-metre
UN	=	United Nations
UNIDO	=	United Nations Industrial Development Organisation.
USA	=	United States of America
USSR	=	Union of Soviet Socialist Republics
$\therefore$	=	Therefore

GLOSSARIES

Additive: Any special material incorporated in a panel in the course of manufacture to impart special properties. The term includes preservatives and water repellents and fire retardants, but not binders.

Adhesive: A substance capable of holding materials together by surface attachment. The term is used to cover the bonding of sheet material and is synonymous with glue.

Binder: Organic bonding agent used to bind together the particles in a particle board.

Core: The centre layer in a panel (particle board).

Curing: The physical-chemical change brought about in thermosetting synthetic resins under the influence of heat and catalyst (polymerization)

Extruded Particle Board: Resin-bonded particle board manufacture by curing the resin in the particles while they are being forced through a die. A board manufactured with the applied pressure in the direction parallel to the plane of the sheet and in the direction of the length as extruded.

Glue: See Adhesive

Flat-Platen Pressed Board: Board pressed in a parallel platen hot press, usually of the multi-platen type. May be pressed in a continuous press. The applied pressure is perpendicular to the plane of the sheet.

Formation (Forming): The laying of the blended mass of particles to form a mat for particle board.

Hot Pressing: A process of pressing between hot platens of a press to form a panel (particle board).

Particle: Distinct fraction of wood or other ligno Cellulosic material produced mechanically for use as the aggregate for a particle board.

Particle Board Core Stock: Common name given to particle board manufactured for use as core stock for veneered or other covered products.

Resin Blending: The application of the binder to the particles and other components, if any (i.e., mixing them together).

Resin Content: The amount of dry solids in the resin, related to the dry weight of the finished board.

Three-Layer Particle Board: A particle board produced with different quality particles for the faces and core.

Veneer: A thin layer or sheet of wood of Uniform thickness, rotary cut, sliced or sawn for use in ply-wood, laminated construction, furniture, veneer container, etc. The word is also used as a verb meaning to overlay with veneer.

CHAPTER - ONE

I N T R O D U C T I O N

1.1 BACKGROUND

When a visit is made to any of maize producing areas of this country, heaps of maize cobs are very likely to be seen. These maize cobs constitute a great disposal problem. Good agricultural practice recommended getting rid of these materials before next planting season in order to avoid crops infection. At moment, the only means of disposing these cobs is by burning. This serves no economic benefit particularly to the farmer and the nation as a whole. It was against this background that the author was stimulated to put this material to serve a useful purpose, instead of disposing it as a garbage.

1.2 NEED FOR THE RESEARCH

The pattern of the available raw material for particle board, and, in fact all forest products is changing. The softwoods (canifers) which have been the preferred species in the particle board manufacture are becoming scarce. Competition for the use of timbers by plywood, fibre board, pulp

and paper industries have resulted in higher costs for the raw materials. These considerations have led to the utilization of wood wastes and some agricultural residues. For example, report by the UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION (UNIDO, 1972) indicates that much research has been carried out on the use of bagasse (fibrous residues from sugar cane) in particle board manufacture and is now employed in commercial production in some part of the world.

The research for cheaper and readily available raw material is an accelerating process. It is in this direction that maize cobs are studied as a potential raw material for particle board manufacture. Large quantities of this material is available in each of the maize producing areas of this country. As mentioned previously, it serves no useful purpose. But if it could be utilized for something beneficial (as in board manufacturing), it would no longer be called agricultural wastes but a useful raw material for board industry. The economic gains so derived will benefit the farmer in particular and the country at large. For this reason, investigation was carried out to determine the suitability of maize cobs for particle board production.

1.3 OBJECTIVES

The purpose of this research work is to:

i. investigate the suitability of maize cobs in the production of particle board using standard process;

ii. produce samples of particle board from maize cobs if found suitable and compare their properties with standards;

iii. identify the possible areas of application of these boards in the light of the results obtained.

1.4 SCOPE AND LIMITATIONS

A research of this type is generally bound to have a wide scope. This is because a new material is being proposed for use in a manufacturing process. Therefore, extensive tests are required if only to prove the economic viability of the material.

Of all the properties of the material and the board made from it, only the basic ones were determined. The properties of material determined were: density, absorption, moisture content and specific gravity. The material was then used to produce boards. Properties specified in the

British Standards (BS 2604 and BS 1142) were determined. Properties like acoustic, thermal conductivity, etc., were not evaluated. This was mainly due to equipment constraints.

1.5 METHODOLOGY

The research work was started by collecting the maize cobs from the local farmers around Samaru Village. The physical and chemical characteristics of the maize cobs were studied in order to determine its suitability.

Having established the suitability of maize cobs, the cobs were then reduced into particles with a pestle and mortar. Particles that were retained on 600 micron and 300 micron laboratory sieves were used. The material was washed, cooked and dried from between 180 and 220 per cent moisture content (m.c.) to an average moisture content of about 4.5 per cent. The study was designed to produce boards using different resin concentration levels based on the oven dry weight of the maize cob furnish. Lumps of Gum arabic was ground into powder and mixed in the laboratory into liquid resin which was used as adhesive binder.

The liquid resin and maize cob were blended. This was then manually formed into a mat inside a 200mm x 200mm forming mould with a steel plate placed at the bottom. After pre-pressing with a wooden block the forming mould was removed and another steel plate was placed on top of the formed mat. The entire mat was later transferred to the pre-heated laboratory hot press. The hot press was a manually operated hydraulic press with electrically heated platen, capable of producing the pressure of about 4.905 N/mm over the 200mm x 200mm mat surface. Press temperature was between 120°C and 145°C while press time ranged from 15 to 30 minutes. Board thickness was varied.

Sample boards were produced for each category of resin concentration. The edges of each produced sample board were trimmed after cooling. Each experimental board was later cut into the test specimens. The physical and mechanical properties evaluated were: bending, tensile, compression, nail resistance, screw-holding, density, surface soundness, deflection, water absorption, thickness swelling and moisture content. Before the testing, the test specimens were conditioned (for 7 days) in the testing room to ensure that the specimens

attained equilibrium moisture content at the time of the test. The testing room condition was at a temperature of about 24°C and the relative humidity was 60 - 65 Per cent. The tests were conducted in accordance with the British Standards (BS 1811 and BS 1142).

CHAPTER - TWO

REVIEW OF LITERATURE

2.1 BOARDS - GENERAL

In order to enable objective assessment of the properties and quality of particle board produced from maize cobs, it is necessary te review the characteristics of its allied products.

Boards are termed as wood-based panel products. This term broadly covers three materials; ply-wood (including block-board and lamin-board), fibre building board and particle board.

Ply-wood is made from thin sheets of wood called veneer. The sheets are glued together under pressure so that the grain of the central veneer runs at right angles to that of the outer sheets. Two, three, five, seven or more veneers may be used and there is a wide variety of ply-woods available, differing in thicknesses, in strength, in durability and in appearance. Ply-wood is used in areas where strength and lightness is of primary importance.

Associated with ply-wood are block-board and lamin-board. They are manufactured by the same mills but construction differs. Block-board and lamin-board differ from ply-wood in that their centres or cores are composed of strips of soft wood up to 25mm thick which are glued together. These materials compete greatly with particle board.

Commercially, ply-wood is obtained in thicknesses ranging from 3mm - 25mm but this range can be extended for special end-uses. The major producing countries include Europe, the United States, Soviet Union, the United Kingdom, Nigeria and Gabon (Leigh, 1980).

Fibre building boards on the other hand are made from wood fibres (i.e., wood pulp). Most fibre boards are made without any additional bonding material since wood fibres are self adhesives. There are two main types of fibre boards, namely: hard-board and soft-board (insulation board).

Insulation board is soft and porous and has relatively little strength. It is predominantly used for its excellent insulating and acoustic properties and it is an ideal inexpensive building

board. It is obtainable in a variety of thicknesses from 9mm up to 25mm.

Hard-board is the most versatile of all the fibre-boards. It is classified according to density as "standard", "medium" and "tempered". Thickness ranges from 2mm to a maximum of 12mm. Hard-board is heavier than ply-wood but, where lightness is not a pre-requisite, its cheapness and the ease with which it takes surface finishes give it many advantages. It is used in furniture making and in building construction.

The major production areas of fibre-boards include; Europe, America, Australia and South Africa (Flemmich, 1959).

2.2 PARTICLE-BOARD

Particle board production was started before 1940 according to Akers (1966). It is therefore, important to start this research work by defining and introducing the particle board.

2.2.1 Definition

Particle board is defined by BS 2604: Part 2, 1970 as "Panel material manufactured under pressure essentially from particles of wood

and/or other ligno-cellulosic fibrous materials (for example wood chips, saw-dust, flax shives, etc.), with or without the addition of an adhesive, hydraulic binders being excluded". It is usually flat-pressed or extruded. It is manufactured in a wide range of densities but, greater part of present production is of density between 480 kg/m^3 and 800 kg/m^3, and is principally used in the manufacture of furnitures and in building industry. Thickness ranges from 2mm up to 30mm.

At present, it is made principally from wood chips, but work is underway in many research centres for the use of cheaper raw materials (Brinkmann, 1979).

2.2.2 Basic Processes in the Manufacture of Particle Board

Two main methods of particle board manufacture are available as ealier mentioned. These are flat platen presses and extrusion. The former is more common and usually involves batch or continuous pressing. The extrusion processes are continuous throughout. For both types of process, the raw material is fed to cutters or shaving machines which produce the particles (splinters or shavings). The particles are

screened, cooked and then dried to a controlled moisture content (5-6 Per cent) before being sprayed with 4 - 15 Per cent resin solution (Flemmich, 1959). Wax may be added to meet water soak requirements.

In flat platen press method, the particles are next spread out on trays to a pre-determined thickness. The trays are then placed in hot pressed and subjected to a carefully controlled pressing schedule of 1.4 - 2.4 N/mm^2 at 100^oC to 140^oC in about 15 minutes. In continuous press method, the particles are spread continuously on to a moving belt which passes through a pre-heater and then through the electrically heated press.

In the extrusion method, the particles are forced through a horizontal or vertical heated extrusion die from which a continuous length of board emerges. This is carefully led onto horizontal table where it is cut to standard lengths. Extruded are always veneered before sale.

After both types of process the boards are trimmed to exact size, conditioned for about a day and crated for shipment.

2.2.3 Origin and Development of Particle Board Plants

Report by the Food and Agriculture Organisation (FAO, 1958) of the United Nations (UN) indicates that some experimental works on particle board production was carried out in both North America and Europe before 1940. But the first commercial plant started in Germany in 1941 and by 1949 the extrusion process was developed. Notable developments were reported by Redmond (1969) in United Kingdom (UK) and in Switzerland where the first three layer board was marketed in 1945.

During the period from 1940 - 1946, the possibility of using some agricultural residues had been explored, and the first plant based on flax shives was put into operation in Belgium in 1947. So particle board really belongs to the post-war years and its development and utilization have been both rapid and widespread throughout the world. It is also known as chip board and flake-board.

World production of particle board between 1966 and 1977 rose from 11 million cubic metres to 37 million cubic metres (Leigh, 1980). The major producing areas include Europe, America, Belgium, Germany, Soviet Union, France and Italy.

2.2.4 Types of Particle Board

Ariba (1970) describes particle board types based on the technique of manufacture as platen-pressed or extruded. The two techniques are described in Section 2.2.2.above.

2.2.5 Classification and Uses of Particle Board

Particle boards are broadly classified by international usage, into three basic classes (or types), according to density. The classification by some sources is as in table 2.1 below.

Generally, particle boards are used in two main areas building and furniture industries.

In building industry, particle board is used as a flooring material either on joist or on a solid sub-floors, roof decking and as a dry wall partitioning and ceiling linings. In concrete form-work linings, the board is normally sealed against water absorption.

In furniture industry, the board is faced with decorative wood veneers or plastic facings to provide panels of strength, stifness and, above all dimensional stability. It is used as core

TABLE - 2.1: Particle-Board Classification

Type of Board	Low Density	Medium Density	High Density	Source
Density (Kg/m^3)	300 - 400	400 - 800	800 - 1200	FAO (1958)
	Less Than 480	480 - 640	640 - 800	Ariba (1970)
	Less Than 480	480 - 800	Greater Than 800	BS 2604: Part 2, 1970

stock for desk tops, drawers fronts, bed rails and shelves.

2.2.6 Advantage and Disadvantage of Particle Board

Particle board has some economic advantages over other wood based panels. Report by (Food and Agriculture Organisation, 1958) indicates that it is cheaper to build a particle board mill than a fibre board or plywood mill. It has been used in preference to other materials for sliding doors in closets and ward-robes because it is less affected by humidity changes. Delamination does not occur in particle board but plywood delaminates when in use. Particle board is also superior to other panel materials in machinability, screw holding, gluing properties and dimentional stability (Leigh, 1980).

The disadvantage of particle board is that it is not suitable for outside applications exposed to sun and rain. If particle board is applied to such area without a plastic covering, surface distortion will occur.

2.3 THE MAIZE PLANT

Maize which is also called Indian corn is one of the main subsistence crops cultivated by man. It originated in the American continent and was first introduced to West Africa by the Portuguese in the sixteenth century (Irvine, 1974). The plant grows in the temperate, tropical and sub-tropical regions of the world. It is an errect annual plant with fibrons roots, large stalk, long arching leaves with evenly ruffled edges and big seed. The corn seed grows in concentric rows around a cylindrical cob forming the "ear". The cob is about 15 - 20 cm long and 2.5 cm in diameter. It is covered by several leaf-like husks which are heavier and tougher than the leaves (see Plate - I).

Botanically, maize belongs to the Graminae family which has only one species, Zea mays. There are many different varieties that grow up to a height of 3 metre. But cultivated maize normally grows to 1.5 - 2.5 metre (Mantell, 1975). The plant grows in most soils except pure clay or sand. It requires an annual rainfall of 750 to 1500mm, of which 375 to 500mm is enough, provided it is evenly distributed over the growing season.



PLATE - I: Maize Plant

It will not grow well in areas with excessive rainfall: 2500 to 50,000mm or more (Irvine, 1974).

Maize is primarily grown for its seeds. The stalk has been used in making paper, building boards and other products before Nineteenth Century (according to Mantell, 1975). The seeds have been used for human food and live stock feed. The yield of maize per hectre is about 250 kg., on average, but the yield may be up to 425 Kg/hectre (Live-stock Feeds, 1986).

2.3.1 Maize Production in Nigeria

Corn is a cereal crop in Nigeria. It is second in importance to Sorghum. Production is however, increasing at much wider areas as many more people prefer it to Sorghum. It gives a greater yield per hectare. Live-stock feed producers also use a lot of maize, hence increasing demand for the crops. It is grown in almost every part of Nigeria. This range from the forest zones in the South where it can be cultivated twice in the year to the Savannah Zone where it is believed to have the greatest production potentials with less diseases and pests.

Other areas will require better management and facilities for good cropping.

The crop could be harvested and cooked as a vegetable or roasted when green but mature. It could also be processed when dried into flour used for many dishes in Nigerian houses. It can be used both locally and industrially for alcohol production. The yield of maize in Nigeria is about 2.5 million tonnes annually (Live-stock Feed, 1986). Major problems associated with corn production in Nigeria include weed, pest and disease.

2.3.2 Uses of Maize

Maize is used for three main purposes;

i. **As a Human Food**

Maize is processed in many forms, from primitive trampling and grinding (or boiling) to the modern maize mill. It is roasted (corn-on-the-cob) and eaten by most African people. Modern human food made from maize include hominy grits, corn flakes, malt syrup, corn sugar, corn oil, corn bread and other bakery products. It is also used in alcohol production.

The protein in maize (Zein) is used in producing synthetic fibre which is reportedly comparable in quality with other protein fibres (Miracle, 1966).

Maize is used extensively for the production of alcohols. Whiskey, ethyl, butyl and acetone are also derived from maize.

Report by Boyd and Brevik (1952) indicates that concrete made from corn cob fragments, sand and cement may be successfully used for farm building construction. The high moisture absorption of such concrete necessitates some method of water proofing the wall surfaces. The cobs are also used for a cork substitute, fuel furfural, pipe bowls, xylose and many other products.

Corn stalks or leaves have been used for manufacturing paper, paper board and wall board.

2.4 THE MAIZE COBS

Maize cobs which are now the area of interest in this research, are part of the maize plant. The maize grain is arranged around the outside of

the cob. The cobs of the common varieties of maize generally are 17 - 20 cm long and 2 - 4 cm in diameter at the butt (Mantell, 1975). The cob tappers to about 2 cm near the opposite end (see Plate - II).

The cobs consist of three main portions; Cortical layer, Wood blast and Pith.

(a) The Cortical Layer

This is the outer layers of the cob on which corn grains are arranged. It consists of fine and coarse chaff. It is yellowish in colour and is good for making fibres.

(b) The Wood-Blast

This is the main part of the cob. It is a hard tough woody layer surrounding a centre of pith. It is good for board making. Its proportion increases from top to the bottom.

(c) The Pith

This is the central portion of the cob. It composed of soft tissues. It easily becomes powdered during grinding process.

The physical and chemical composition of the cob, by weight, is given by Mantell (1975) in table 2.2 and table 2.3 respectively.



PLATE - II: Maize Cobs

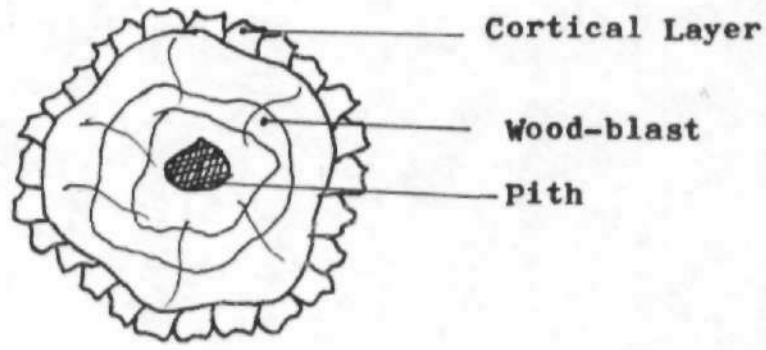


FIGURE - 2.1: Cross-section of Maize Cob

TABLE - 2.2: Physical Composition of the Maize Cob

Pait	Average %
Cortical Layer	24.97
Wood-blast	73.36
Pith	1.67
Total	100.00

TABLE - 2.3: Chemical Composition of Maize Cob

Constituent	Average (%)
Ash	3.2
Pentosan	20.6
Lignin	31.2
Cellulose	45.0

In addition to these compesitions, the following physical properties of the maize cob particles were also determined in the laboratory as follows:

i. Specific Gravity

This was done according to BS 812, Part 2. A quantity of the maize cob particles retained on 600 μm and 300 μm sieves (250gm) was weighed. The sample was immersed in water for 24 hours, the weight of this wet sample was determined by weighing under water with the aid of a pycnometer. The maize cob sample was then surface dried by spreading it on a metallic sheet and gently blowing air from a ceiling fan. The weight of the saturated surface dry sample was determined. This was then dried for 24 hours in an oven at 100°C to 110°C, cooled and re-weighed.

Calculations

Let weight of maize cob in its natural state = a

Weight of saturated surface dry sample = b

weight of pycnometer full of water = c

weight pycnometer containing both water and maize cob = d

weight of water displaced = (b + c) - d

weight of oven-dry sample = e

$$\therefore \text{ specific gravity, } g = \frac{e}{(b + c) - d}$$

for the maize cob sample;

a = 250gm

b = 587.5gm

c = 1660gm

d = 1632.5gm

e = 239.24gm

$$\text{specific gravity, } g = \frac{e}{(b + c) - d}$$

$$= \frac{239.24}{(587.5 + 1660) - 1632.5}$$

$$= 0.389$$

ii. <u>Moisture Properties of Maize Cob Particles</u>

The water absorption capacity and moisture content of maize cob particles were determined using the results obtained for the specific gravity calculations as follows:

$$\text{Water Absorption, } A = \frac{b - a}{a} \times 100\%$$

$$= \frac{587.5 - 250.0}{250.0} \times 100\%$$

$$= 135\%$$

$$\text{Moisture Content, } M_c = \frac{a - e}{e} \times 100\%$$

$$= \frac{250.0 - 239.24}{239.24} \times 100\%$$

$$= 4.5\%$$

iii. Density

The density of a material is defined as the weight of material held by a container of unit volume when filled and compacted under a defined condition.

For the maize cob particles, the density was determined using a cylindrical container of 150mm diameter and 300mm depth. The container was weighed and then filled with the material in three equal layers. Each of the layer was tamped with 25 strokes of a 20mm diameter standard rammer, the top was levelled off and the weight of the compacted maize cob determined.

Calculations:

Let W_1 = weight of container

W_2 = weight of container plus maize cob

W_3 = weight of maize cob

V = volume of container

$\therefore$ Density, $= \frac{W_3}{V}$

For the maize cob sample,

$W_1 = 28.60$ Kg

$W_2 = 29.92$ Kg

$W_3 = W_2 - W_1 = 1.32$ Kg

$V = \frac{D^2H}{4}$

$= \frac{22}{7} \times (0.15)^2 \times 0.3$

$= 5.30 \times 10^{-3}$ m^3

$\therefore$ Density, $= \frac{W_3}{V}$

$= \frac{1.32}{5.30 \times 10^{-3}}$

$= 2.49$ Kg/m^3 or 0.249 g/cm^3

The average results of these properties are given in table 2.4 below:

TABLE - 2.4: Physical Properties of Maize Cob

Property	Average Value
Specific Gravity, g	0.389
Density, g/cm^3	0.250
Absorption, %	135
Moisture Content, %	4.5

2.4.1 Suitability of the Maize Cobs in Board Production

The suitability of the raw material to be used in particle board production is of paramount importance. In fact, it is one of the main aim of this thesis. A knowledge of physical and chemical characteristics is therefore, needful. This will assist in knowing the constituents of the raw material and the extent to which it can be used for the intended purpose. For these reasons, the physical and chemical compositions of the maize cob particles were studied. Although the values given in the table 2.2 and 2.3 were not determined by the author for local cobs. The differences in their quantitative constituents would not be significant since they are components of the same agricultural products. The figures can therefore, be taken as the

representative for the maize cobs used in this research.

The results of tests illustrated in table 2.4 show that the density of the maize cob samples is lower than the minimum of 0.40 Kg/m^3 specified by (Food and Agricultural Organisation, 1963) for most wood species. This may lead to a better product since according to Hse (1975) the lower the density of board material the higher the quality of the board. The moisture content (M_c) of the maize cob particles of 4.5 percent is satisfactory since the M_c of board making material ranged from 5 to 12 percent (BS 2604, 1970).

The specific gravity for the cobs is 0.389 as compared to 0.31 to 0.88 for most wood species (Kubler, 1980). Thus, it is within the range for the species used in particle board manufacture. The absorption capacity of the maize cob is relatively high. This is because of many pores in it.

The principal chemical constituents of the maize cobs are cellulose, pentosans and lignin (table 2.3). These are mainly from the wood

blast and cortical layers of the cob. Cellulose and lignin are usually good for board manufacture (Leigh, 1980). The absence of acid and extractive content shows that the board properties may not be affected. These contents according to Foster (1967) affect the board quality. It was therefore, assumed tentatively that maize cobs might be a suitable raw material for particle board manufacture. The cobs are then used to produce particle board samples. The various production processes involved are out-lined in the preceeding chapter.

The pentosan content of 20.6 percent shows that the maize cobs could be used in the manufacture of furfurals and other products (Mantell, 1975).

CHAPTER - THREE

LABORATORY PRODUCTION AND TESTING OF SPECIMENS

3.1 PROCESS AND EQUIPMENT

The maize cobs used for the manufacture of particle board were collected from farms around Samaru Village. The production of the board was done by the following steps listed below;

i. Grinding
ii. Sieving
iii. Washing
iv. Cooking
v. Drying
vi. Resin Blending
vii. Mat Forming
viii. Pressing
ix. Conditioning and Trimming

3.1.1 Grinding and Sieving

The process of manufacture begins with the grinding of maize cobs. This was done manually by employing a mortar and pestle. The maize cobs were pounded until visually observed that finer particles are attained.

In order to have a knowledge of the sizes of the particles produced, a sieve analysis was carried out as described in BS 812, Part I. This was done by passing 5.0 Kg of the grounded particles through 2.36 mm, 1.18 mm, 600 m, 300 m and 150 m sieve sizes. The sieves were shaken manually. The result obtained is as follows:

TABLE - 3.1: Sieve Analysis for the Ground Maize Cob Particles

Total Weight Sieved = 5 Kg.

BS Sieve Sizes	Weight Retained (Kg)	Percentage Retained (%)	Percentage Passing (%)
2.36 mm	2.288	45.76	54.24
1.18 mm	1.021	20.41	33.83
600 micron	0.541	10.82	23.01
300 micron	0.778	15.56	7.45
150 micron	0.241	4.83	2.62
Pan	0.130	2.61	0.01
Total	4.999	99.99	

The particles used were those retained on 600 micron and 300 micron sieves. The standard size (according to Chittenden, et al. 1972) ranges from 600 micron - 1.18 mm. The particles

retained on 150 micron and pan were mainly pith and fines. These are not good for particle board manufacture. Those retained on 1.18 mm and 2.36 mm sieves were re-pounded for more finer particles. The sieves were shown in Plate III.

3.1.2 Washing, Cooking and Drying

The particles were submerged in container half full of water for about 15 minutes to remove dust, sand particles and other foreign products. After submerging the particles, those which sank to the bottom of the container were rejected. The floating particles were collected for use. The submerging also increased the moisture content of the particles from the initial 4.5 percent (oven-dry bases) to more than 100 per cent.

After the washing process is completed, the particles were cooked for 2 - 3 hours. The cooking was done in head pan containing some quantity of water using a portable gas cooker (Plate IV). The essence of cooking process is to softened the particles. Also by this cooking process, complete mechanical disintegration of the material is achieved.

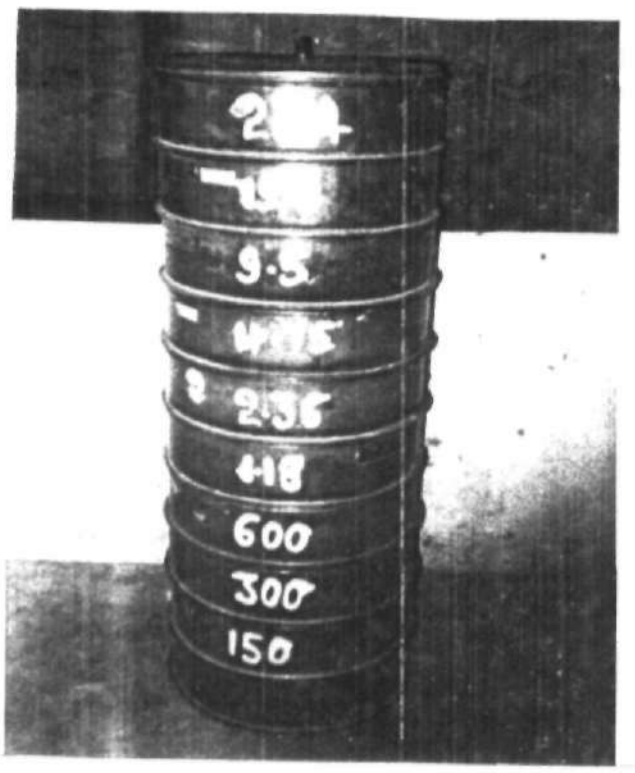


PLATE - III: Laboratory Sieves

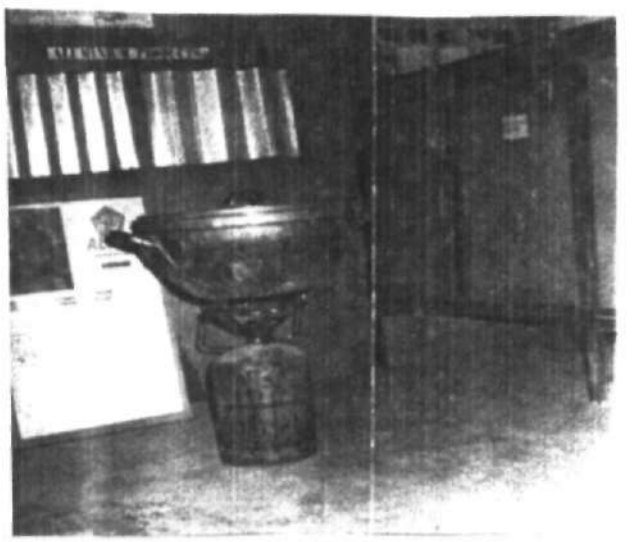


PLATE - IV: Cooking Equipments

On completing the cooking process, the whole content of the cooking basin was emptied into a sieve to remove the excess of hot water. The particles obtained were found to have a moisture content of well over 100 percent. (oven-dry basis). The wet particles were spread on a metal sheet and dried for 24 hours to a residual moisture content of about 4 - 10 per cent (oven-dry basis).

3.1.3 Resin, Resin Preparation and Blending

For this research work, Gum Arabic was used as resin. It is an adhesive substance derived as exudes from the back of Acacia tree. Acacia tree is commonly found in Maiduguri and Sokoto areas of Northern part of this country. It is a small thorny tree of height up to 7.6 metre. It has a feathery leaves and white flowers. The Gum Arabic is produced commercially by making an incision in the back of the tree. The gum exudes slowly in places along the wound and eventually dries into small lumps. The lumps are usually transparent, yellowish, pinkish, amber or almost colourless each about the size of walnut. These lumps called "tears" are collected, bleached in the sun and shipped

to all parts of the world. The collection is repeated throughout the year.

Chemically, the gum composed of complex compounds derived from carbohydrates. Specifically, the compounds are the neutral salts, either potassium, magnesium or calcium of acidic polysaccharides. The acidity of which is due to Uronic acid in their structure. The gum is soluble in water and is used in many products, including machines (as an emulsifier and demulcent), confectionery, cosmetics, textiles, paper, water colours, pastes and polishes, ice cream and salad dressing. (Britanica, 1975).

The initial stage of preparing the resin is the grinding of the gum (by using pestle and mortar) to a very fine powder. The reason for the grinding is to prevent lumping in the mixture. The ground powdered gum was sieved with a sieve having an aperture of 300 micron to get the fine powder. This was then added to a container of clean water. The mixture was warmed for about 10 minutes to facilitate dispersion of the gum. The composition (by weight) of the liquid resin is given as follows;

Gum Arabic Powder - 40 Percent

Water - 60 "

The resin prepared was immediately used in order to avoid possible contamination if kept for some time.

Blending of the resin and maize cob particles was done with the aid of a compressed air sprayer. A weighed quantity of the maize cob particles was placed in a partly covered container (head pan). The jet of the compressed air - resin was directed towards it. The sprayer gun was held very close to the head pan in order to minimize lost of resin to the atmosphere. To achieve uniform blending, it was necessary to agitate the particles. This was done manually and also by the action of the air pressure from the sprayer.

3.1.4 Mat Forming

The forming mould was produced in the workshop. It consists of a square wooden box (200mm x 200mm x 50mm) and two stainless steel plates (225mm x 225mm). To produce the mat, a steel plate is positioned on a horizontal surface and the wooden box placed on it. A sheet of

spreaded
aluminium foil was then/in the box (to act as non-stick surface) and "the resin blended particles" were put inside in an even pattern. After filling the mould, it is levelled with a straight edge. The particles were then slightly compacted by tapping with a wooden block to aid box removal. When the box was removed another aluminium foil was placed on top of the mould and the second plate placed ready for pressing.

3.1.5 Pressing

The press used in this research work is a hydraulic pressing machine (Plate V). This machine is fitted with a temperature and pressure indicating devices and a timer. It has the following specifications:

Temperature Limit	- 200 - 300^{o}C
Maximum Pressure	- 4.905 N/mm^{2}
Voltage	- 230 - 240 V at 50 Hz
Plate Size	- 200mm x 200mm

The pressing process is of two stages: Pre-pressing and Final pressing.

In pre-pressing, the machine plates were heated to a temperature of 80 - 90^{o}C before the mat was introduced and pressed to a pressure lower than



PLATE - V: Hydraulic Pressing Machine

that required for the final pressing. The pressed mat was allowed to stay at this temperature and pressure for about one minute after which the pressure was released. This pre-pressing was necessary in order to remove the trapped gases and steam.

In the final pressing, the pre-pressed mat was removed and the temperature of the machine plates raised to between 110 - 140^{o}C. This heat is necessary for curing resins in the mat. The pre-pressed mat was re-introduced into the press and pressed steadily to the required pressure. The pressed mat was left in the press at the same temperature and pressure for a certain specified time. The temperature was then allowed to drop steadily for another specified time after which the board formed was removed from the press for conditioning.

3.1.6 Conditioning

The process of conditioning involves keeping the board produced in a cool place for about 24 hours. The board was then trimmed and conditioned in the same cool place for seven days before any test was carried out. The

purpose for this process is to equalize the moisture content throughout the board and thus minimizing warpage that might otherwise occur.

The following factors affecting the properties of the produced board were varied in order to determine their influence on its properties; resin content, forming pressure, temperature and pressing time. The data of the produced samples are presented in Table 3.2 below.

TABLE - 3.2; Board Production Data

Board Number	Pressure (N/mm^2)	Press Temperature (^oC)	Press Time (Minutes)	Board Density (Kg/m^3)
1.	2.25	125	20	550
2.	2.25	120	20	600
3.	2.25	125	15	630
4.	2.25	125	23	670
5.	2.25	130	20	710
6.	2.75	130	20	750
7.	2.75	125	25	790
8.	3.00	135	20	830
9.	3.00	135	26	870
10.	3.50	140	25	900
11.	3.50	145	30	950

3.1.7 Process Flow Chart

The experimental boards were produced as discussed earlier and as presented with the simplified flow chart in Figure 3.1. The boards were subjected to some tests for the evaluation of their physical and mechanical properties in use as an engineering material. The tests and test procedures carried out are out-lined in the following section.

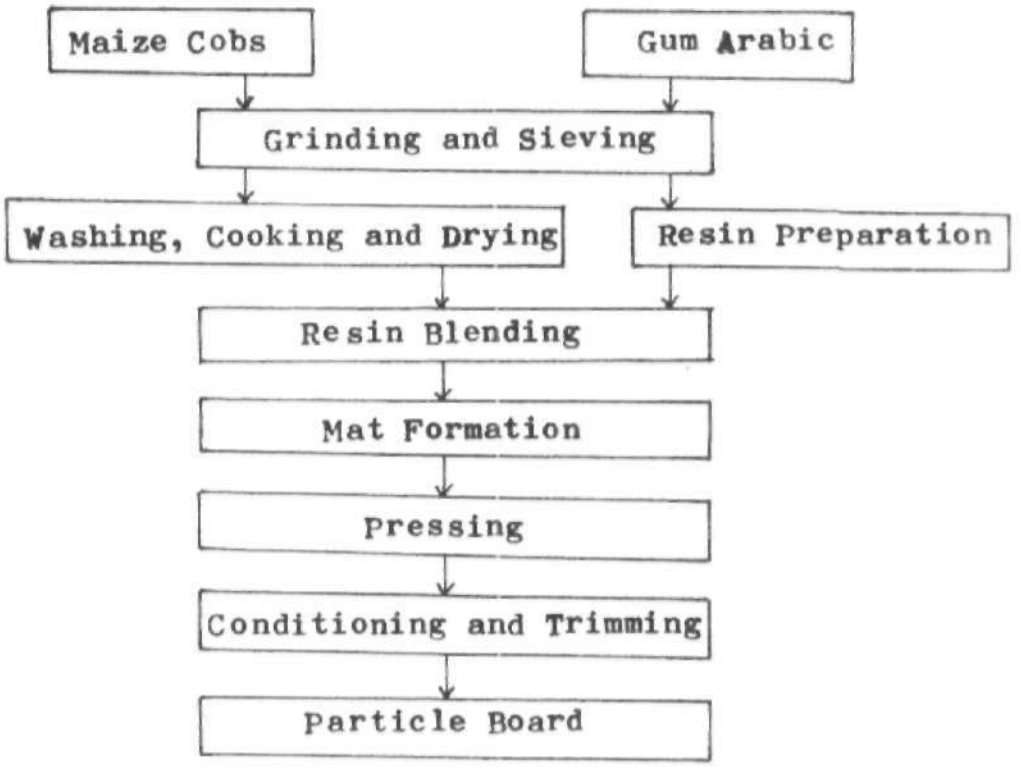


Figure - 3.1: A Simplified Flow-Chart of the Laboratory Production of Particle Board from Maize Cobs

3.2 TESTS OF THE SPECIMENS

In order to determine the suitability of the particle board produced from maize cobs, in use as engineering material, the products had to be tested for the accurate evaluation of their physical and mechanical properties. The tests carried out were basically of the destructive nature.

The tests and test procedures carried out are briefly described below. These tests were carried out in accordance with the procedures specified in BS 1811, Part 2, 1969 (methods of test for wood chip-boards and other particle boards) and BS 1142, Part 1, 1972 (methods of tests for fibre boards). The test results are tabulated and are shown photographically in plates. Sample calculations for all tests are presented in Appendix - I.

3.2.1 Determination of Density

The dimensions of each test specimen were taken at four different points and the average (mean) obtained in each case as the agreed dimension of the specimen. A pair of callipers was used for the

measurement. Each test specimen was weighed to an accuracy of 0.01 gm. The volume of the specimen was calculated to the nearest 100 cm^3 as recommended in the standards.

The average density of each specimen was calculated to the nearest 10 Kg/m^3 as follows:

$$= M/V$$

where, = Density in Kg/m^3

M = Mass in Kg of the test specimen

V = Volume in m^3 of the test specimen

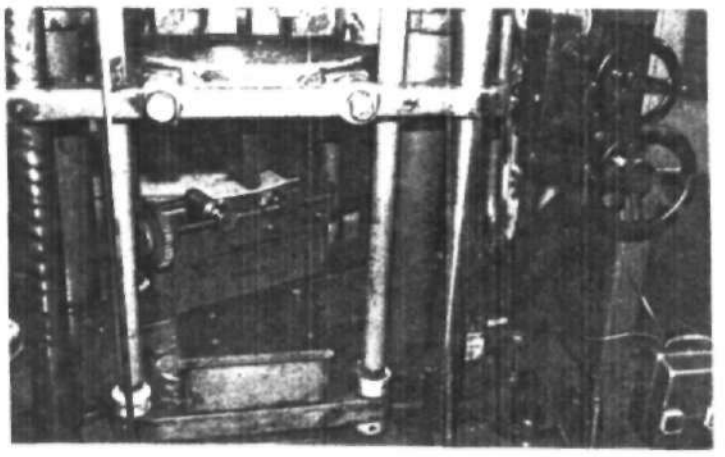
The test results are presented in table 3.2.

3.2.2 Bending Strength (Modulus of Rupture) Test

Three specimens of 180mm x 45mm x t mm. from each sample were tested on rollers of 85mm x 20mm diameter. The rollers were kept at 152.5mm apart and load applied at the centre by the Denison Machine (see Figure 3.2 and Plate VI). The speed of tests on this machine was 2mm per minute. The results were obtained using the following formula given by the standard.

$$S = \frac{3Pd}{2bt^2}$$

where, S = Bending Strength in N/mm^2



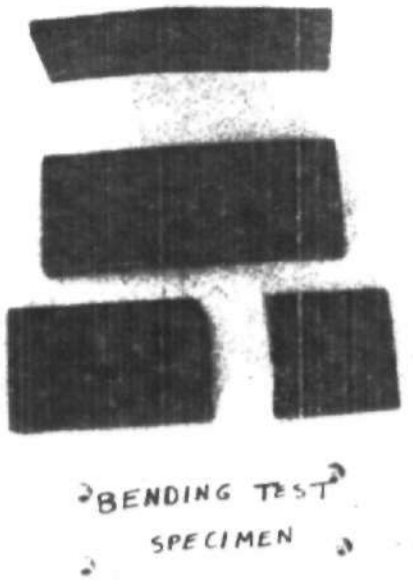


PLATE - VI: Bending Test

P = Load at rupture in newtons (N)

= Distance between support in millimetres (mm)

b = Width of the test specimen in millimetres (mm)

t = Thickness of the test specimen in millimetres (mm)

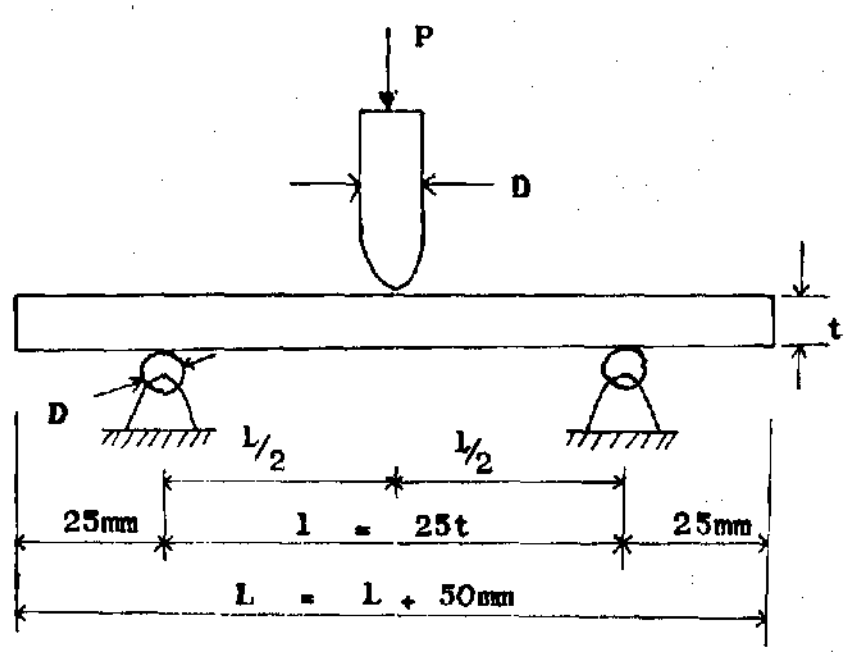


FIGURE - 3.2; Bending Strength Apparatus

3.2.3 Tensile Strength Parallel to Surface Test

Three specimens from each sample were tested for tensile strength test.

The effective dimensions of each specimen were 34mm x t(mm) and the lengths were 184mm. The test was performed on Denison Testing machine

(see Plate VII). The tensile strength was calculated by using the following formula:

$$T = \frac{P}{A}$$

where, T = Tensile strength in N/mm^2

P = Maximum Load in newtons (N)

A = Cross-sectional area (mm^2)

3.2.4 Tensile Strength Perpendicular to the Surface Test

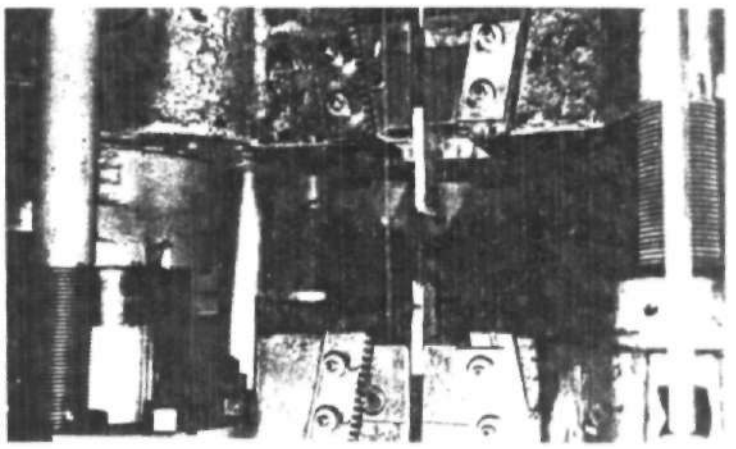
Specimens used here were of side 35mm x 35mm glued between two wooden pieces of slightly higher dimensions.

A 40mm wood screws were used as fixture for applying the load using Denison Testing machine until the board fractured at about the middle. The tensile strength perpendicular to the surface was calculated using the same formula presented above.

3.2.5 Compressive Strength Test

This test was made on specimens with the load applied parallel and perpendicular to the long dimension of the board. The dimensions relatively were;

Thickness - t (mm)



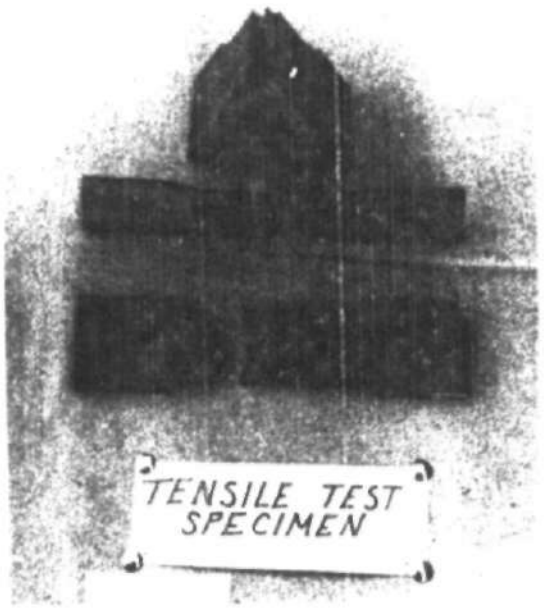


PLATE - VII: Tensile Test

Width - t (mm)

Length - 4t (mm)

Load was applied using the Denison Testing machine.

The compressive strength was obtained by using the following formula:

$$C = \frac{P}{A}$$

where, C = Compressive Strength (N/mm^2)

P = Rupture Load (N)

A = Cross-sectional Area (mm^2)

3.2.6 Nail Resistance Test

The nail resistance test was done for both parallel and perpendicular direction (with reference to the long dimension). With the Denison Testing Machine, the load required to push the nail through the test specimen, for the push through test or to pull the nail out, (in the case of the lateral nail withdrawal test) was applied. The diameter and length of the nail used are 2.78mm and 48mm respectively.

3.2.7 Screw Withdrawal Test

To perform this test, specimens (35mm x 35mm) were prepared. In each specimen, a 40mm

Number 6 wood screw was threaded into a pre pre-bored hole (1.6mm diameter and about 4mm deep) at the mid-point of the specimen. Care was taken to ensure that the nail is perpendicular to the board's face.

The axial load required to withdraw the screw was obtained from the Denison Testing Machine.

3.2.8 Surface Soundness

Soundness of the surface of a particle board is the force that will tear-off the surface layer. To measure this force, a board piece of 30mm x 30mm was glued between two wood pieces of sides 50mm x 50mm (see Plate VIII). Load was applied just as in the case of perpendicular tensile strength test.

Here, fracture took place at the surface of the board unlike in the tension case where fracture was at the centre.

3.2.9 Water Absorption and Thickness Swelling Tests

All boards produced in this research work had no water repellents added. The test specimens were square (100mm x 100mm) (see Plate IX). Three specimens from each board were used. The steps in this test were;

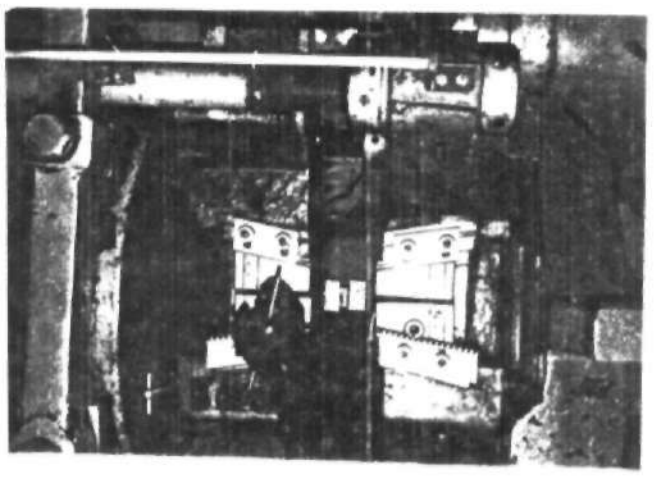


PLATE - VIII: Surface Soundness Test

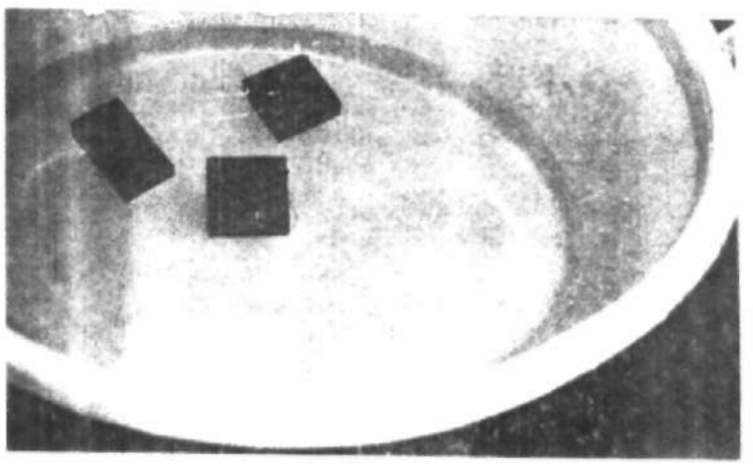


PLATE - IX: Water Absorption and Thickness Swelling Tests

(a) Measurements of weights, thickness and length were done by means of a balance and vernier callipers.

(b) Specimens were placed in clean and calm water (having a temperature 20°C) to soak. They were made to be completely covered in the water.

(c) After one hour the specimens were removed and wiped the excess water with a damp cloth.

(d) The weight and dimensions of the specimens were taken again.

(e) The water absorption of each board was calculated in accordance with the following formula:

$$A = \frac{M_2 - M_1}{M_1} \times 100 \text{ Percent}$$

where, A = Water Absorption (Percent)

M_1 = Mass of the test specimen before immersion (gm)

M_2 = Mass of the test specimen after immersion (gm)

(f) The swelling in thickness of each test specimen was obtained by using the following formula;

$$G = \frac{t_2 - t_1}{t_1} \times 100 \text{ Percent}$$

where,

t_2 = Thickness of the test specimen before immersion (mm)

t_1 = Thickness of the test specimen after immersion (mm)

3.2.10 Moisture Content Test

The moisture content of the boards was measured by weighing the board on a beam balance, drying in an oven (see Plate XI) for a period of 24 hours at a temperature of 105°C to a constant mass and then cooling in a desicator and weighing for the second time.

Three specimens (100mm x 100mm) from each board were used, and the results were obtained by using the following formula;

$$M_c = \frac{M_i - M_o}{M_o} \times 100 \text{ Percent}$$

where, M_c = Moisture content of the board (%)

M_i = Inicial mass of the test specimen (gm)

M_o = Oven dry mass of test specimen (gm)

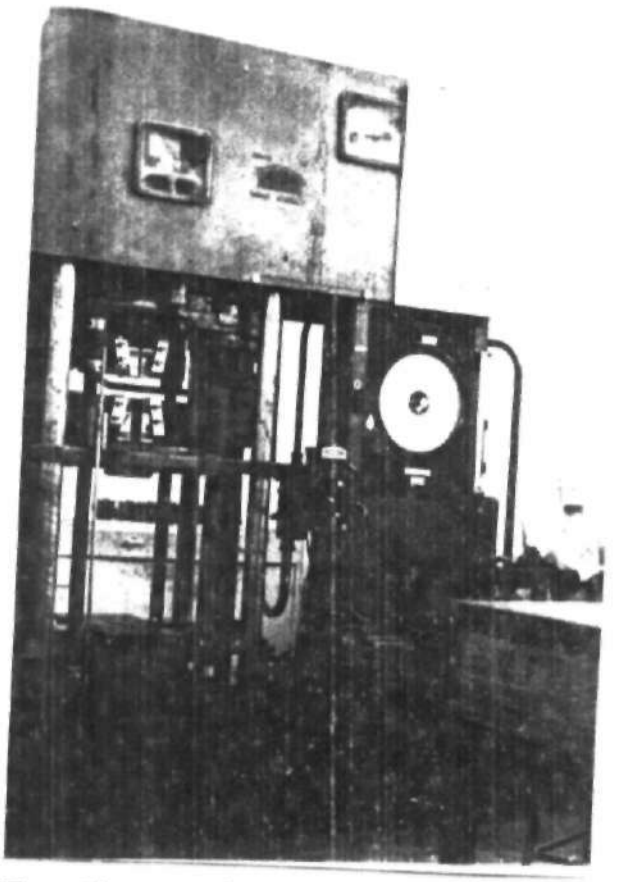


PLATE - X: Denison Testing Machine

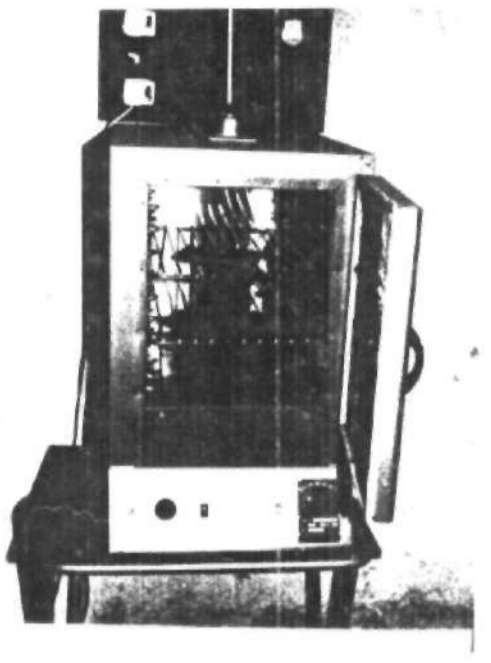


PLATE - XI: Drying the Specimen

3.2.11 Deflection Test

Three specimens of 180mm x 75mm x t (mm) (from each board) were tested on two parallel rollers of 75mm x 25mm diameter. The rollers were kept at 150mm apart and the load was applied at the centre continuously at a speed of 2mm per minute until a load of 30 N was reached by the Denison Testing Machine. The deflection was then read directly from a dial gauge (see Plate XII). This test was performed in accordance with BS 1142, Part 2, 1972.

In view of the results got from these test, discussions are to be made and conclusions to be drawn. This was done in the next chapter.

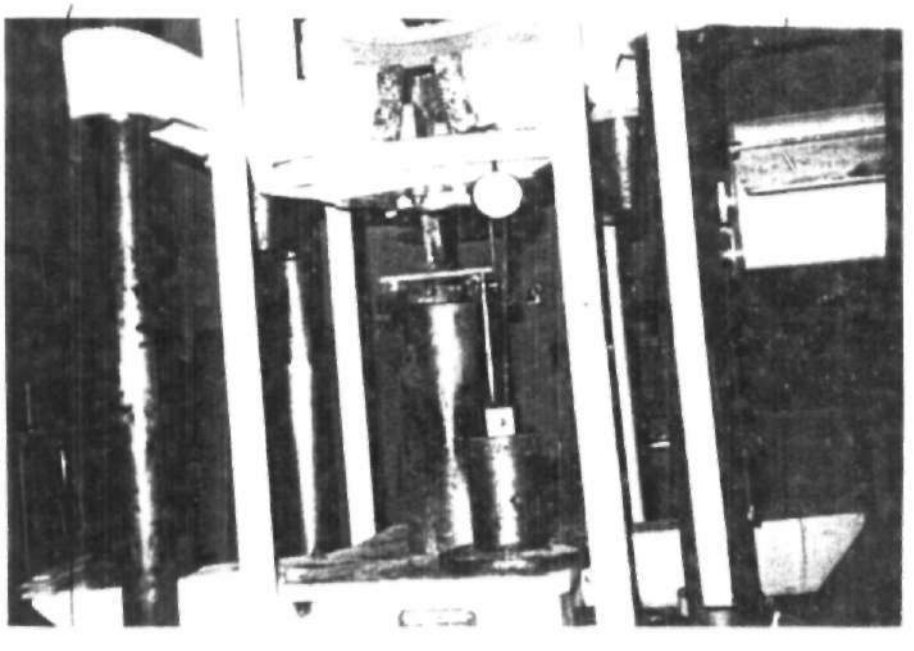


PLATE - XII: Deflection Test

CHAPTER - FOUR

RESULTS AND DISCUSSIONS

The discussion in this chapter is based on the test results of experimental boards produced from maize cobs. The results obtained are compared with the standard values set for the boards contained in British Standards: BS 2604, Part 2, 1970 (for particle boards). This comparison is necessary since these boards (within the same density range) are to be used almost to serve the same purposes, for example in furniture and building constructions.

To ease the discussion, a summary of test results are shown in tables and also illustrated in figures.

4.1 BENDING STRENGTH

The result of this test is presented in table 4.1 below. It was observed that as the density of the boards increases, a corresponding increase in bending strength was recorded. This relation is shown in figure 4.1.

The strength values ranged from 2.3 N/mm^2 for boards with lower density (550 Kg/m^3) to 16.6 N/mm^2 for boards with highest density (950 Kg/m^3). These values are above the minimum

set for wood particle board with average strength ranging from 5.5 to 13.8 N/mm^2 (BS 2604, Part 2, 1970). It is found also from Figure 4.1 (by interpolation) that a satisfactory board in respect of this property can be produced from a board density of 862 Kg/m^3. This board would have a bending strength of 13.8 N/mm^2.

TABLE - 4.1: Bending Strength Test Result

Board No.	Density (Kg/m^3)	Thickness t(mm)	Rupture Load, P(N)	Mean Bending Strength (N/mm^2)
1.	550	12.7	75	2.36
2.	600	10.6	83	3.75
3.	630	9.0	83.5	5.24
4.	670	7.0	65.5	6.80
5.	710	6.9	77.5	8.28
6.	750	6.7	88.5	10.02
7.	790	6.3	87.5	11.21
8.	830	5.8	81.5	12.32
9.	870	5.2	75	14.10
10.	900	5.3	87	15.74
11.	950	5.1	85	16.61

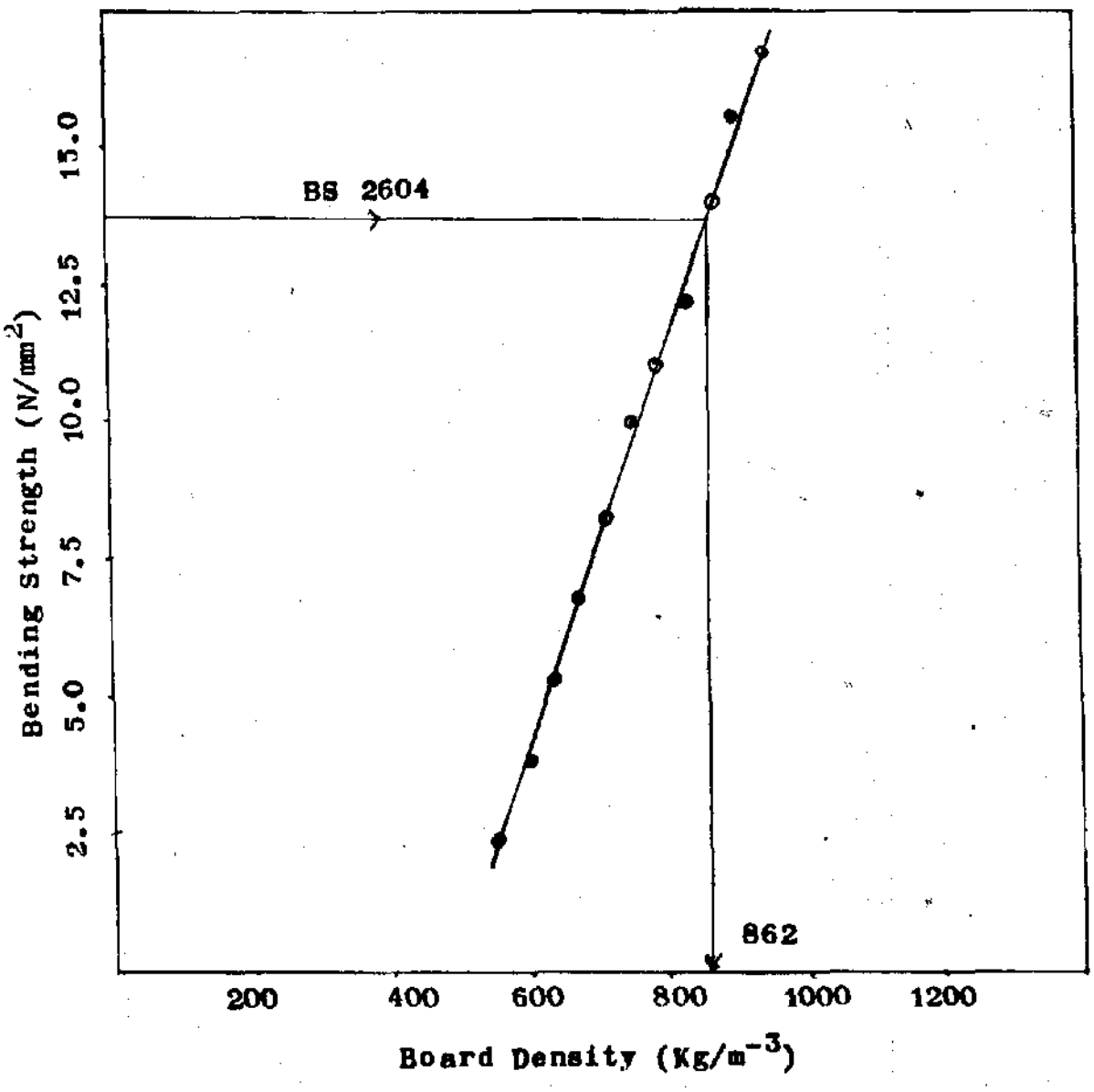


FIGURE - 4.1: Bending Strength Property as Affected by Increase in Board Density

4.2 TENSILE STRENGTH

The test results of tensile strength perpendicular to the surface of the board (table 4.2a) appear to show a consistent relationship between the tensile strength and the board density. The perpendicular tensile strength values for the sample boards increased from 0.084 N/mm^2 for board with 550 Kg/m^3 density to about 0.588 N/mm^2 for board samples with 950 Kg/m^3 density (Figure 4.2a). The typical mean value specified for wood particle board in the same density range with the experimental boards is 0.340 N/mm^2 (BS 2604, Part 2, 1970). The perpendicular tensile strength values obtained for boards with densities from 750 to 950 Kg/m^3 are above the mean value specified. While the values for boards with density ranges of 550 - 710 Kg/m^3 are either below or close to the minimum value established for the wood particle board. Thus, a satisfactory board would have a minimum density of 760 Kg/m^3. The board would have a tensile strength of 0.34 N/mm^2 (Figure 4.2a).

The tensile strength parallel to the surface of the board decreases as the board density increase (as noted from Figure 4.2b). This test had no definite standard to compare with.

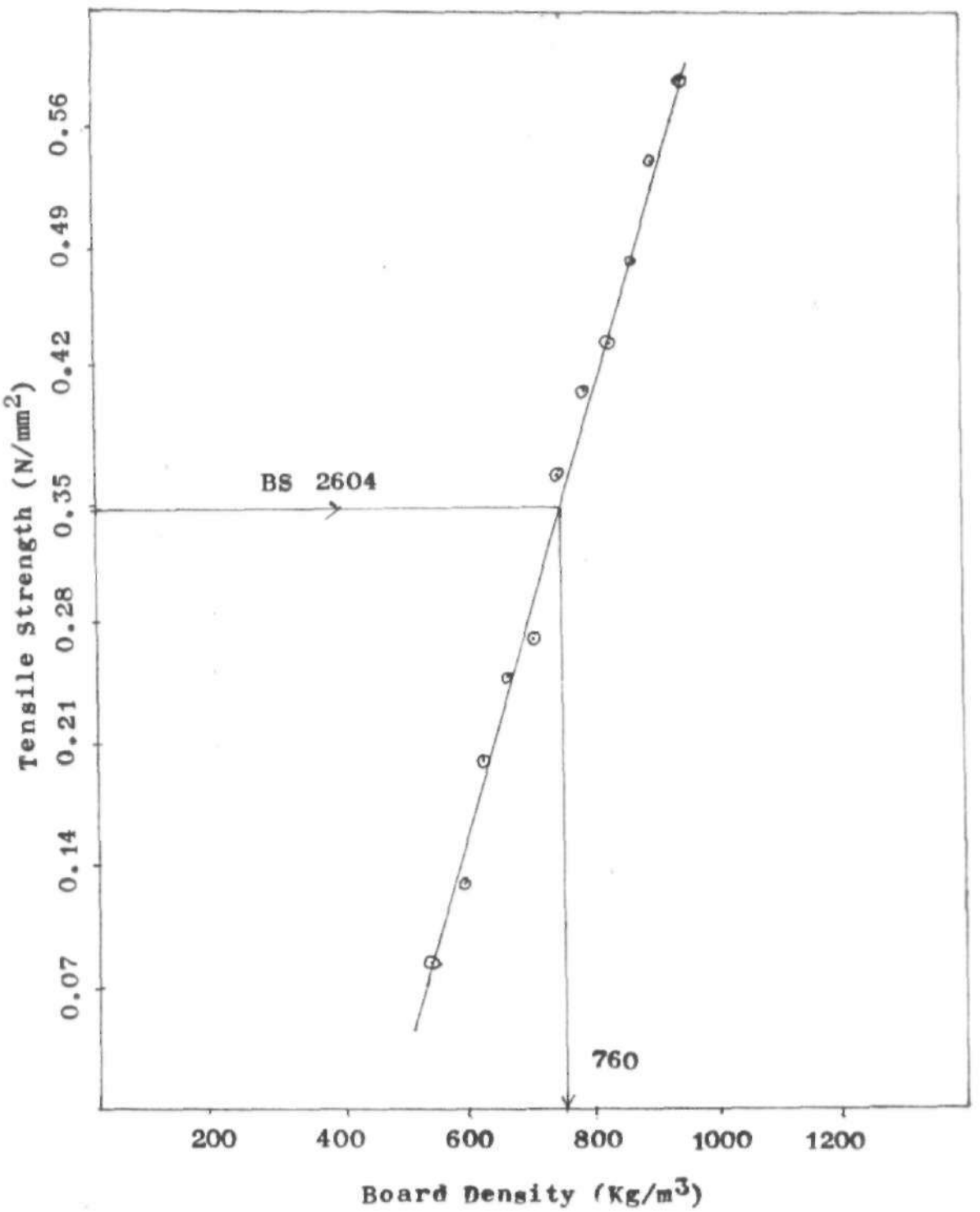


FIGURE - 4.2(a): Relation between Tensile Strength Perpendicular to the Plane of the Board and Board Density

TABLE - 4.2a: Tensile Strength Perpendicular to Surface Result

Board Number	Density (Kg/m^3)	Failure Load, P(N)	Mean Tensile Strength (N/mm^2)
1.	550	103	0.084
2.	660	154	0.126
3.	630	240	0.196
4.	670	301	0.245
5.	710	325.5	0.266
6.	750	437.5	0.357
7.	790	497	0.406
8.	830	532	0.434
9.	870	591.5	0.483
10.	900	660	0.539
11.	950	717.5	0.588

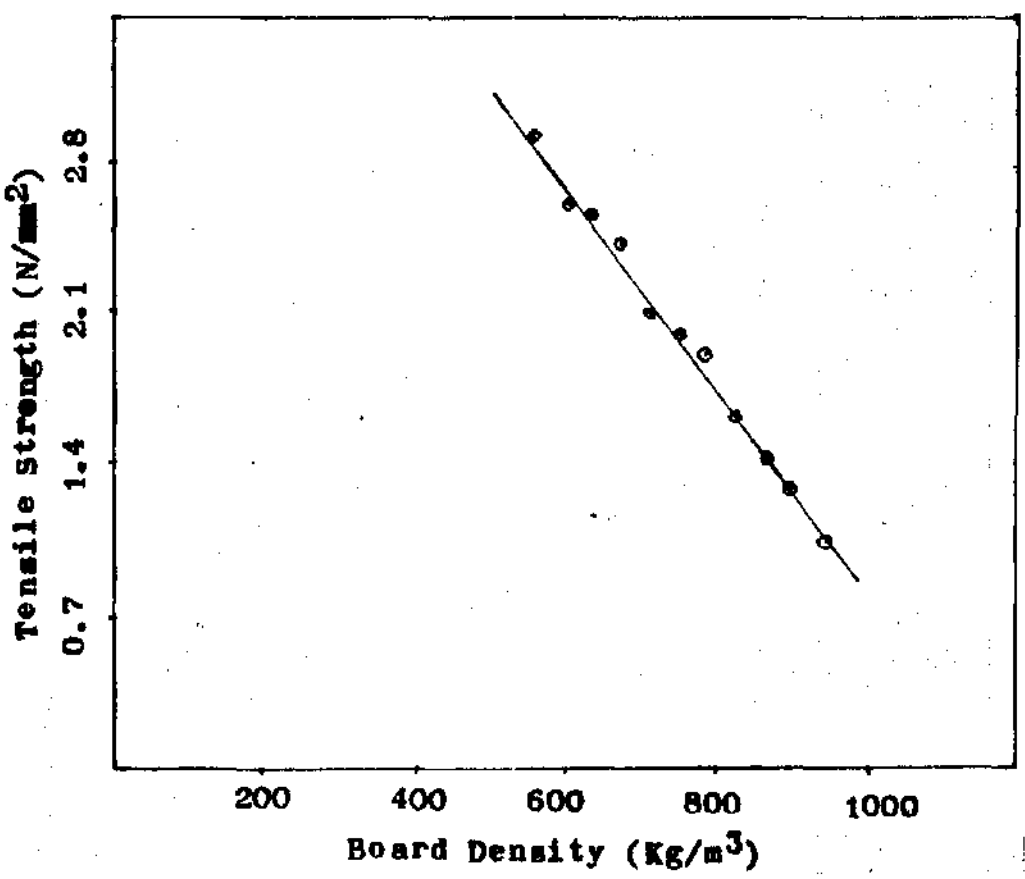


FIGURE - 4.2(b): Relation between Tensile Strength Parallel to the Surface of the Board and Board Density

TABLE - 4.2b: Tensile Strength Parallel to Surface Result

Board Number	Density Kg/m^3	Thickness t(mm)	Maximum Load (N)	Mean Tensile Strength (N/mm^2)
1.	550	12.7	1260	2.919
2.	600	10.6	956	2.653
3.	630	9.0	788	2.576
4.	670	7.0	583	2.450
5.	710	6.9	493	2.100
6.	750	6.7	456	2.002
7.	790	6.3	411	1.918
8.	830	5.8	319	1.624
9.	870	5.2	258	1.456
10.	900	5.3	236	1.309
11.	950	5.1	178.5	1.029

4.3 COMPRESSIVE STRENGTH

No standard exist for compressive strength. The results of this test also show that the compressive strength increases as the board density increase. This relation was illustrated in Figure 4.3.

TABLE - 4.3a: Test Results for the Compressive Strength Parallel to Surface

Board Number	Density Kg/m^3	Thickness t(mm)	Rupture Load (N)	Mean Compressive Strength (N/mm^2)
1.	550	12.7	967.5	1.50
2.	600	10.6	1212.5	2.70
3.	630	9.0	955	2.95
4.	670	7.0	557.5	2.85
5.	710	6.9	932.5	4.90
6.	750	6.7	1032.5	5.75
7.	790	6.3	1095	6.90
8.	830	5.8	1037.5	7.70
9.	870	5.2	897.5	8.30
10.	900	5.3	1047.5	9.35
11.	950	5.1	1202	11.55

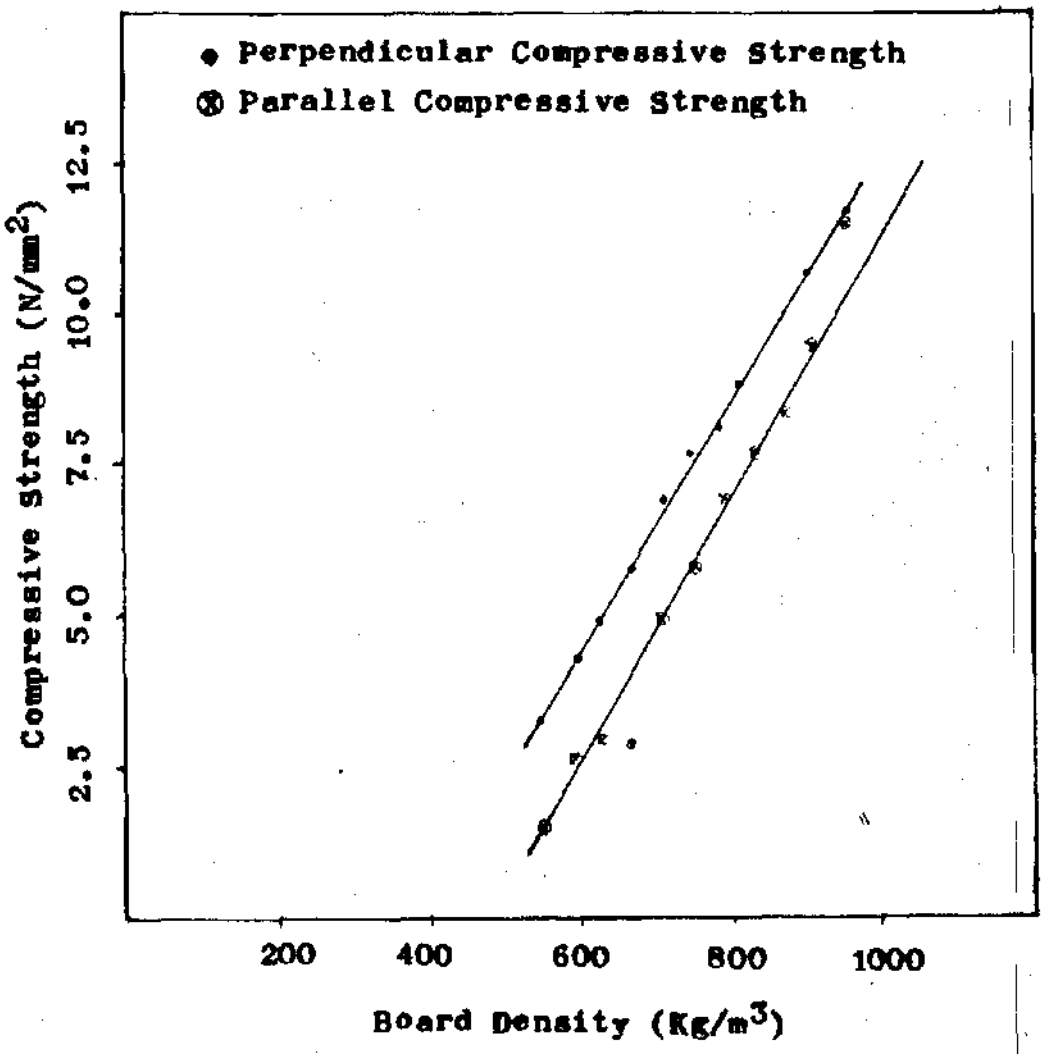


FIGURE - 4.3: Effect of Density Increase on Compressive Strength

TABLE - 4.3b: Compressive Strength Perpendicular to Surface Test Results

Board Number	Density Kg/m^3	Thickness t(mm)	Failure Load (N)	Mean Compressive Strength (N/mm^2)
1.	550	12.7	522.5	3.25
2.	600	10.6	482.5	4.30
3.	630	9.0	392.5	4.90
4.	670	7.0	282.5	5.75
5.	710	6.9	327.5	6.90
6.	750	6.7	345.0	7.70
7.	790	6.3	320.0	8.10
8.	830	5.8	275.0	8.20
9.	870	5.2	235.0	8.70
10.	900	5.3	300.0	10.70
11.	950	5.1	305.0	11.70

4.4 NAIL PUSH-THROUGH AND SCREW HOLDING

The screw holding property of the board samples increased linearly from 200 to 975 N. It is found from Figure 4.4 that a satisfactory board would have a minimum density of 640 Kg/m . Such board would meet the required minimum value of 360 N (specified in BS 2604, Part 2, 1970) in respect of this property.

The nail tests show similar results as the screw test (Figures 4.4(a) and 4.4(b)). But no standards exist with which to compare.

TABLE - 4.4: Screw Holding and Nail Tests Results

Board Number	Density (Kg/m^3)	Screw Holding (N)	Push Through Force (N)	Pull Out Force(N)
1.	550	200	190	34
2.	600	290	225	40
3.	630	350	240	43
4.	670	375	300	54
5.	710	540	350	66
6.	750	580	360	67
7.	790	630	395	75
8.	830	770	430	86
9.	870	820	465	93
10.	900	875	475	95
11.	950	975	525	105

4.5 SURFACE SOUNDNESS

The surface soundness values ranged from 820 to 1385 N for boards with lower and highest densities respectively. It can be seen from Figure 4.5 that only boards of minimum density of 770 Kg/m satisfy the minimum requirement of 1100 N specified in BS 2604.

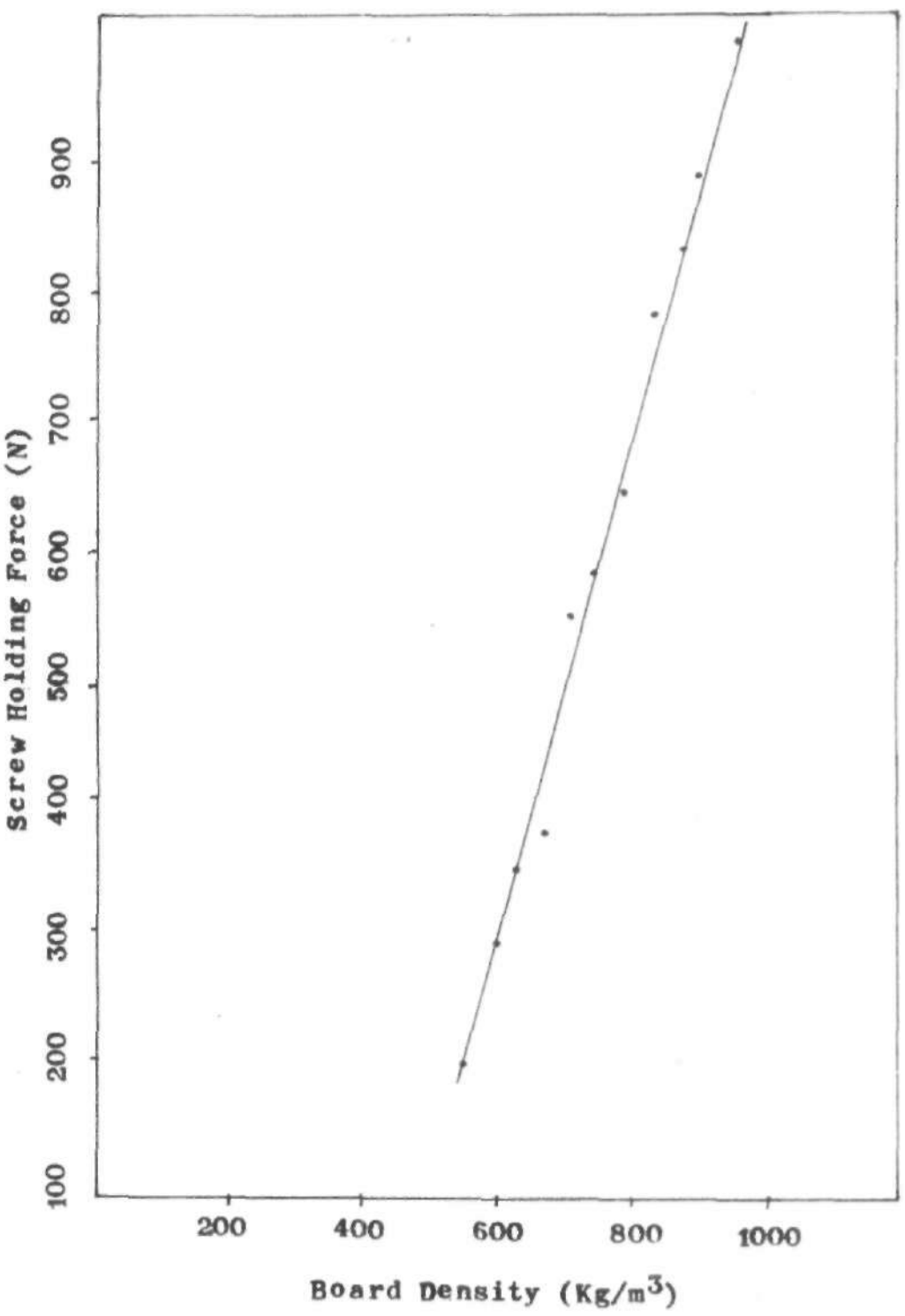


FIGURE - 4.4: Density Increase Effect on Screw Holding Property

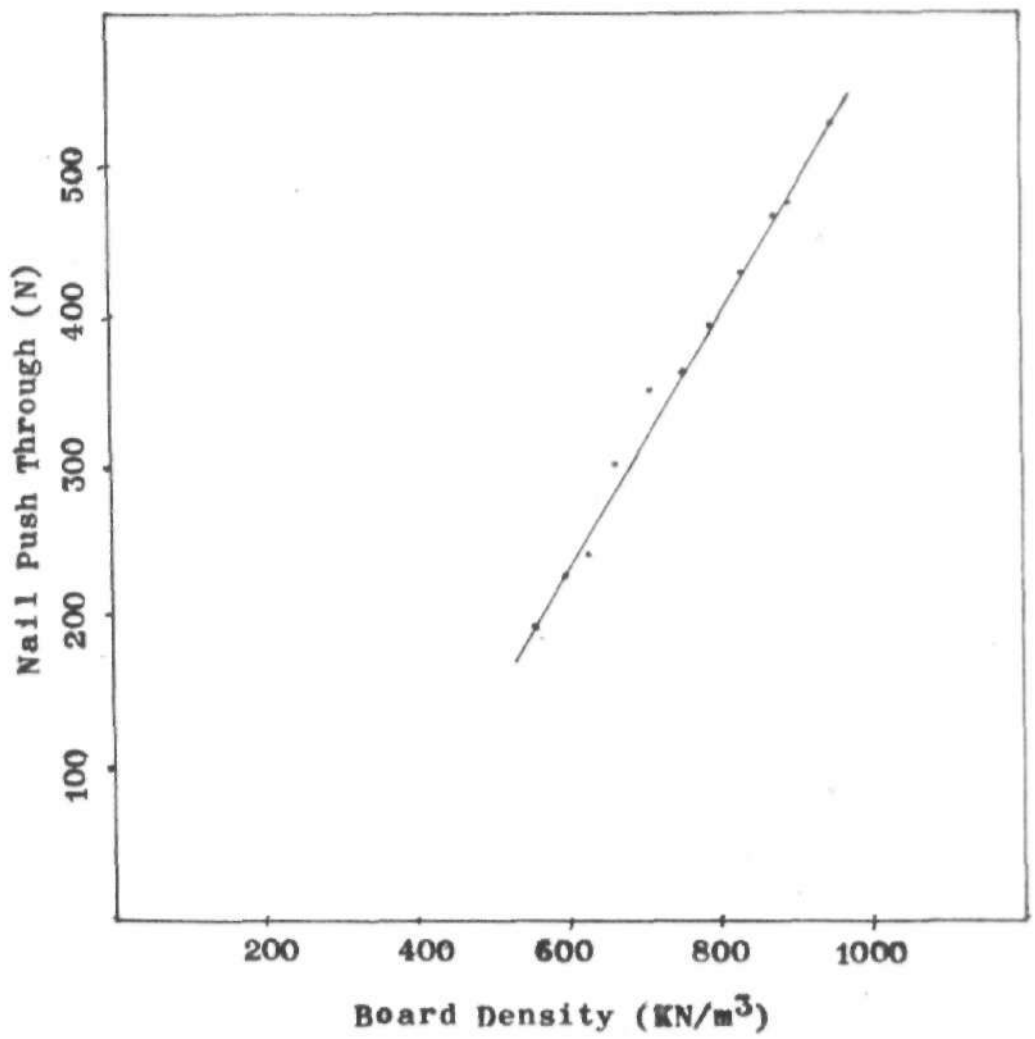


FIGURE - 4.4(a): Relation of Nail Push Through and Density of Experimental Maize cob Particle Boards

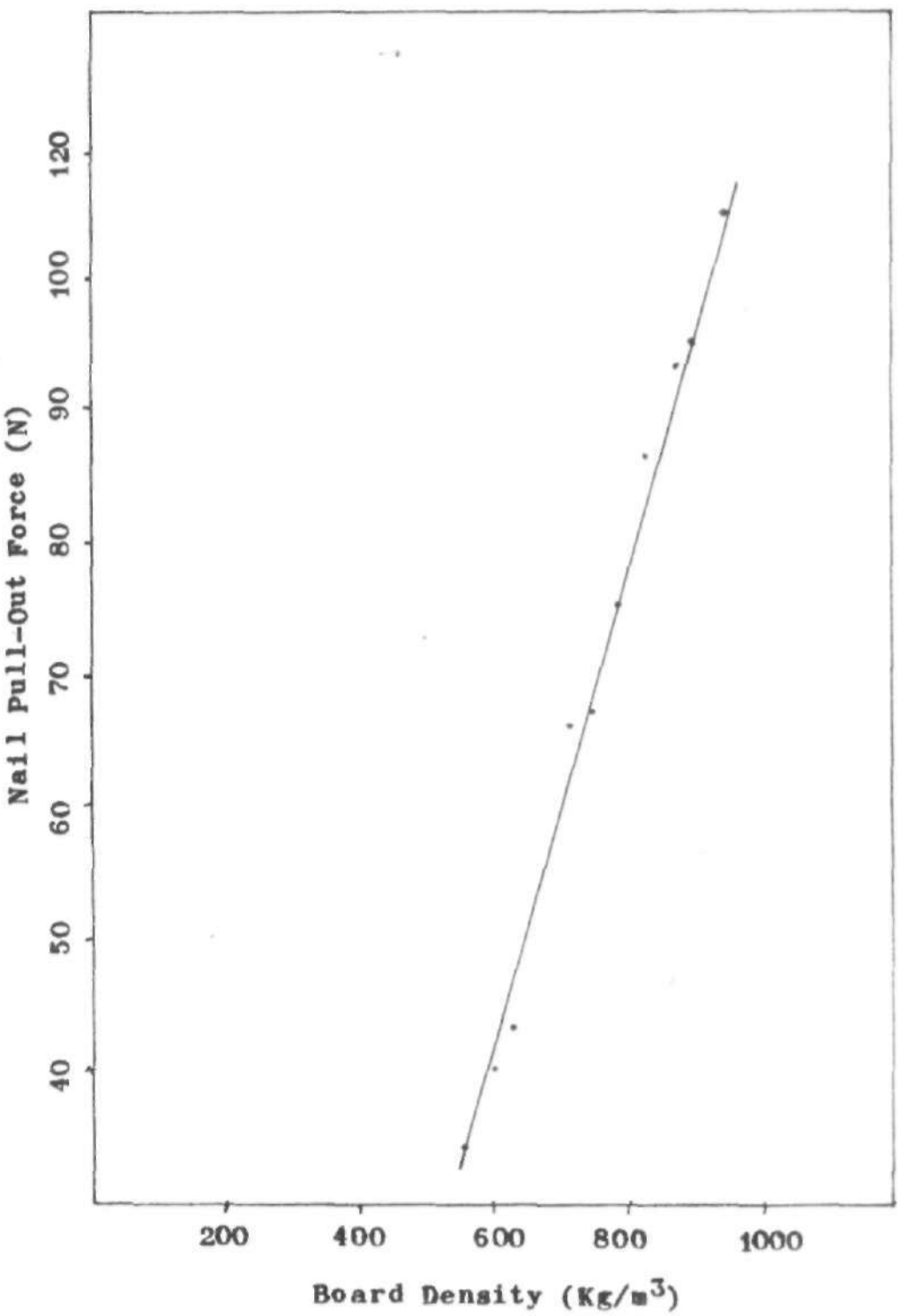


FIGURE - 4.4(b): Relation Between the Nail Pull-out Characteristics and Density of Board Samples

TABLE - 4.5: Surface Soundness Test Results

Board Number	1	2	3	4	5	6	7	8	9	10	11
Density (Kg/m^3)	550	600	630	670	710	750	790	830	870	900	950
Surface Soundness (N)	820	870	930	985	1050	1090	1155	1225	1295	1300	1385

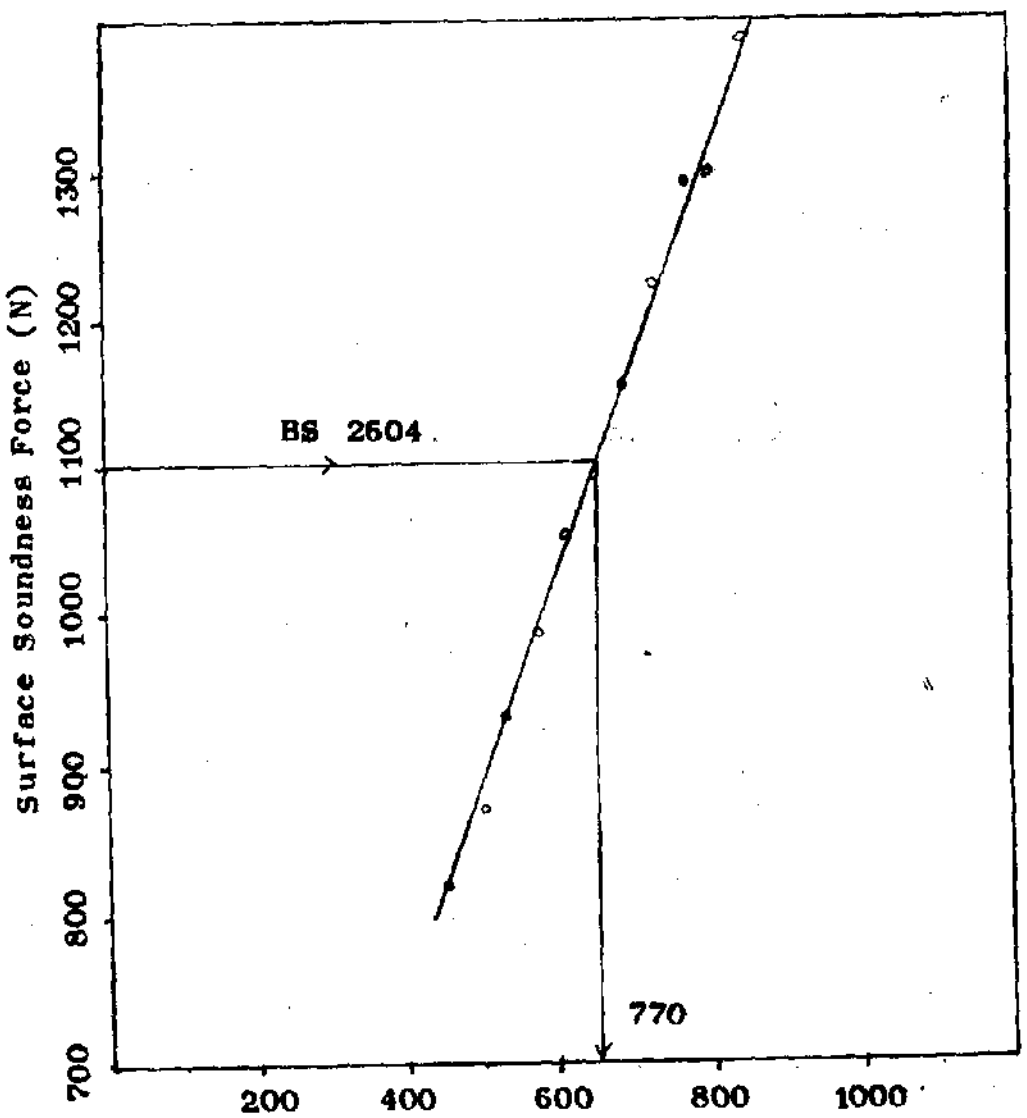


FIGURE - 4.5: Relation of Surface Soundness Property and Board Density

4.6 WATER ABSORPTION AND THICKNESS SWELLING TEST RESULTS

The water absorption of the board samples was very high and quick. The one hour water absorption decreased from 98.4 to 83.4 percent (by weight). However, the decrease is non-linear (Figure 4.6). This range is higher than the limit (of 75 Per cent) set in BS 2604, 1955. The water swelling characteristics of sample boards exhibited a similar trend. Sample boards with lower density recorded the highest percentage of thickness swell as against those with higher density.

These results do not mean that maize cob particle boards have bad water absorption and thickness swelling properties, what it shows is the importance of water repellents. If water repellents like wax was added, it would have closed the 'water ways'. Thus, reducing the swell in thickness and the water absorption characteristics.

4.7 MOISTURE CONTENT

Result of this test shows all the experimental values are within the range (6 - 14 Per cent) specified in BS 2604 for wood particle board in the same density range. Therefore, it can be said that the board samples satisfied the set standard.

TABLE - 4.6: Water Absorption and Thickness Swelling Test Results

Board Number	Density (Kg/m3)	Thickness t(mm)	Water Absorption (%)	Thickness Swelling (%)
1.	550	12.7	98.4	84.2
2.	600	10.6	95.3	82.5
3.	630	9.0	94.5	81.4
4.	670	7.0	93.7	81.6
5.	710	6.9	90.8	81.3
6.	750	6.7	88.9	80.8
7.	790	6.3	86.7	80.5
8.	830	5.8	85.7	80.0
9.	870	5.2	84.2	79.8
10.	900	5.3	82.9	79.5
11.	950	5.1	83.4	78.7

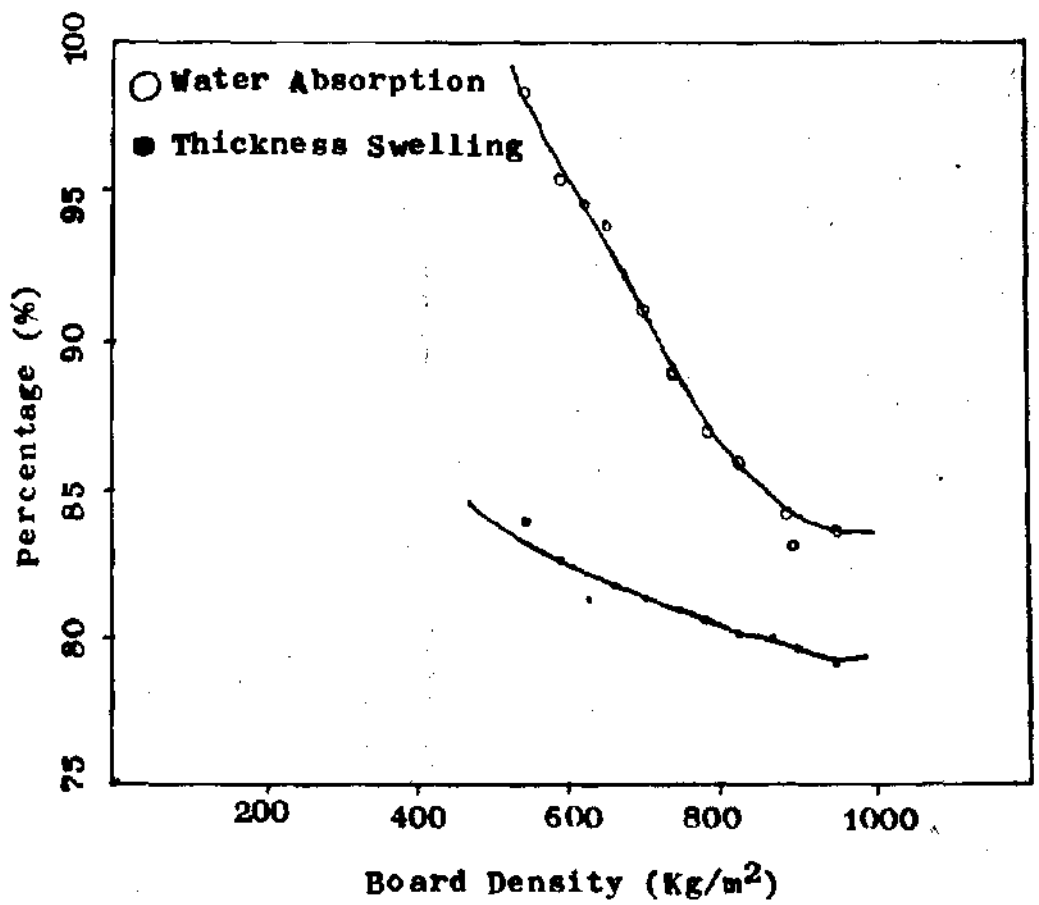


FIGURE - 4.6: Water Absorption and Thickness Swelling Characteristics of Board Samples as Affected by Density Increase

TABLE - 4.7: Moisture Content Test Results

Board Number	1	2	3	4	5	6	7	8	9	10	11
Density (Kg/m)	500	600	630	670	710	750	790	830	870	900	950
Thickness (mm)	12.7	10.6	9.0	7.0	6.9	6.7	6.3	5.8	5.2	5.3	5.1
Moisture Content (%)	6.64	6.52	6.68	6.23	7.35	8.04	6.83	7.41	6.50	6.49	6.44

4.8 DEFLECTION

The deflection results are given in table 4.8 below, while Figure 4.7 gives a graphical presentation. The result shows that the deflection property of the boards is satisfactory as it decreased from 3.8 to 1.5mm. The maximum value is less than the maximum allowable value of 4 mm established in BS 2604. It is also observable that as the density of the boards increases, a corresponding decrease in deflection property is recorded.

4.9 BOARD DENSITY

The density of most of the boards produced (Table 3.2) are within the range recommended in BS 2604 for "medium density particle board" (MDP). It was generally observed that the board density increases as platen pressure, press time and temperature; and resin concentration are varied. Also as the board density increases the following effects are observed;

i. increase in most of the mechanical properties tested, and

ii. reduction in tensile strength parallel to the board's surface. The probable

TABLE - 4.8: DEFLECTION RESULT

Beard Number	1	2	3	4	5	6	7	8	9	10	11
Density (Kg/m)	550	600	630	670	710	750	790	830	870	900	950
Thickness (mm)	12.7	10.6	9.0	7.0	6.9	6.7	6.3	5.8	5.2	5.3	5.1
Deflection (mm)	3.8	3.5	3.4	3.1	2.9	2.6	2.4	2.2	1.9	1.8	1.5

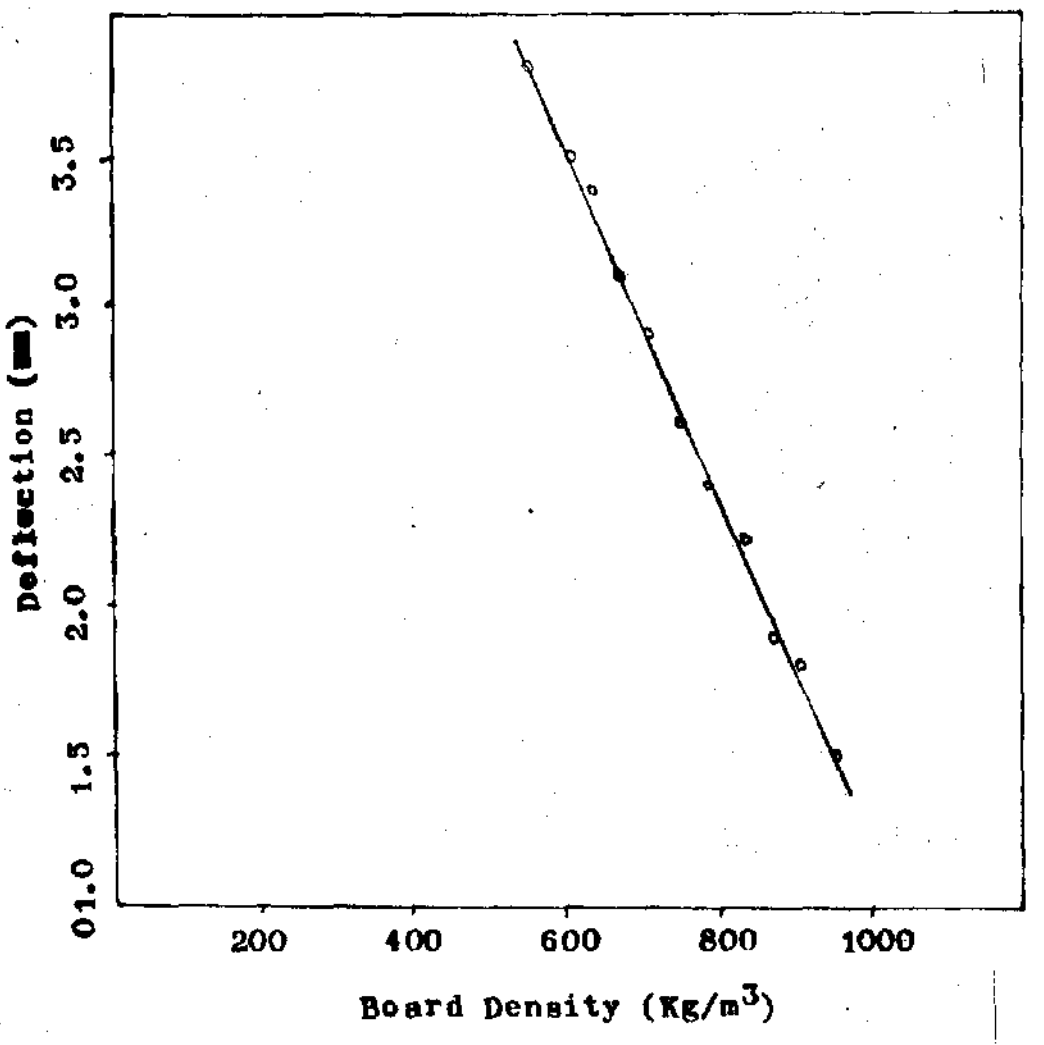


FIGURE - 4.7: Effect of Increase in Density of Board Samples on Deflection Property

reason for this was that higher temperatures and pressures during forming tend to make the boards brittle when timing is not increased correspondingly.

4.10 EFFECT OF VARYING THE RESIN CONCENTRATION LEVEL

The liquid resin based on the oven dry weight of maize cob particles was varied from 9 to 14 percent. The results of the tests carried out is shown in table 4.9 and also illustrated graphically. These results are compared with those of BS 2604, Part 2, 1970. The latter shows the level of quality to be attained by maize cob particle boards in the same density range. The values given in BS 2604 for bending strength, tensile strength, screw holding and surface soundness are the specific minimum for these properties.

The strength defined by bending of the sample boards increased proportionally (from 3.06 to 16.17 N/mm^2) with increase in the amount of liquid resin (Figure 4.8). The maximum value at 14 per cent liquid resin content is about 17 percent higher than the required minimum of

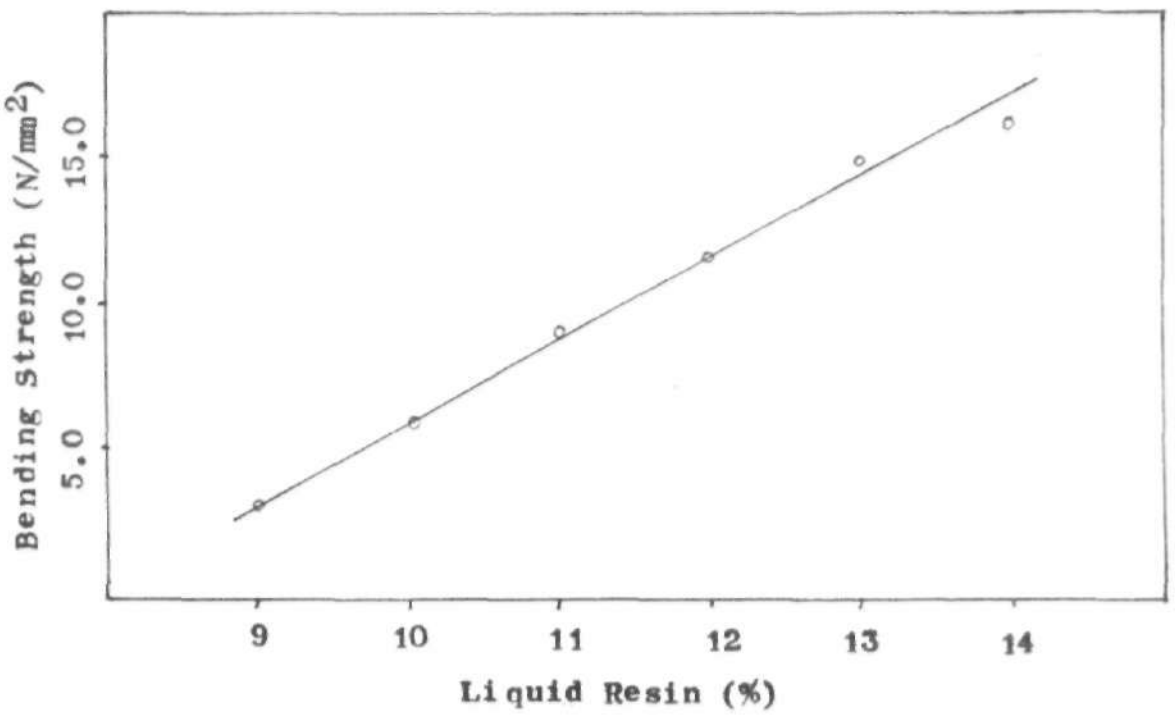


FIGURE - 4.8: Bending Strength of Experimental Boards as Affected by Resin Content

TABLE - 4.9; Variation of Resin Concentration Levels

P R O P E R T Y	Liquid Resin (Percentage)						BS 2604, Part 2, 1970
	9	10	11	12	13	14	
Board Density (Kg/m^3)	575	640	715	755	790	800	480 Minimum
Thickness (mm)	12.7	12.6	12.4	12.3	12.1	12.0	12
Bending Strength (N/mm^2)	3.06	6.02	9.15	11.76	14.92	16.17	13.8
Tensile Strength Perpendicular the Plane of the Board (N/mm^2)	0.105	0.220	0.311	0.420	0.511	0.563	0.34
Surface Soundness (N)	845	955	1070	1190	1295	1380	1100
Screw Holding (N)	245	450	560	700	845	925	360
Water Absorption (Percentage)	96.86	94.10	89.84	86.22	83.55	83.18	*75 Maximum
Thickness Swelling (1 Hour)(%)	83.35	81.50	81.06	80.28	79.62	79.10	19.1
Moisture Content (Percentage)	6.58	6.45	7.69	7.12	6.49	6.46	6 - 14
Deflection (mm)	3.6	3.2	2.7	2.3	1.8	1.5	4 Maximum

*Water absorption has no limit set in BS 2604, Part 2, 1970 but BS 2604, 1955 set a limit of 75 Per cent and has been used in this table.

13.8 N/mm in BS 2604. A similar trend is also observed in the tensile strength perpendicular to surface. Board with the highest resin content (14 Per cent) were better in perpendicular tensile strength than those with lower resin content (Figure 4.9). The tensile strength values ranged from 0.105 to 0.563 N/mm . The maximum value is about 65 Percent higher than the minimum (of 0.34 N/mm) specified in BS 2604.

The surface soundness values for the sample boards increased from 845 to 1380 N with increase in liquid resin (Figure 4.10). The typical mean value specified in BS 2604 for wood particle board in the same density range with the experimental boards is 1100 N. The surface soundness value obtained for boards with 14 Per cent liquid resin is about 25 percent better than the mean value specified.

A similar results is also obtained in screw holding test. Its values ranged from 245 to 925 N. Figure 4.11 illustrates the relationship between the resin content level and the screw holding characteristics of the sample boards. It can be seen from the figure that the screw holding property of sample boards increases as

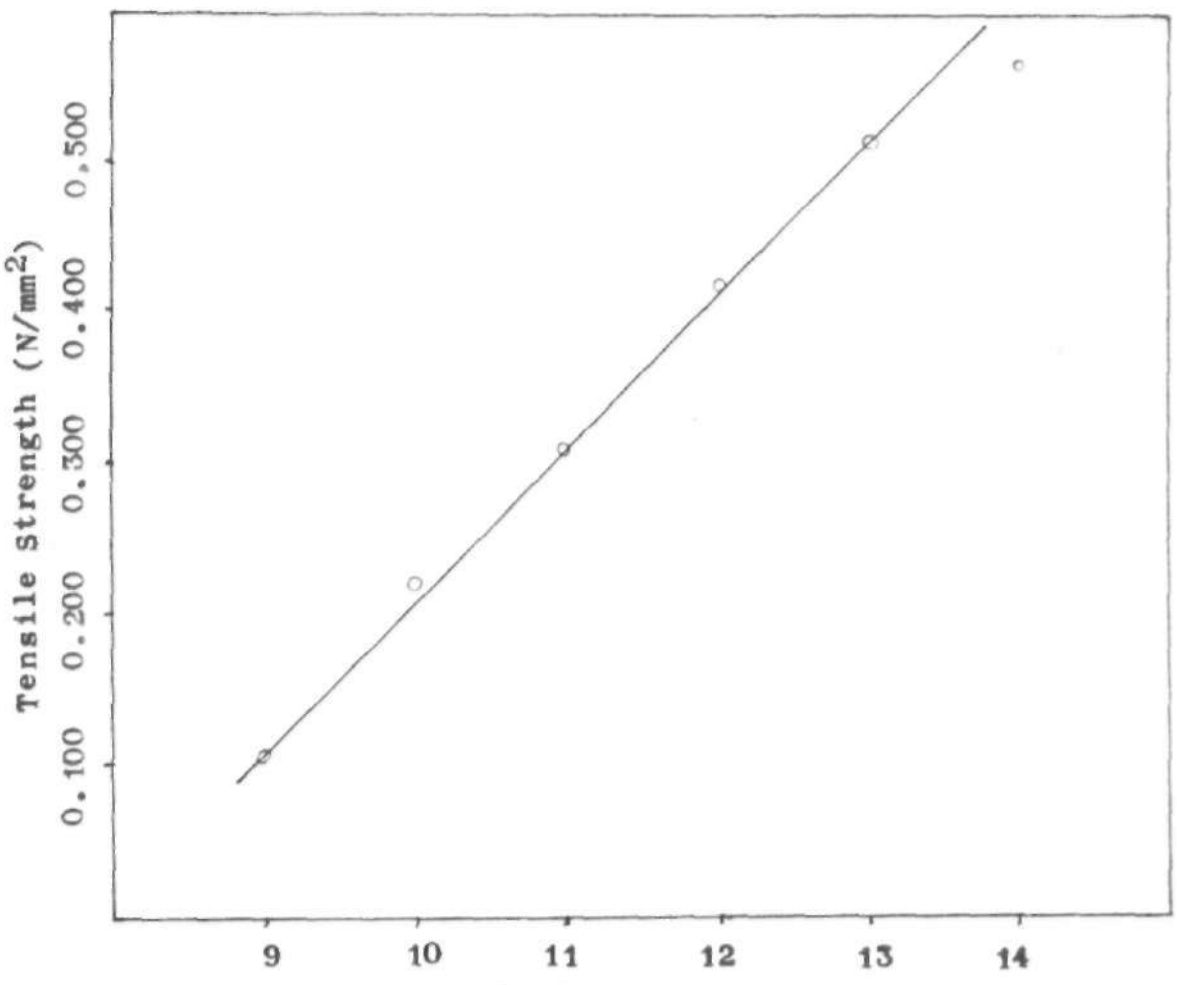


FIGURE - 4.9: Tensile Strength Perpendicular to the Surface of the Boards as Affected by Resin Content Levels

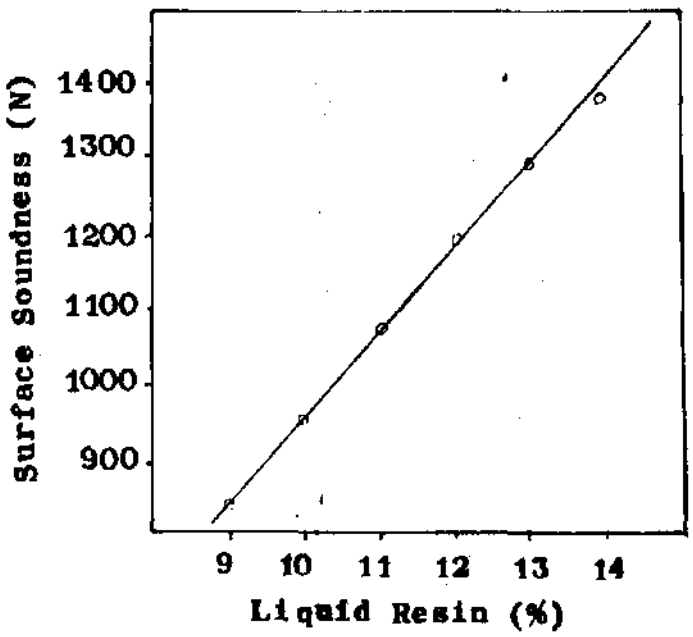


FIGURE - 4.10: Effect of Resin Content on Surface Soundness of Maize Cob Particle Boards

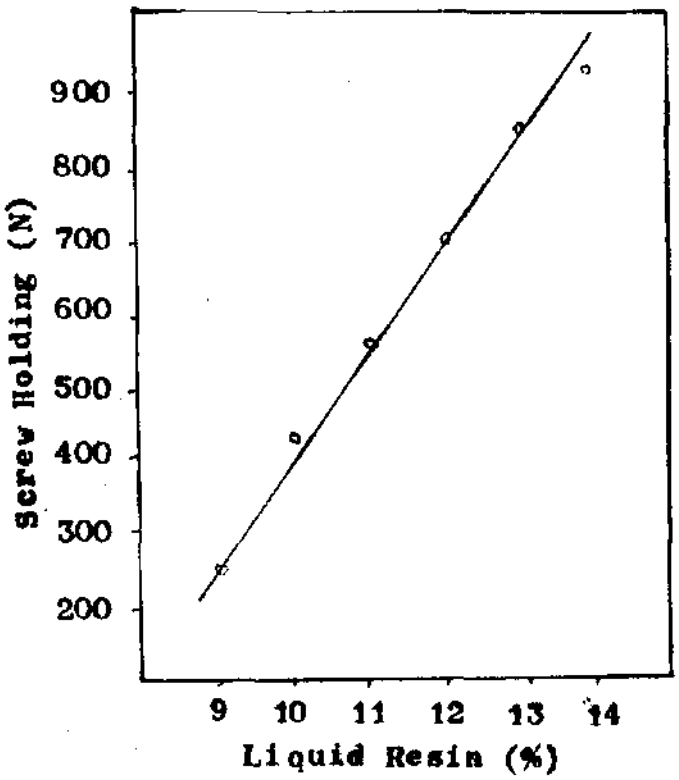


FIGURE - 4.11: Screw Holding Characteristics of Maize Cob Particle Board as Affected by Resin Content

the adhesive content increases from 9 to 14 percent. The screw holding of boards produced from 10 to 14 percent liquid resin contents exceeded the required minimum value of 360 in BS 2604. The property is therefore, satisfactory for these resin contents.

The water absorption of sample boards decreased from 96.86 to 83.18 per cent (Figure 4.12) with increasing resin content. The upper limit of 75 percent specified in BS 2604 was exceeded. This property is therefore, not satisfactory. A similar trend is also observed with thickness swelling property. Its values decreased from 83.35 to 79.10 percent with increase in resin content (Figure 4.12). This result is not satisfactory when compared with standard. Probable reason might be due to lack of water repellent (like wax).

The result of moisture content shows that all the sample boards satisfy the BS 2604 requirement which ranges between 6 and 14 per cent. The values of deflection test decreased from 3.6 to 1.5 mm as the resin content increases (Figure 4.13). This result satisfy the maximum

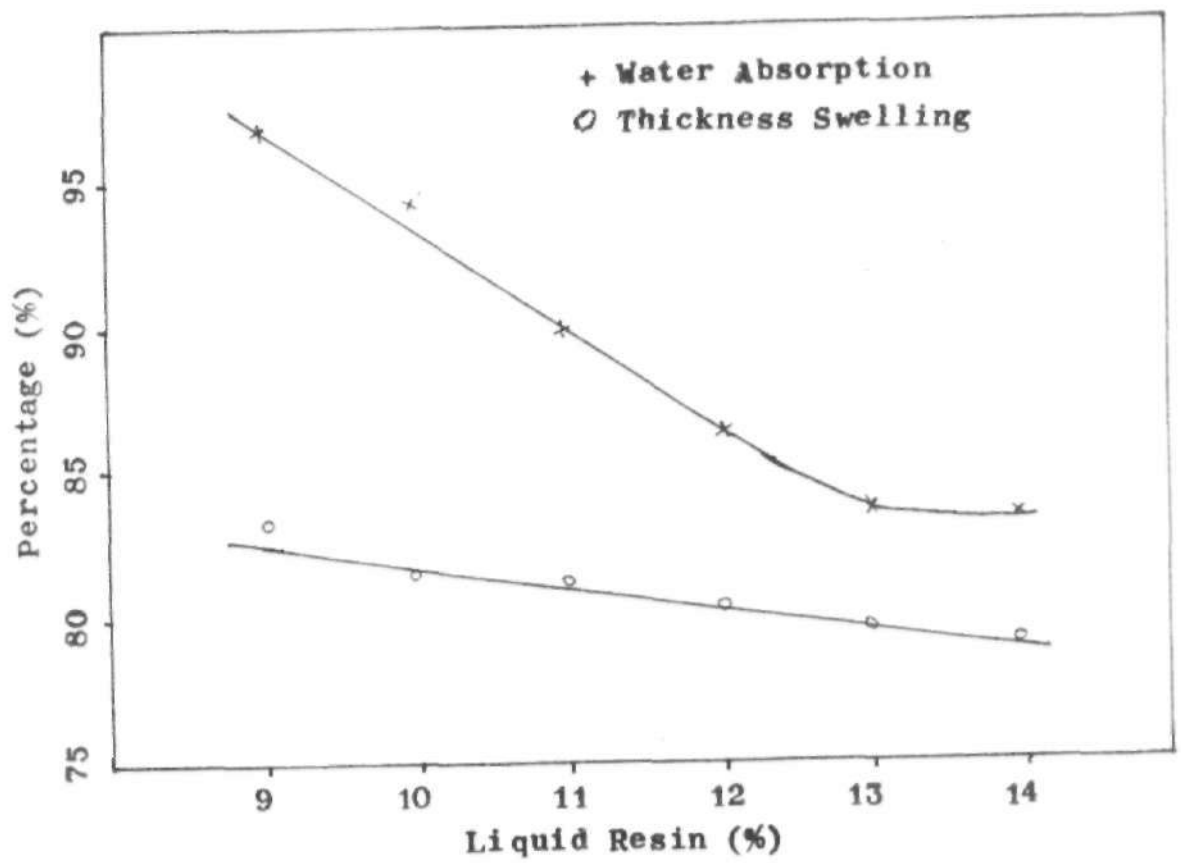


FIGURE - 4.12: Water Absorption and Thickness Swelling Properties of Experimental Maize Cob Particle Boards as Affected by Resin Content Levels

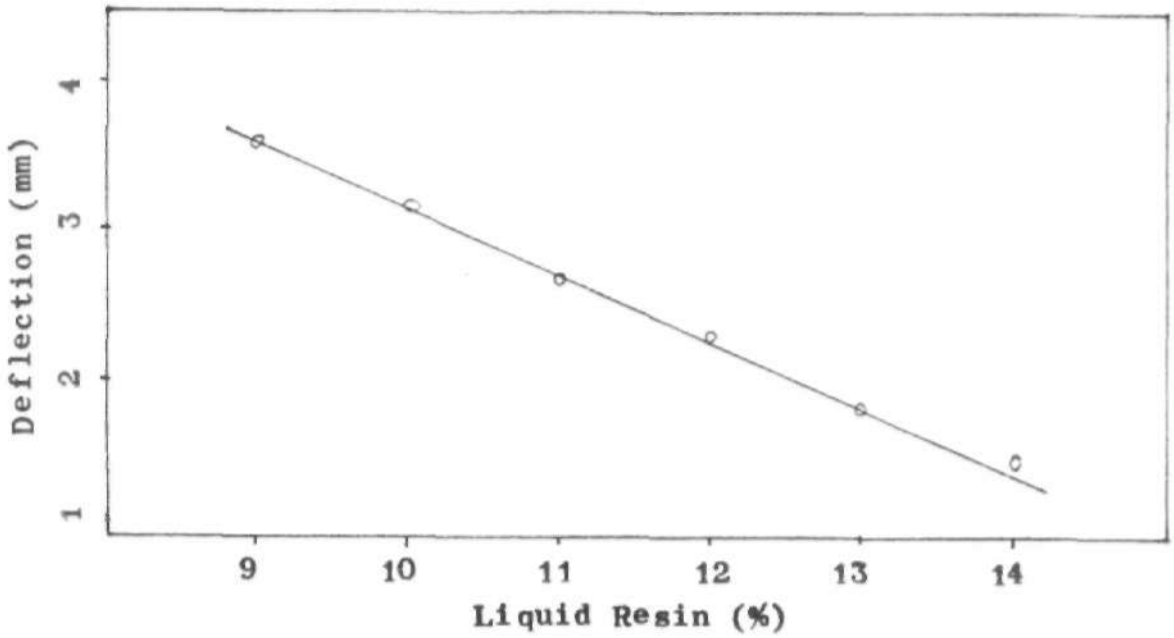


FIGURE - 4.13: Effect of Increasing Resin Content Level on Deflection of Maize Cob Particle Board Samples

value of 4 mm specified in BS 2604. Therefore, the sample boards are satisfactory in respect of deflection property. The density of sample boards also increases as the resin concentration level increases.

The detail of experimental readings are given in table 5.9(R) (Appendix - II).

CHAPTER - FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

From the results of this study, the following conclusions can be drawn;

i. Only water absorption and thickness swelling properties gave unsatisfactory results. While all other properties evaluated satisfy the minimum standard for the wood particle board in the same density range.

ii. All the test values for bending strength, tensile strength perpendicular to the surface of the board, nail resistance and screw holding increased as the density of the board increases. While the test values for water absorption and thickness swelling properties decreased with increase in the board density.

iii. Most of the boards produced are of medium density range and meet the structural strength requirements specified in the standard.

iv. The board properties were generally dependent on the adhesive concentration level. Sample boards with higher resin content were superior in board properties than those with lower resin content levels.

v. From the evaluation of board properties carried out under laboratory conditions, there appears to be a good raw material for manufacturing particle board from maize cob.

5.2 RECOMMENDATIONS

i. Since the properties of maize cobs are quite many, thorough investigations should be carried out before maize cobs from a particular source can be used for particle board manufacture.

ii. Maize cob particle board should be used for furniture making (as core stock for veneers) pending the out-come of further investigation on the dimensional changes associated with changes in relative humidities. Water repellent (such as wax) should be used as a necessary additive to avert the board's high water absorption and thickness swelling.

iii. Tests should also be conducted on the board's flame resistance, fungal resistance, thermal conductivity and acoustical properties and proved adequate before use can be made in building construction.

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STANDARDS

1. BS. 812: Part 1, 1969 - Specification for Test Sieves.

2. BS. 1142: Part 1, 1972 - Specification for Fibre Building Boards, Method of Test.

3. BS. 1142: Part 2, 1972 - Specification for Fibre Building Boards, Medium Board and Hard-Board.

4. BS. 1142: Part 3, 1972 - Specification for Fibre Building Boards, Insulating Board (Soft-Board).

5. BS. 1811: Part 2, 1969 - Methods of Tests for Wood Chip Boards and Other Particle Boards.

6. BS. 2604: Part 2, 1970 - Specification for Resin Bonded Wood Chip Board.

APPENDIX - I

SAMPLE CALCULATIONS

1. **Density**

$$= \frac{m}{V} \quad (Kg/m^3)$$

$$M = 56.70 \times 10^{-3} \text{ Kg}$$

$$V = 100 \times 100 \times 9 \times 10^{-9} \text{ M}^3$$

$$= \frac{56.70 \times 10^{-3}}{100 \times 100 \times 9 \times 10^{-9}} = 630 \text{ Kg/m}^3$$

2. **Bending Strength**

$$S = 3P/2bt^2 \quad (N/mm^2)$$

$$P = 87.5 \text{ N}$$

$$= 152.5\text{mm}$$

$$b = 45\text{mm}$$

$$t = 6.3\text{mm}$$

$$S = \frac{3 \times 87.5 \times 152.5}{2 \times 45 \times (6.3)^2} \text{ N/mm}^2$$

$$= 11.21 \text{ N/mm}^2$$

3. **Tensile Strength Parallel to Surface**

$$T = \frac{P}{A} \quad (N/mm^2)$$

$$P = 956 \text{ N}$$

$$A = 10.6 \times 34 \text{ mm}^2$$

$$T = \frac{956}{10.6 \times 34} \text{ N/mm}^2$$

$$= 2.653 \text{ N/mm}^2$$

4. **Tensile Strength Perpendicular to Surface**

$$T = \frac{P}{A} \text{ (N/mm}^2\text{)}$$

$$P = 591.5 \text{ N}$$

$$A = 35 \times 35 \text{ mm}^2$$

$$T = \frac{591.5}{35 \times 35} \text{ N/mm}^2$$

$$= 0.483 \text{ N/mm}^2$$

5. **Compressive Strength Parallel to Surface**

$$C = \frac{P}{A} \text{ (N/mm}^2\text{)}$$

$$P = 1202 \text{ N}$$

$$A = t \times 4t \text{ mm}^2$$

$$= 5.1 \times (4 \times 5.1) \text{ mm}^2$$

$$C = \frac{1202}{5.1 \times (4 \times 5.1)} \text{ N/mm}^2$$

$$= 11.55 \text{ N/mm}^2$$

6. **Compressive Strength Perpendicular to Surface**

$$C = \frac{P}{A} \text{ (N/mm}^2\text{)}$$

$$P = 470 \text{ N}$$

$$A = 5.2 \times 5.2 \text{ mm}^2$$

$$C = \frac{235}{5.2 \times 5.2} \text{ N/mm}^2$$

$$= 8.7 \text{ N/mm}^2$$

7. **Moisture Content**

$$M_c = \frac{M_i - M_o}{M_o} \times 100\%$$

M_i = 95.5 gm.

M_o = 89.9 gm.

$$M_c = \frac{95.5 - 89.9}{89.9} \times 100\%$$

$$= 6.23\%$$

8. **Water Absorption**

$$A = \frac{M_2 - M_1}{M_1} \times 100\%$$

M_1 = 73.5g.gm.

M_2 = 140.2 gm.

$$A = \frac{140.2 - 73.5}{73.5} \times 100\%$$

$$= 90.8\%$$

9. **Thickness Swelling**

$$G = \frac{t_2 - t_1}{t_1} \times 100\%$$

t_1 = 9.00 mm

t_2 = 16.33 mm

$$G = \frac{16.33 - 9.00}{9.00} \times 100\%$$

$$= 81.4\%$$

APPENDIX - II

TABLE - 5.9(R): Experimental Readings for Variation of Resin Content

Liquid Resin Content (%)	PROPERTY							
	Bending Strength	Tensile Strength	Water Absorption		Thickness Swelling		Moisture Content	
	Measured Parameter							
	P	P	M_1	M_2	t_1	t_2	M_1	M_e
9	97.10	128.62	56.70	111.62	12.7	23.28	95.50	101.78
10	188.03	269.50	56.60	109.86	12.6	22.87	95.62	101.79
11	276.79	380.97	56.64	107.52	12.4	22.45	95.81	103.18
12	350.03	514.50	56.52	105.25	12.3	22.17	95.32	102.11
13	429.77	625.97	56.57	103.83	12.1	21.73	95.26	101.44
14	458.11	689.67	56.47	103.44	12.0	21.49	94.89	101.02

NOTE:

P = Load at rupture in Newtons (N).

P = Maximum Load, (N).

M_1 = Mass of test piece before immersion, (gm).

M_2 = Mass of test piece after one hour immersion, (gm).

t_1 = Mean thickness before immersion, (mm).

t_2 = Mean thickness after one our immersion, (mm).

M_i = Initial mass of test specimen, (gm).

M_o = Oven-dry mass of test specimen, (gm).