EFFECT OF TEMPERING TIME, SODIUM CARBONATE ADDITION AND METHOD OF PREPARATION ON THE PROPERTIES OF FOUNDRY MOULDING SANDS

By

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A thesis submitted to the Postgraduate School, Ahmadu Bello University, in partial fulfillment of the requirements for the award of Master of Engineering (M.Eng.) degree in production Engineering.

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April, 1984

DECLARATION

I hereby declare that the content of this thesis is purely a record of my own research work. It has not been accepted in any previous application for higher degree. All the sources of information are specifically acknowledged by means of reference.

Abiola Olanrewaju

DEDICATIONS

In memory of my late mother, Mrs Christiana Adebisi Olanrewaju who passed away on the 29 August 1983.

It's unfortunate that we have to pass through life without you.

Anyway, we'll carry on,

how you taught us,

to be respectful,

to be honest,

to be kind,

to all people,

Thank you for everything mama

And God bless.

- Biola

"A man will do nothing if he waits till he
has done it that nobody finds fault in it"

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to Dr P. Mathew and Professor S. Y. Aku, my Supervisors to whom my obligations are due in very large measure for their valuable and immense guidiance without which this project wouldn't have been a success.

My sincere gratitude goes to Mr Y. A. Aminu and late Mr George Cloworaran (late Chief Technician) who provided me with the departmental generator which I used whenever there was power out.

I am also grateful to my senior brother Mr J. Olugbenga Dare (Head of Electronics/Telecom. Department, N.A.A., Aminu Kano International Airport, Kano) and his wife Mrs Banke Dare for their parently advice and both financial and moral support throughout this course.

And special thanks goes to Mr Lateef Oladapo Omotosho of Dean's Office, Faculty of Engineering, A. B. U. Zaria, who helped me with the typing of the Thesis.

A B S T R A C T

The effect of tempering time (i.e storing time after preparation) on the properties of synthetic sands prepared from two clays, viz. Battatti and Kankara clays and Giwa river bed sand at different moisture contents was investigated. Foundry moulding sands prepared from these two clays were stored in airtight containers for different periods of time after preparation before being tested. The results of the investigations showed that increase in tempering time does not necessarily bring about significant improvements on properties of these sands. However slight changes in properties of the sand mixtures were noted when the tempering time was increased from 4 to 24 hours. While some properties were slightly improved, some were impaired. The author considers a tempering time of about 12 to 16 hours suitable for storing sand mixtures prepared from both clay sands as on the overall, improvements were obtained within this period and also it is more convenient to prepare sand mixtures and store them overnight before used.

The effect of cation exchange reaction brought about by Na_2CO_3 addition on foundry moulding sands was another aspect investigated. The results showed that a combination of improvements on properties of foundry moulding sands prepared from Battatti and Kankara clays could be achieved by the addition of small amounts of Na_2CO_3 to the sand mixtures. The use of 0.1 percent Na_2CO_3 is recommended for sands prepared from these two clays. Slightly higher amounts of Na_2CO_3 than 0.1 percent (about 0.2 percent) brought more improvements in some properties

but higher amounts of Na_2CO_3 will lower the refractoriness of the sands as the melting point of Na_2CO_3 is only 852°C.

The effects of using improved or better methods of preparation to prepare sand mixtures containing different percentages of Na_2CO_3 were also investigated. Five different methods of preparation; methods 1, 2, 3, 4 and 5 were used to prepare the sand mixtures containing different percentages of Na_2CO_3. Method 1 was the normal method where sand was mulled for 2 minutes dry and 5 minutes wet after a calculated amount of water was added to the sand mixtures. Method 2 was mulling 2 minutes dry and 10 minutes wet continously (i.e increase in mulling time). Method 3 was two-stage mulling using 5 percent water during the first mulling, airdrying the sand mixtures, and then remulling with calculated amounts of water (using no excess water during the initial mulling). Method 4 was two-stage mulling using 7.5 percent water during the initial mulling, airdrying the sand mixtures, then remulling with calculated amounts of water (slightly excess amount of water during the initial mulling). Method 5 was mulling with 10 percent water during the initial mulling, airdrying the sand mixtures, then remulling with calculated amounts of water (using excess amount of water during the initial mulling).

The results of the investigations showed that highest substantial improvements on properties of foundry moulding sands were generally brought about when method 5 was used to prepare sand mixtures containing different percentages of Na_2CO_3.

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CHAPTER ONE

INTRODUCTION

The greater part of the output of the foundry industry consists of castings made in refractory moulds, mainly in clay bonded sand moulds. In progressive foundries, it is recognised that the foundry sand deserves as much attention as the metal to be cast.

Efficient sand control usually cuts the cost of the finished castings, firstly by ensuring that the moulds are of good quality, thus minimizing the number of defective castings attributable to bad moulds and, secondly, by avoiding the use of unnecessarily expensive moulding sand.

Transportation cost accounts for the major share of the total cost of foundry sands. Therefore it is important that efforts are concentrated in substituting locally available moulding materials for the ones obtained from far away places. In such substitution, extensive laboratory work is required to arrive at the right moulding mixtures and this is followed by foundry trials. But most of the foundries in Nigeria do not have any sand testing facilities and they use the sands without knowing their properties. Therefore Universities and Research Institutions with available research facilities should concentrate on these areas in order to help the foundries.

Previous investigations by Mathew (1977) have shown that some sand mixtures prepared from local sand and clay materials are not of high enough quality to provide good quality moulds.

Therefore it becomes necessary to investigate ways of improving the quality of these sand mixtures. This work is an effort in that line and it is carried out to study the following:

1. The effect of Tempering Time on the properties of foundry moulding sands.
2. The improvement of properties of foundry moulding sands by cation exchange reaction brought about by Na_2CO_3 addition.
3. The combined effects of methods of preparation and cation exchange reaction brought about by Na_2CO_3 addition on properties of foundry moulding sands prepared from local materials.

CHAPTER TWO

FOUNDRY MOULDING SANDS AND THEIR PROPERTIES

2.1 The Ingredients of Moulding Sands

The major ingredients of clay bonded moulding sands are sand, clay and water. Sand is defined as the grannular refractory particles resulting from the breakdown of rocks. Moulding sands usually contain silica (SiO_2), Zircon ($ZrSiO_4$), Olivine ($2(MgFe)O.SiO_2$), Mullite ($Al_2O_3SiO_2$), Carbon or Chammote as base sand which forms 65 to 95 percent by weight of the moulding sand mixtures.

Clay may be defined as a natural earthy material which becomes plastic when moistened. Clay consists usually of flake-shaped particles that can be classified on the basis of their structure and composition. Clay, which is usually 3 to 35 percent by weight of moulding sands, binds or imparts cohesiveness to sand particles while the water which is usually 2 to 8 percent lubricates and helps the clay to develop its binding properties.

Apart from these three major ingredients, moulding sands may also contain one or more additives between 0 to 10 percent which are used to improve some properties or to avoid certain casting defects.

2.2 Natural and Synthetic Sands

Frequently sands are found in nature in intimate contact with clay, and in these cases the sand-clay mixtures may be used in the as mined condition after adding just the temper

water. Such sands are termed Natural sands.

Sands are also found free of clay or it may be purposely washed and separated from clay. These sands must be blended, before used, with clay and such other materials as desired or required. Such sands are called synthetic sands.

Natural and Synthetic sands have unique differences. As natural sands are used in the as mined condition, they may contain some amounts of organic and inorganic matters. The effect of this is to reduce the refractoriness of the sands and may only be used for casting non-ferrous metals and cast iron. Synthetic sands were originally exploited for steel foundry use because of their greater refractoriness as compared with natural sands and because of their lower required moisture content. More recently however, synthetic sands have become widely applicable for casting of other types of metals as they enable easy control of sand properties. This work deals with only synthetic sands.

2.3 Functional Requirements of Moulding Materials

Certain properties are required of moulding sands before they are considered suitable for moulding purposes. Moulding sands with good properties usually reduce the number of defective castings attributable to bad moulds. In general the following properties are considered important for any mould sand.

(1) Green Strength

One of the principal properties the sand must provide to the mould is the green strength. The need for green strength

arises when the pattern is withdrawn and the mould must retain its shape without distortion or collapse. The green strength enables the handling of the mould without breakage and must be sufficient to provide resistance to the initial washing of the sand by the molten metal during pouring.

(2) Flowability

The flowability of a moulding sand is its ability to be compacted effectively to a uniform density. The flowability of sand may be controlled by exercising control over the shape of the sand particles, the composition of the sand mix, green strength, deformation and toughness. The property tends to have an inverse relationship with the green strength.

(3) Dry Strength

As the molten metal is poured into a green sand mould, the sand in contact with hot metal quickly dries out. In dry sand moulding, the mould is dried in an oven before pouring. In either case, the mould must be able to withstand the erosive forces and the pressure of the liquid metal. This property is highly required in green sand practice to avoid friability should the mould dry out on standing before casting.

(4) Permeability

One of the greatest problems in casting especially in green sands is the gas and steam evolved and displaced from the mould. When hot metal is poured into the mould, large quantities of gas and steam are produced and also hot metal itself would contain some dissolved gases. To provide a path for the escape of these gases, permeability is an essential

property, giving protection against surface blows and similar defects.

(5) Toughness

The sand should not be very brittle and should be able to deform without rupture under forces applied on it during moulding. This is especially important during the withdrawal of the pattern.

(6) Refractoriness

The sand should have high refractoriness or the ability to withstand high temperature without fussion or any major physical change. This property is of very great importance in the manufacture of high melting point alloys, especially steel.

(7) Thermal Stability

The mould surface should be relatively stable and should not crack, or flake off under rapid heating when hot metal is poured into the mould.

(8) High Temperature Properties

Depending upon the mass of the casting, the moulding sand may require a combination of high temperature properties; including hot strength to withstand distortion, and capacity for deformation to yield to the contraction of the casting. Collapsibility determines the readiness with which the moulding material will break down in knock out and cleaning operations. High temperature tests enable moulds to be assessed under conditions similar to those existing during the casting and the cooling circle.

(9) Finish

The mould surface should be of good surface finish in order to obtain a smooth casting surface without any defect due to metal penetration.

(10) Durability

The sand should have the capacity to withstand repeated cycles of heating and cooling in intergrated sand system, that is, it should be reusable.

2.4 Methods of Testing Sand Properties and Apparatuses Used

The foundry sand Handbook published by the American Foundrymen's Society (A.F.S) gives the standard way of testing many of the sand properties. These A.F.S standards have world wide acceptance and many countries have adopted A.F.S systems for many aspects of sand testing. Thus for the purpose of this research work also, the A.F.S standards were used in most cases.

Detailed procedures for testing the various sand properties are not given here as they are obtainable from the "Operating Instructions" supplied by the manufacturers of the apparatuses, but the general principles and apparatuses used in testing various properties are given below.

2.4.1 Mechanical Analysis Test

The object of the mechanical analysis test is to determine the percentages of different sizes of sand grains and the amount of A.F.S clay which the sand contains.

The mechanical analysis is carried out in two stages:

(1) Clay content test

(2) Sieve analysis test

1. Clay Content Test

One major difference between clay and sand is the grain size difference. According to A.F.S, particles having sizes below 20μm are regarded as clay, but careful analysis shows that non clay particles (i.e particles which do not develop plasticity on water addition) are also included among these particles. Hence, this kind of clay is called 'A.F.S clay' by American Foundrymen's Society.

Plate I illustrates the Ridsdale-Dietert Rapid Sand Washer used for the clay content test conducted during this work. The unit, by means of rapid agitation separates the clay particles from the sand grains, in a sand. The clay is held in suspension, removed by means of a syphon, and is determined by loss of weight of the original sample after drying.

2. Sieve Analysis Test

The residue from clay content test was used for this test. The Combs Sieve Shaker and a set of British Standard Sieves were used for the test. Residue from clay content test was placed in the top sieve, the machine, through gyratory action shakes and ensures uniform distribution of material over the whole area of each sieve and the percentage of material retained on each sieve is determined.

A set of sieves contains the following sieves;

Aperture Size (μm)	Formerly Mesh No.	Remarks
2,000	8	Very Coarse
1,700	10	
1,000	16	Coarse
710	22	
500	30	
355	44	Medium
250	60	
150	100	Fine
106	150	
75	200	Coarse Silt
53	300	Fine Silt
PAN		

Plate II shows the set of sieves and the sieve shaker used for this test.

2.4.2 Moisture Content Test

Moisture content of a foundry sand is expressed as the percentage by weight of water present in moist sand which can be driven off at a temperature of 105 to 110°C. Moisture content may be determined by the loss of weight after evaporation. A 50g of tempered sample is weighed, dried at 105 to 110°C, cooled to room temperature in a desiccator and reweighed. Moisture content is expressed in percent by weight and is equal to twice the loss of weight noted after drying the sample.

An instrument for the determination of moisture content is the Moisture Teller.



PLATE I: RIDSDALE-DIETERT RAPID CAN WASHER

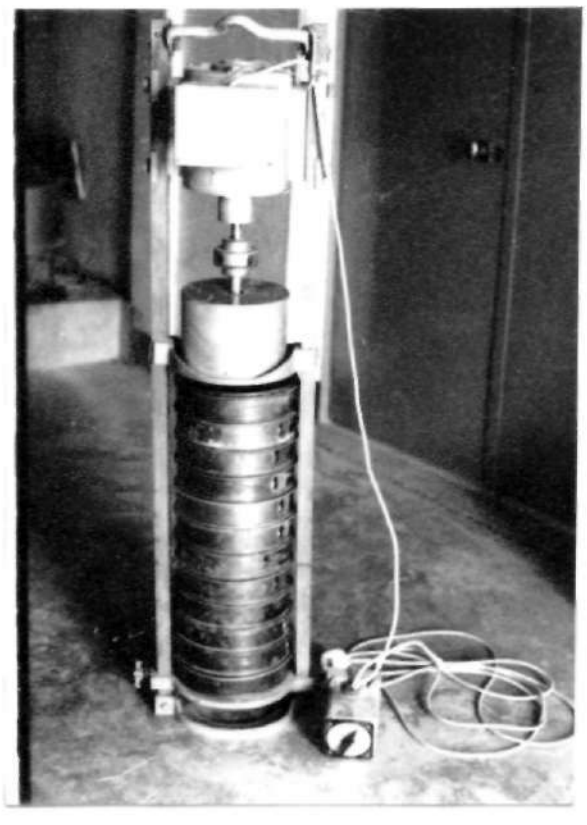


PLATE II: COMBS MECHANICAL SIEVE SHAKER
AND SET OF SIEVES

In the instrument, there is provision for blowing preheated air through the sand sample. A weighed representative sample of the moist material is placed in a special pan with fine gauze base and hot air at thermostatically controlled temperature is blown through it to remove the moisture. When all the moisture has been removed, the sample pan and contents are cooled and reweighed. From the loss in weight the percentage moisture is read directly on the dial of the special moist balance attached to the instrument.

Moisture content may also be determined by means of a chemical reaction. The instrument used is known as the Speedy Moisture Tester. About 7g of sand sample is weighed and placed in the cap of the tester. A measure of fine powdered calcium carbide is poured into the tester. The tester is then held sideways and carefully covered with the cap containing the sand sample. The cap is then tightened properly, and the instrument brought to the vertical position and then shaken well. The reaction produces a measurable amount of acetylene gas proportional to the amount of moisture in the sand. Moisture content is read directly from the calibrated scale on the instrument.

The major advantages of Speedy Moisture Tester over Moisture Teller are:

(1) Test made with this device is not affected by other volatile materials.

(2) Test is fast, reasonably accurate, and does not require much skill.

Speedy Moisture Tester was used for moisture determination in this project and is illustrated in Plate III.

2.4.3 Density Test

The density of moulding sand can be determined by Density Indicator attached to the A.F.S Sand Rammer. 165g of sand is weighed, poured into the specimen tube covered at the bottom with a pedestal cup, and then rammed with three drops of the sliding weight. The Ridsdale-Dietert Density Indicator attached to A.F.S Sand Rammer used for this project is shown in Plate IV.

2.4.4 A.F.S Standard Specimen

The standard specimen recommended by American Foundrymen's Society (A.F.S) for various room temperature tests is cylindrical in shape and has a diameter of 5.08cm (2in) and a height of 5.08cm (2in). The correct weight of sand to form an A.F.S standard specimen can be readily obtained from the density indicator. The standard specimen is needed for testing green strength, dry strength, air set strength, toughness (shatter index), permeability and green hardness.

2.4.5 Green Strength Test

Green Strength of moulding sand may be determined in compression, shear or in tension, but the most often used test is the compression strength test. Green compression strength is obtained by applying a uniformly increasing load on a standard specimen until fracture occurs. The Ridsdale-Dietert Universal Sand Strength Machine illustrated in Plate V was used for all strength tests performed in this project.

2.4.6 Oven Dry Strength Test

The dry strength is normally measured in compression. The standard specimen is usually dried in an oven at specific



PLATE XXI: SPEEDY MOISTURE TESTER

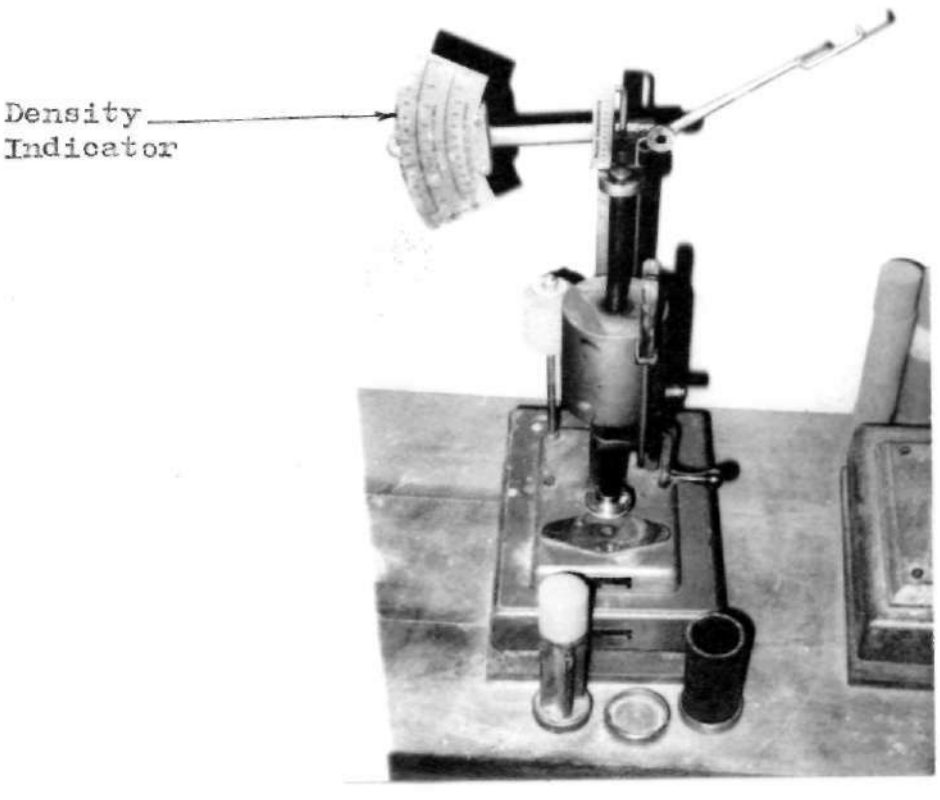


PLATE IV: RIDSDALE-DIETERT RAMMER AND SAND SPECIMEN

temperature for a specified period of time. For this work, the standard test specimen were prepared in the usual way and dried in a ventilated oven at 105 to 110°C for 2 hours. They were then placed in the compression heads and the load was gradually applied until specimen collapsed. The oven dry strength was then read on the scale designated 'Dry Compression'.

Full mould drying is usually accomplished in ovens operating at specified temperatures. Some moulds however are only surface dried, the practice being intermediate between green sand and full dry sand.

2.4.7 Air Set Strength Test

Green sand when left open to the atmosphere can easily lose water and the surfaces and the edges become dry. If the sand does not have sufficient air set strength, the air dried sand becomes loose and can cause dirts or inclusions in the casting. Thus it is advantageous to check the air set strength in order to avoid the use of sand with low air set strength. Standard specimens (5.08cm x 5.08cm d) were prepared and allowed to dry in the atmosphere then tested in the Ridsdale-Dietert Universal Sand Strength Machine.

2.4.8 Toughness Test

The mould should not be brittle so that satisfactory lift is obtained during pattern withdrawal. A number called the Sand Toughness Number (STN) is used in the United States

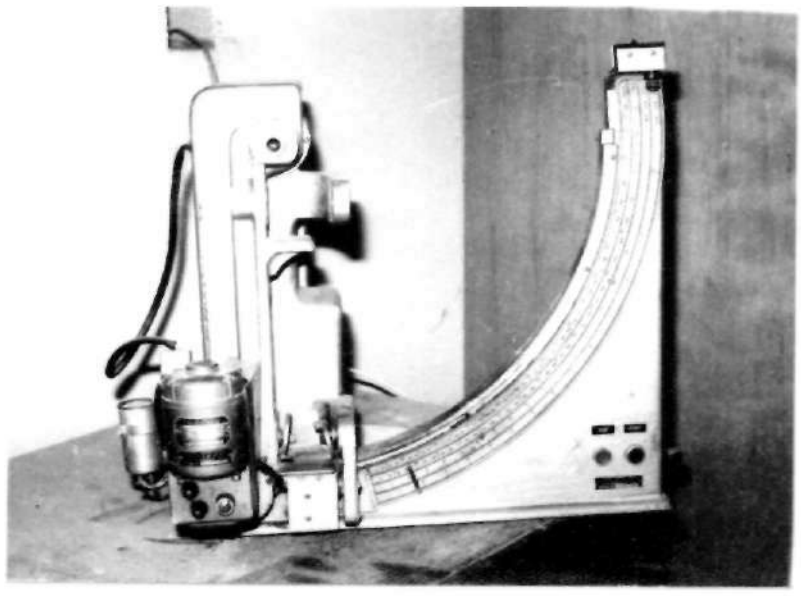


PLATE V (a): RIDSDALE DIETERT UNIVERSAL SAND STRENGTH MACHINE (MOTORIZED)

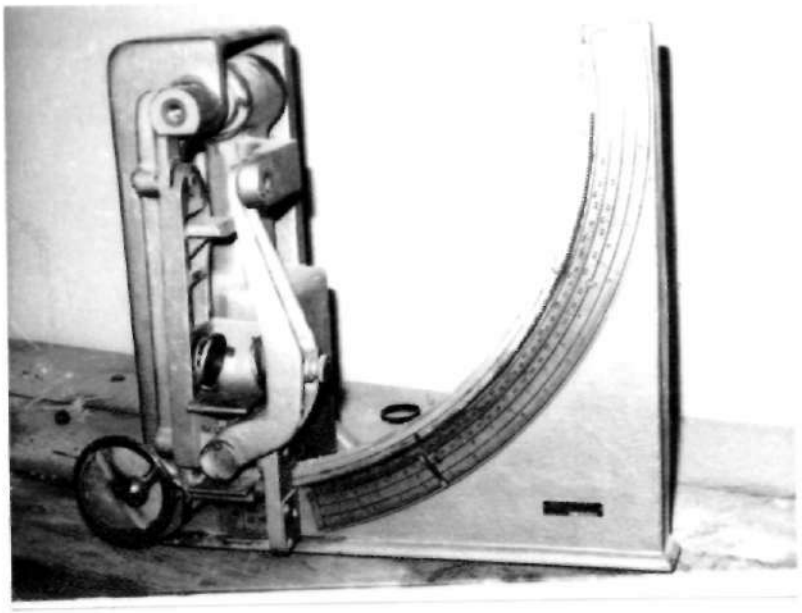


PLATE V (b): RIDSDALE DIETERT UNIVERSAL SAND STRENGTH MACHINE (HAND OPERATED) + ATTACHMENT.

to indicate workability of sand.

The product of deformation and green strength is used as the index of toughness.

Sand Toughness Number (STN) = d x s x 1,000

where d = deformation (in)

s = green compression strength (lbf/in^2)

The deformation or plasticity of a moulding sand is determined from the decrease in length of the cylindrical specimen during the green compression test.

The shatter index is a further measure of sand toughness. The Ridsdale Shatter Index Tester used in this project is shown in Plate VI. This equipment is designed to allow the free fall of an A.F.S standard specimen (5.08cm x 5.08cm d) of moulding sand from a height of 1.83m (6ft) onto a steel anvil. By measuring the degree of disintergration of the specimen the toughness or plasticity is determined. A low value of shatter index indicates friability in pattern withdrawal and subsequent handling operations, too high a value may indicate unsatisfactory moulding qualities resulting from excessive clay or water content. Values of 50 to 80 have been quoted by Davies (1950) as representing the mouldable range.

2.4.9 Permeability Test

Permeability is determined by measuring the rate of air passing through a compacted specimen under standard conditions.

PLATE VI: RIDSDALE SHATTER TESTER

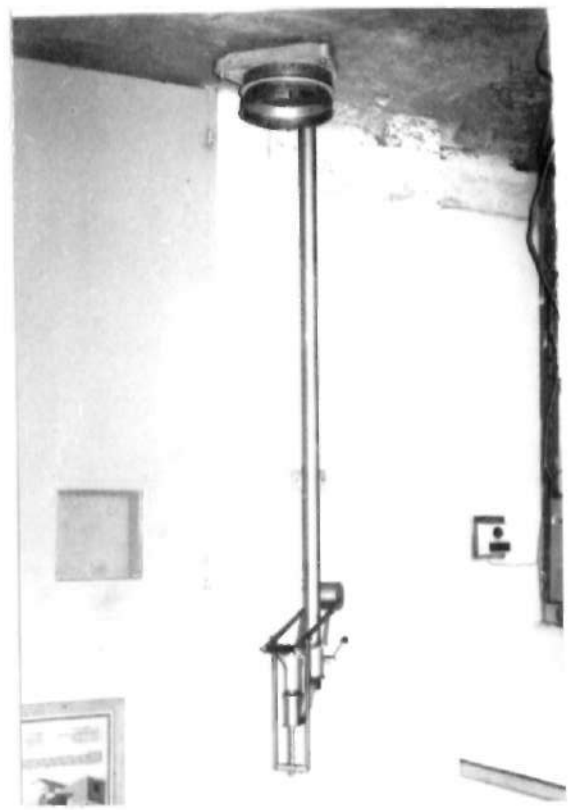


PLATE VII: RIDSDALE-DIFFERT
ELECTRIC PERMEATER



The test for green permeability is carried out on an A.F.S standard cylindrical specimen retained in the specimen tube.

The permeability number, P, as defined by the A.F.S, is the volume of air in cm^3/min passing through a specimen of 1cm length and cross-sectional area of $1cm^2$, under a pressure difference of 1cm water gauge.

$$P = \frac{V\,h}{p\,a\,t}$$

where P = permeability
V = volume of air ml passing through
h = height of testing specimen cm
p = pressure of air in cm of water
a = area of cross-section of specimen in cm^2
t = time in minutes

The standaard method requires that 2000 ml of air should be forced through a standard specimen (5.08cm x 5.08cm) of area $20.268cm^2$, thus substituting a values of V, h, and a and measuring time in seconds, the formula becomes

$$P = \frac{30072}{\text{air pressure in cm of water x time in seconds}}$$

so from the value of the time taken for 2000ml of air at a known pressure to pass through a standard specimen (5.08cm x 5.08cm) the permeability is determined.

Alternatively, a permeability meter with calibrated orifices may be used to meter the rate of flow of air through the sand specimen and by measuring the pressure between the

orifice and the specimen, the permeability may be obtained by referring to the attached table or the transparent direct reading scale. The Ridsdale-Dietert Electric Permmeter used for this project (illustrated in Plate VII) works on this method.

2.4.10 Compactability Test

The compactability test is carried out in conjuction with an A.F.S sand rammer. The test measures the decrease in height of a riddled mass of sand 12.07cm ($4\frac{3}{4}$in) high, under the influence of a standard compacting force.

By this means the degree of temper of sand can be measured and the water requirement determined. The Ridsdale-Dietert Compactability Tester used for this project is illustrated in Plate VIII.

2.4.11 Flowability Test

The flowability of a moulding sand as defined earlier is its ability to be compacted effectively to a uniform density. The flowability is measured by a dial indicator which can readily be attached to the A.F.S Standard Rammer such a way as to measure the plunger movement between the fourth and the fifth ram. If the plunger does not decend any further between the fourth and the fifth ram then the flowability is 100 percent. The further the plunger docends on fifth ram, the lower the flowability.

Plate IX illustrates the Ridsdale-Dietert Flowability Indicator used for this project. The gauge measures the ability of a sand to flow and fill up mould interstices when



PLATE VIII: RIDSDALE-DIETERT TUBE FILLER FOR COMPACTABILITY TEST

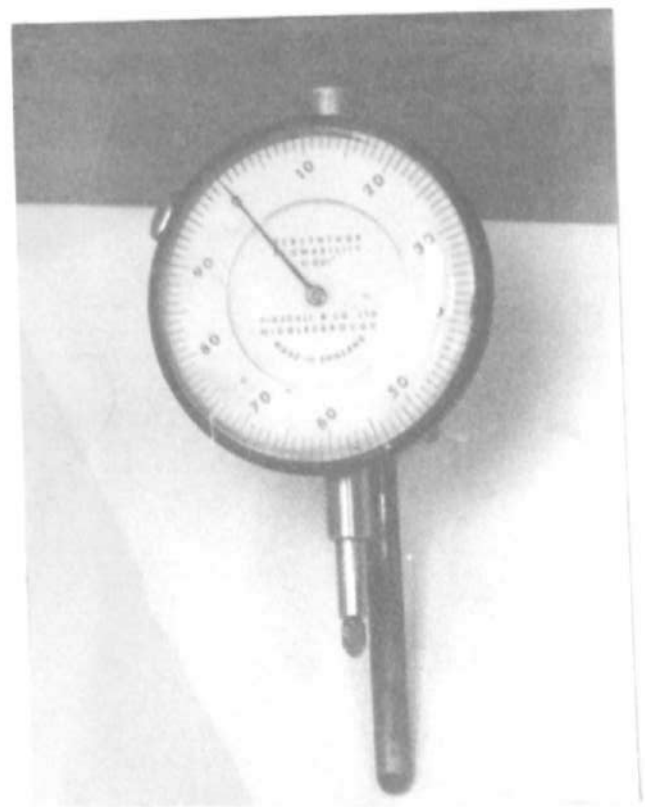


PLATE IX: RIDSDALE-DIETERT FLOWABILITY INDICATOR

subjected to ramming.

2.4.12 Green Hardness Test

The green hardness test is similar to the Brinell Hardness Test - the softer the mould surface, the greater the penetration of the probe into the mould. Ridsdale-Dietert Green Hardness Tester used for this project is shown in Plate X. The hardness number indicated is the measurement of depth of penetration of the probe in thousandth of an inch (0.0254mm).

A mould offering no resistance to penetration has zero hardness and one that completely resists penetration has hardness of 100. Other types of hardness are available for dry sands but are much less widely used.

2.4.13 High Temperature Tests

High temperature properties are not dealt with in this project.

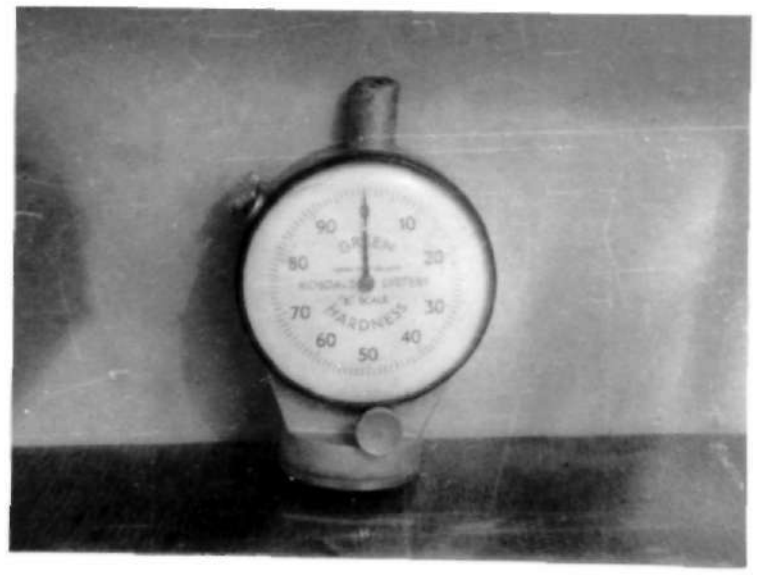


PLATE X: RIDSDALE-DIETERT GREEN HARDNESS TESTER

CHAPTER THREE

SELECTION OF FOUNDRY SAND MATERIALS

The first step in the preparation of moulding sand mixtures is to collect the ingredients, the most essential being sand and clay. Sand and clay collected from different locations usually have different characteristics.

3.1 Base Sand Selection

The sand commonly used for moulding is silica sand. It is usually found in river beds, lakes, sea shores and deserts. Moulding sands can also be prepared using zircon, olivine, chamotte, coke, dolomite, mullite or sillimanite grains mixed with clay, portland cement, plaster of Paris, petroleum residue or bitumens as binders. Silica (SiO_2) sand due to its wide availability is the base of the moulding sand in which most castings are made.

The base sand used for these investigations was from Giwa river bed which is accessible from Giwa village along Zaria - Funtua road. Quite a large quantity of sand is available at this location and commercial utilization is possible for at least medium sized foundries. Sand was collected at different depths from many locations of the river bed area and mixed thoroughly to have a representative sample. When a base sand is being chosen, the following characteristics are to be considered:-

1. The amount of clay present
2. Size and size distribution of the sand grains

3. Shape of the sand grains

4. Organic and inorganic impurities present

3.1.1 Clay Content of Giwa-River Bed Sand

It is essential to have knowledge of the clay content in sand deposits as this will be helpful for deciding the amount of clay to be added for preparation of the sand mixtures. The clay content of Giwa river bed sand was determined using a Ridsdale-Dietert Rapid Sand Washer and was found to be about 0.7 percent which is satisfactory for synthetic sand preparation.

3.1.2 Size and Size Distribution of the Sand Grains

The smoothness of casting (surface finish), permeability and to a lesser degree thermal stability, refractoriness and strength depend upon size and size distribution of sand grains. Elimination of large sand grains is beneficial in improving the casting finish but results in decrease of permeability. Coarser sand particles have large voids between them, therefore provide large permeability but poor surface finish. The permeability and surface finish seem to have an inverse relation as regards size and size distribution and therefore requires a compromise between them for the sand moulds to provide casting of good quality. The use of the finest sand that gives the required permeability is good practice.

A closer distribution of sand grains provides higher permeability than a wider distribution. When distribution is wider, the small grains fill the voids of the bigger grains reducing the permeability.

Dietert and Valtier (1933) in a joint paper state that fine sand grains will have absolute control of permeability of sand when they constitute 70 percent or more by weight. Therefore, a 70 percent addition of finer sand grains will cause permeability of the sand to reduce to the permeability of the fine sand material added. Similarly the addition of upto 30 percent of coarse sand will have only a slight effect in increasing permeability of a sand but will roughen the casting surface. If the permeability is to be increased by the addition of coarse grains, the percentage of the coarser sand added should be more than 30 percent. In short, the fine grains of a sand have a greater influence on permeability than the coarser grains.

As the sand is heated, it expands almost uniformly until it reaches a temperature of 573°C followed by a sudden expansion at that temperature due to the crystal change from α to β quartz. If the expansion of the sand can not be contained by the mould itself, the mould will become out of shape or the mould will buckle or crack causing casting defects. Parks (1971) says there is evidence that a uniformly sized sand expands more and is less thermally stable than a sand containing grains of varying sizes. The reason is said to be that in a uniform sand, all the grains in the surface layer of the mould heat up at the same rate and reach 573°C and at that temperature they receive the shock of the very rapid expansion due to the crystal change. With a wider distribution, the smaller grains heat up more rapidly than the larger ones and

would be contracting slightly as the larger grains reach the temperature of 573°C. This reduces the sudden expansion at the change point and reduces the casting defects due to the sand expansion. For this reason, four screen sand where 90 percent or more of the sand is retained on four adjacent sieves each having more than 10 percent retained on it is generally recognized as a popular one.

Similarly, a coarse sand has less expansion than a fine sand as the thicker clay coating on the coarser sand can compensate the expansion of the sand grains. Because of this thicker coating, coarser sand has also higher strength than a finer sand for the same amount of clay when the amount is not high. But where there is sufficient amount of clay to coat all the sand grains well, the finer grains give a higher strength as there are more interparticle contacts. But the effect of sand grains is not very high and therefore, sand grain size control is never used to control the strength of the moulding sands.

3.1.3 Size and Size Distribution of Giwa River-Bed Sand

The residue of the clay content tests were used to conduct the sieve analysis test using the Comb Sieve Shaker and a set of British Standard sieves. The result obtained is presented in table 3.1.

The above result can be represented with a bar chart as shown in Figure 3.1.

3.1.4 A.F.S Grain Fineness Number for Giwa River Bed Sand

The grain fineness number is approximately the number of meshes per inch of that sieve which would pass the sample if its grain were of uniform size, that is the average sizes of grains in the sample. It is obtained by multiplying the percentage of sand on each sieve and in the pan, by the sieve number of the sieve through which the sand has passed, adding the figures so obtained and dividing the sum by the total percentage of sand grains in the sand. The grain fineness number of Giwa river-bed sand is calculated as shown in table 3.3.

The grain fineness number of Giwa river-bed sand sieved with 710μm sieve was found to be 45 and the foundry sand grading classification of the sand is 6B as obtained from Ekey and Winter (1958). The sand is considered satisfactory for medium and heavy castings.

3.1.5 Sand Shape

Four different shapes of sand are recognised in foundry practice, they are round, subangular, angular and compound shapes. Round grain is considered the best for foundry use. It has higher flowability and requires less ramming energy to pack into moulds. But round grains are very rare and much more expensive than the others. Angular grains if well packed will have higher strength than round grains but lesser permeability. The compound grain is the most common but this sand usually breaks up during ramming so that the expected permeability and

TABLE 3.3: GRAIN FINENESS NUMBER CALCULATION FOR GIWA RIVER BED SAND SIEVED WITH 710μm SIEVE.

Sieve Size μm	Sand Retained			Multiplier	Product
	Weight (g)	Percent (%)	Cummulative Percentage		
1,000	0	0	0	10	0
710	0.25	0.5	0.5	16	8
500	7.7	15.4	15.9	22	338.8
355	19.3	38.6	54.5	30	1158
250	11.0	22.0	76.5	44	968
150	8.0	16.0	92.5	60	960
106	1.45	2.9	95.4	100	290
75	1.15	2.3	97.7	150	345
53	0.45	0.9	98.6	200	180
PAN	0.35	0.7	99.3	300	210
TOTAL	49.65	99.3	99.3		4,457.8
CLAY	0.35	0.7	100.		

Grain fineness No. = $\frac{\text{Total product}}{\text{Percent Sand Substance}} = \frac{4,457.8}{99.3}$

$= \underline{45}$

other sand properties are affected and therefore are not suitable for foundry use.

The Giwa river-bed sand when examined under a low magnification microscope was found to consist of mainly subangular grains which is satisfactory for foundry use.

3.1.6. Sand Impurities

The main effect of sand impurities is to lower the refractoriness of the sand. Pure silica has a melting point of 1,700°C and is considered highly refractory for most foundry applications. But impurities like organic matter, feldspar and mica fuse at lower temperatures and lower the refractoriness of the sand.

Giwa river-bed sand used for this projeot did not contain much organic impurities but it was found to contain minerals like mica and feldspar apart from the main mineral quartz or SiO_2. Thus Giwa river-bed sand may not be suitable for casting steel and other high melting point alloys unless it is washed and screened before use.

3.2 Clay Selection

Clay particles essentially are oomposed of Hydrous Aluminium Silicate and small amount of metallic ions substituted in the orystal. They are flake-shaped particles with very large surface area and small thickness.

The best clay for any synthetio sand mixture is that clay which gives best combination of sand properties with minimum cost. The main type of clay minerals in foundry use are:

(1) Montmorillonite or Bentonite

(2) Kaolinite

(3) Illite

The best for foundry use of these clay minerals is montmorillonite because it has much finer particle size than the other two types of clays. Montmorillonite clay gets hydrated

easily and when moistened, it swells and coats the sand particles more effectively than the other two clays. Because of this, montmorillonite is considered more plastic than the other two clay minerals.

Sand bonded with bentonite usually contains, only 3 to 6 percent clay and 2.5 to 4.1 percent water; illite, 5 to 7 percent clay and 4.1 to 6.1 percent water; kaolinite, 10 to 15 percent clay, 4 to 8 percent water. Because of the low clay content and low water requirement of montmorillonite, sand bonded with it is usually employed for steel casting and for casting other high melting point alloys.

The two types of clays used for this project are locally available and were collected from two different locations. They are:

(1) Battatti Clay: This was collected from Battatti clay deposit a few kilometers away from Bida in Niger State.

(2) Kankara Clay: This was collected from Kankara clay deposit, a few kilometers away from Malunfashi along Malunfashi - Katsina road in Kaduna State.

Fairly large deposits of clay have been found in these two locations and commercial utilization is possible. According to the information obtained from Geological Survey of Nigeria, Kaduna, the Kankara clay is almost pure kaolinite type of clay and Battatti clay is also mainly a kaolinite type but contains appreciable amounts of montmorillonite as well.

Fairly large quantities of clay were collected from these clay deposits and ground to fine particles by motorized

grinder of the Fine Arts Department of A.B.U. Zaria. The ground clays were later sieved through 250 µm sieve and all larger particles were removed. It was then decided to perform the clay content test of the two types of clays.

3.2.1 A.F.S Clay Content of the Two Clays

A.F.S standard procedure was applied to obtain the clay content of the two clays and results are as follows:

Battatti clay - 88.0%

Kankara clay - 80.3%

The residue of the clay content test was then used to conduct the sieve analysis test of the clays. The result of the sieve analysis is represented in table 3.4.

TABLE 3.4: MECHANICAL ANALYSIS OF BATTATTI AND KANKARA CLAYS

Sieve Size μm	Battatti Clay		Kankara Clay	
	Percentage Retained	Cummulative Percentage	Percentage Retained	Commulative Percentage
above 355	0	0	0	0
355	0.4	0.4	0.8	0.8
250	0.6	1.0	1.0	1.8
150	1.5	2.5	2.4	4.2
106	2.0	4.5	2.5	6.7
75	2.3	6.8	3.0	9.7
53	2.5	9.3	3.1	12.8
PAN	2.7	12.0	6.9	19.7
CLAY	88.0	100.0	80.3	100.0

3.3 Importance of Water and Amount of Water Required in Foundry Sand Mixtures

Water is the third important ingredient of foundry moulding sand. It affects almost all the properties of the moulding sand and sand quality; therefore control of the amount of water added to a moulding sand is extremely important.

There should be just sufficient amount of water to plasticize the clay. If the amount of water is not sufficient, the clay will not develop enough plasticity and strength. If in excess, water may be librated from the sand at an explosive rate causing blows and other defects in casting. Excess water can also lead to casting oversize and overweight due to higher deformation of sand. Thus as excess water is a serious source of trouble in casting, the

amount of water added is of extreme importance in preparation of the moulding sand especially the ones to be used in the green state.

The amount of water added depends on:

(i) the amount and type of clay

(ii) the fineness of the sand

and

(iii) the amount and type of additives.

Water added to a sand mixture is absorbed by :

(i) the surface of the grains

(ii) the clay bond

(iii) the additives

Therefore the actual percentage of water added does not determine whether the moisture is enough, high or low.

When the amount of water in the green state is just sufficient to plasticize the clay particles and produce good bond strength, the sand at this moisture level is said to be correctly tempered or at the correct degree of temper. Some Moulders through experience are able to determine whether a moulding sand mixture is at the correct degree of temper or not by ordinary hand feel. This is popularly known as Moulder's Handfeel, but it is not impossible that the judgement of different moulders for correct degree of temper of the moulding sand to vary.

Some investigators, however, have shown that compactability is a good indication of the degree of temper of sand and at 45 percent compactability, the sand can be considered as correctly tempered for green sand moulding.

In dry sand moulding, excess water can be used as sand gives better workability and higher strength at higher moisture levels and there is no need for fear of blows and swellings as the water is removed before pouring.

3.4 Sand Additives

The principal constituents of a moulding sand mixture are base refractory and the bonding material, but other substances are added to confer special qualities.

Additives are added to sand for the following reasons:

(i) To improve certain properties mainly dry strength and toughness.

(ii) To improve the surface finish of the casting.

(iii) To avoid casting defects such as expansion defects like scabbing, rat-tailing etc.

(iv) To make shake out easier.

The common types of additives used for foundry purposes can be classified as follows:

(i) Carbonaceous additives (facing additives)

(ii) Cereal additives

(iii) Cellulose materials (cushioning additives)

(iv) Fine additives

(v) Chemical additives

3.4.1 Carbonaceous Additives (Facing Additives)

Facing additives such as coal, pitch, oil and carbon are all of carbonaceous in nature. Seacoal is generally a mix of several high volatile low ash, low sulphur coals, ground to different degrees of fineness. The coarser grades are used for

heavier castings. Sea coal retards the expansion and increases the hot deformation and also retards the heat flow into sand. Solid and liquid asphaltic residues from the petroleum cracking processes are also used as facing additives to foundry sands. Petroleum hydrocarbons are available in liquids and dry powdered form. These materials may be emulsified so that they mix readily with water. This is one form of facing additive that does not hinder the tempering of sand.

Pitch, a by-product of gas houses, in a dry finely ground state, is a common foundry material used both as a facing additive and a binder in dry sand moulds.

Finely ground graphite and hydrocarbon powder may also be added to a moulding sand to secure better castings.

All these additives are called facing additives because they improve the surface finish of the casting. They usually form a carbonaceous layer on the metal-sand interface of the mould. A reducing atmosphere is also formed thus preventing oxidation of iron and hence formation of iron silicate in cast iron or steel casting.

3.4.2 Cereal Additives

Cereal additives of various grades (cereals, sugar, starch, molasis etc.) find a definite use in improving the moulding sands. The cereal additive improves the toughness, green strength, air set strength, dry strength and hot strength of a sand resulting in better lifts and cleaner casting.

3.4.3 Cellulose Material (Cushioning Additives)

Cellulose materials commonly referred to as wood flour after grinding, are extensively used by foundries in their sand mixtures to improve the casting surface finish and to reduce surface defects. Other types of cellulose materials used are horse manure, grain husks and nut hulls.

Dietert (1954) in a paper stated that cellulose material additives in the order of from 0.5 to 2 percent reduce the dry, hot and retained strength and also spalling. The addition of cellulose material to moulding sand will eliminate or reduce the mould wall fractures. Due to the cushioning effect of cellulose additive on the metal interface and the mould, expansion of the mould which usually affects the cast part is prevented. Shake out is also made easier.

3.4.4 Fine Additives

The additives such as silica flour, and iron oxide may be grouped into fine additive. In this group, one may place silica flour, zircon flour, olivine flour, fly ash, alumina flour and iron oxide (very small quantity of iron oxide is normally used so that the casting is not affected due to the formation of iron silicate).

Silica flour is used extensively in foundries and the effect it has on the mechanical properties of a sand should be well known. The strength properties are affected as follows: Green, dry, hot and retained strengths are materially increased with increasing quantity of silica flour additives. The sintering, green deformation, hot deformation, density and expansion are all increased with increase in silica flour.

Both permeability and flowability are decreased. Thus silica flour may be considered largely as an increasing additive.

Olivine flour, if it were available at an economical price, would find good use in the foundry due to the fact that it has no free silica. Other finely ground materials such as alumina, boiler fly ash, iron oxide will perform as well as silica flour.

3.4.5 Chemical Additives

The practice of adding chemicals to moulding sand is the most recent except in sand used for magnessium casting where the practice of adding chemicals is well established. In this, the purpose is to avoid oxidation of magnessium metal and to give a smooth casting surface.

A number of steel foundries are adding sodium carbonate to the moulding sand. The pH value is held at or near 7.7. When one changes the pH value of a sand, whether by an additive or by the acidity of water, one should recorgnise that a pH change can result in a base exchange that will alter all the properties of the clay contained in the sand.

For this research work, sodium carbonate was used as a chemical additive to subject the sands to cation exchange treatment and thus to study its effect on the properties of the sands.

CHAPTER FOUR

THE EFFECT OF TEMPERING TIME ON PROPERTIES OF FOUNDRY MOULDING SANDS PREPARED FROM LOCAL MATERIALS

4.1 Introduction

One major factor to be considered in the preparation of moulding sands is the time for which the prepared sand mixture has to be stored or left in closed containers before moulding. The storing period is called the tempering time and is highly essential as a clay cannot develop all its binding properties during the short period of mulling.

In the American Foundrymen's Society's Foundry Sand Handbook, (1952), sixth edition, it is stated that for research work, the sand mixtures should be left in air-tight containers for 2 hours before being tested. Some investigators however suggest that the sand mixtures should be left to temper overnight before they are tested.

It was therefore decided to investigate to see how the variation in the tempering time would affect the properties of foundry sands in order to suggest a suitable tempering time for sand mixtures. Two local sand mixtures, Giwa river bed sand + Battatti clay sand mixture and Giwa river bed sand + Kankara clay sand mixture were used for this purpose.

4.2 Experimental Procedure

The first step was to decide the clay to sand ratio for preparation of the sand mixtures. Previous investigations by Mathew (1977) on Battatti and Kankara clays showed that sand mixtures suitable for a variety of applications can be obtained

by mixing a base sand with 15 percent Battatti clay and 15 percent Kankara clay. It was therefore decided to carry out the experiments using the same composition.

Davies (1950) has suggested that the sand mixture has to be first mixed 2 minutes dry and then at least 4 minutes wet after adding the temper water so that all the sand grains could be evenly coated with bond materials thus improving the strengbh of the sand mixture. But the degree of mulling to a large extent will depend on the efficiency of the muller and the amount of sand mulled at a time. For these investigations therefore, it was decided to prepare all the samples by mulling 2 minutes dry and for 5 minutes wet after adding a calculated amount of water to get approximately the required moisture levels after preparation, for different samples. The calculated amount was slightly in excess of the required amount for desired moisture level so as to allow for losses due to evaporation, initial wetting of the muller and other factors. Sand mixtures were prepared in a Riddale Laboratory Mill, with rotating wheels shown in Plate XI. The sand mixtures were then taken out and stored in air tight containers for the following tempering times before testing for the properties:

(i) 4 hours
(ii) 8 hours
(iii) 12 hours
(iv) 16 hours
(v) 20 hours
(vi) 24 hours

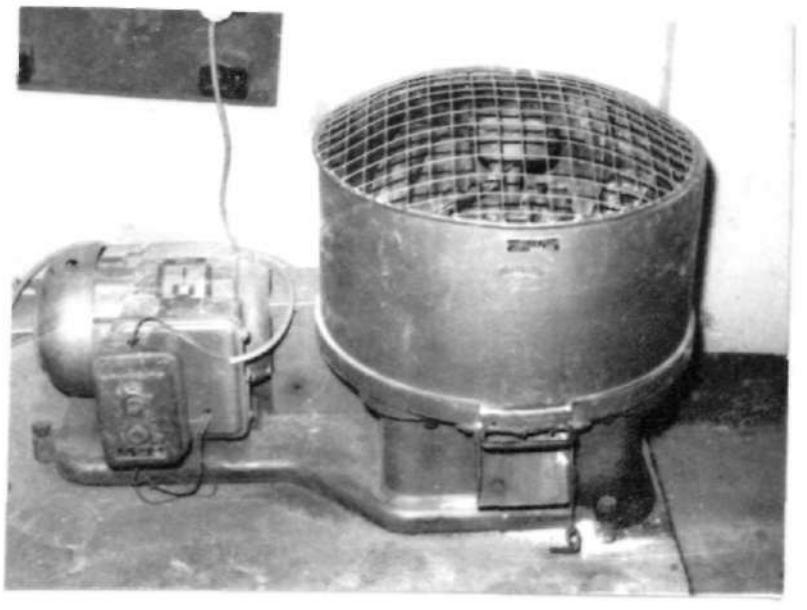


PLATE XI: RIDSDALE LABORATORY MILL WITH ROTATING WHEELS

Sand mixtures weighing 2kg where prepared at 5 moisture levels for each of the tempering time. A total of about 60 samples were prepared and tested in these investigations. At the end of each tempering time, the following properties of sand mixtures were determined.

(1) Moisture Content
(2) Density
(3) Permeability
(4) Green Compression Strength
(5) Oven Dry Strength
(6) Air Set Strength
(7) Shatter Index
(8) Compactability
(9) Green Hardness
(10) Flowability

4.3 Results

The results of the investigations are presented graphically in figures 4.1 to 4.6. The letter "T" marked on the curves represent the values of the properties at temper points. These values at the temper points are again shown in Table 4.1. and Table 4.2.

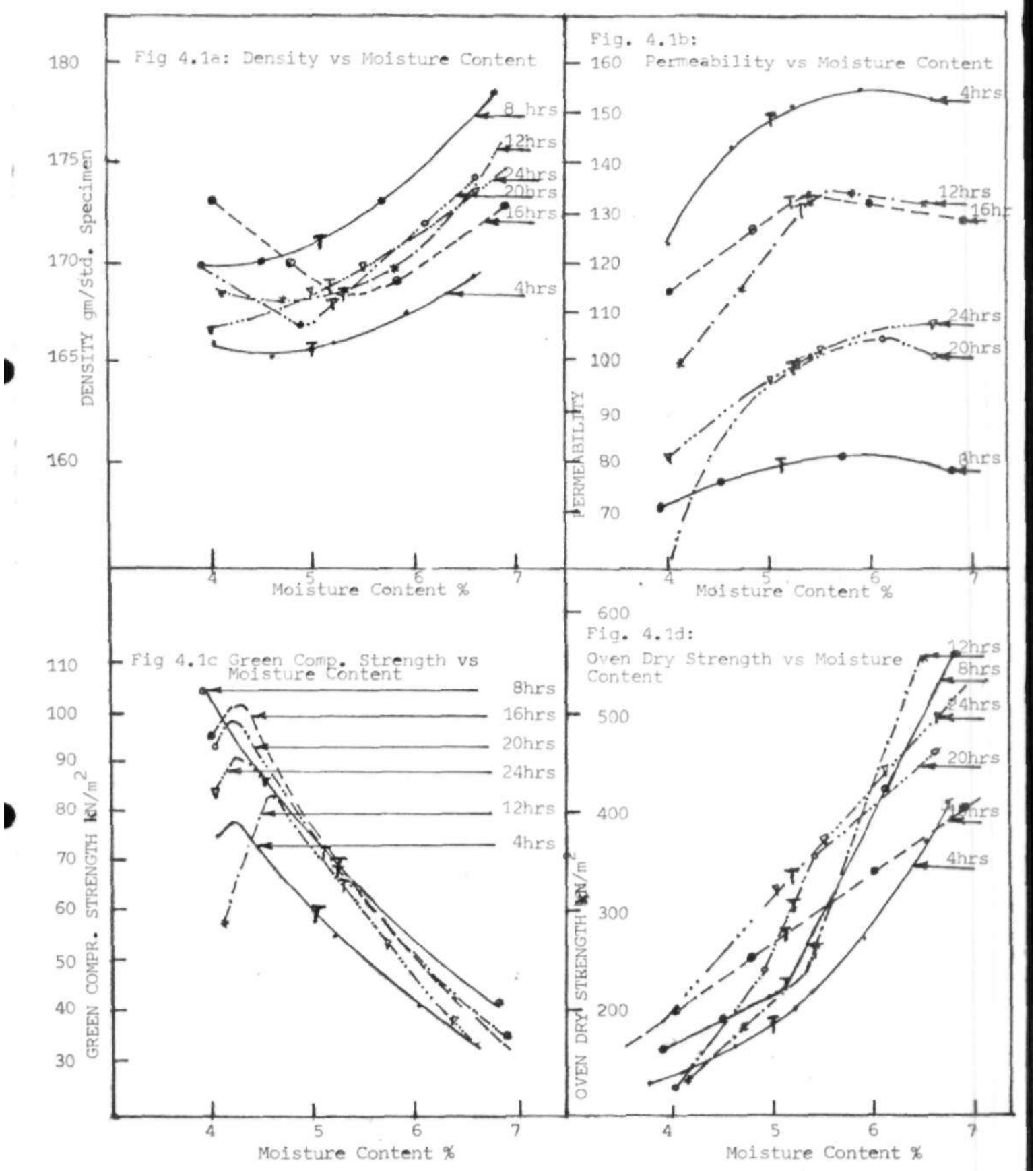


FIG. 4.1: EFFECT OF TEMPERING TIME ON DENSITY, PERMEABILITY, GREEN COMPR. STRENGTH AND OVEN DRY STRENGTH OF BATTATTI CLAY SANDS.

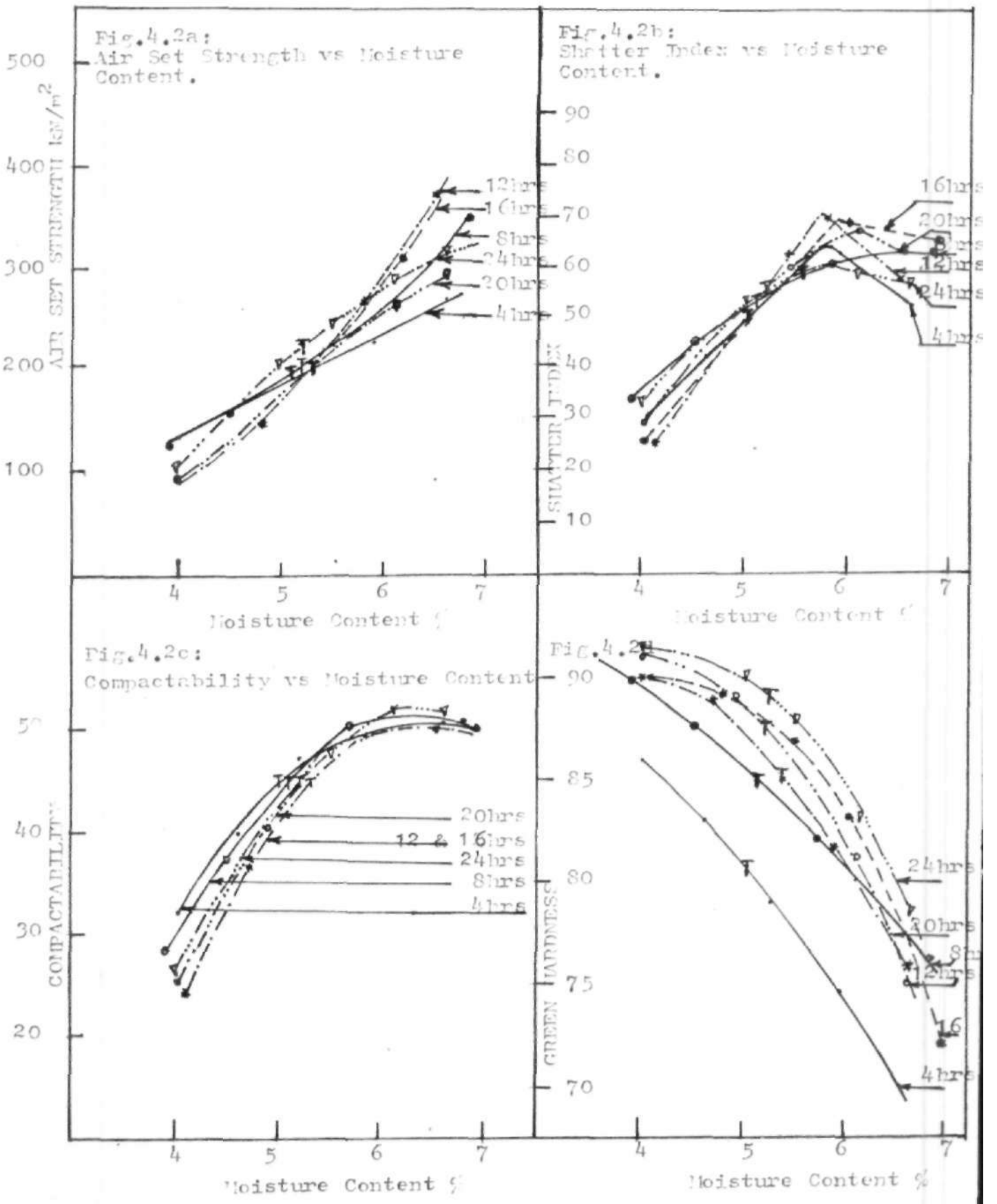


FIG. 4.2: EFFECT OF TEMPERING TIME ON AIR SET STRENGTH, SHATTER INDEX, COMPACTABILITY, GREEN HARDNESS OF BATTATTI CLAY SANDS.

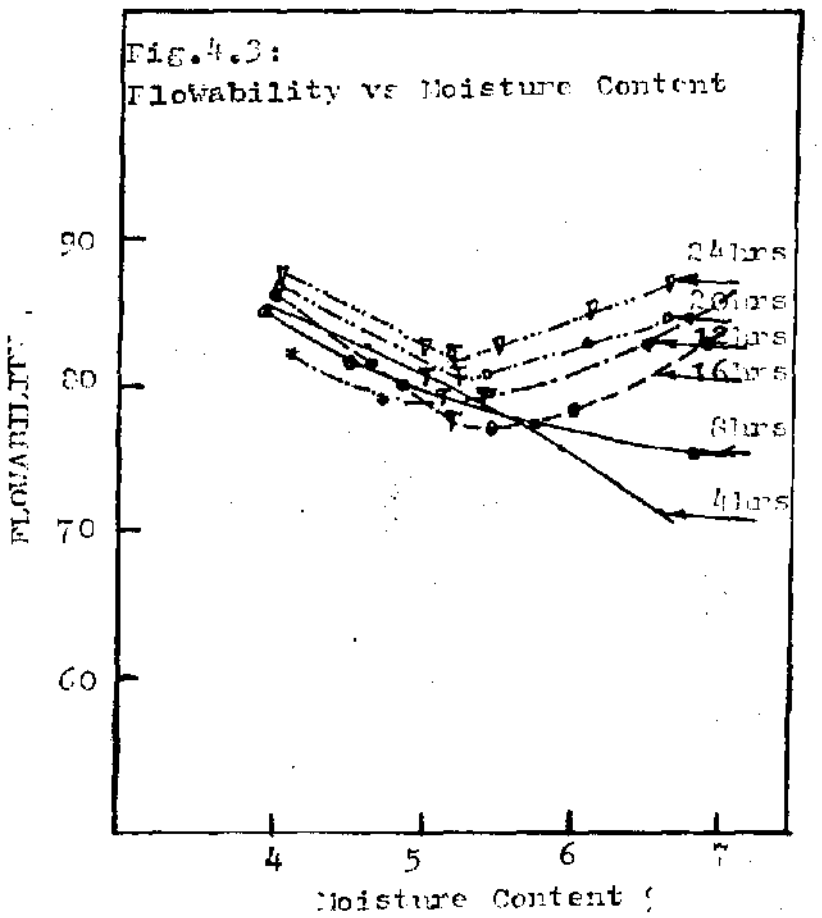


FIG. 4.3: EFFECT OF TEMPERING TIME ON FLOWABILITY OF BATTATTI CLAY SANDS.

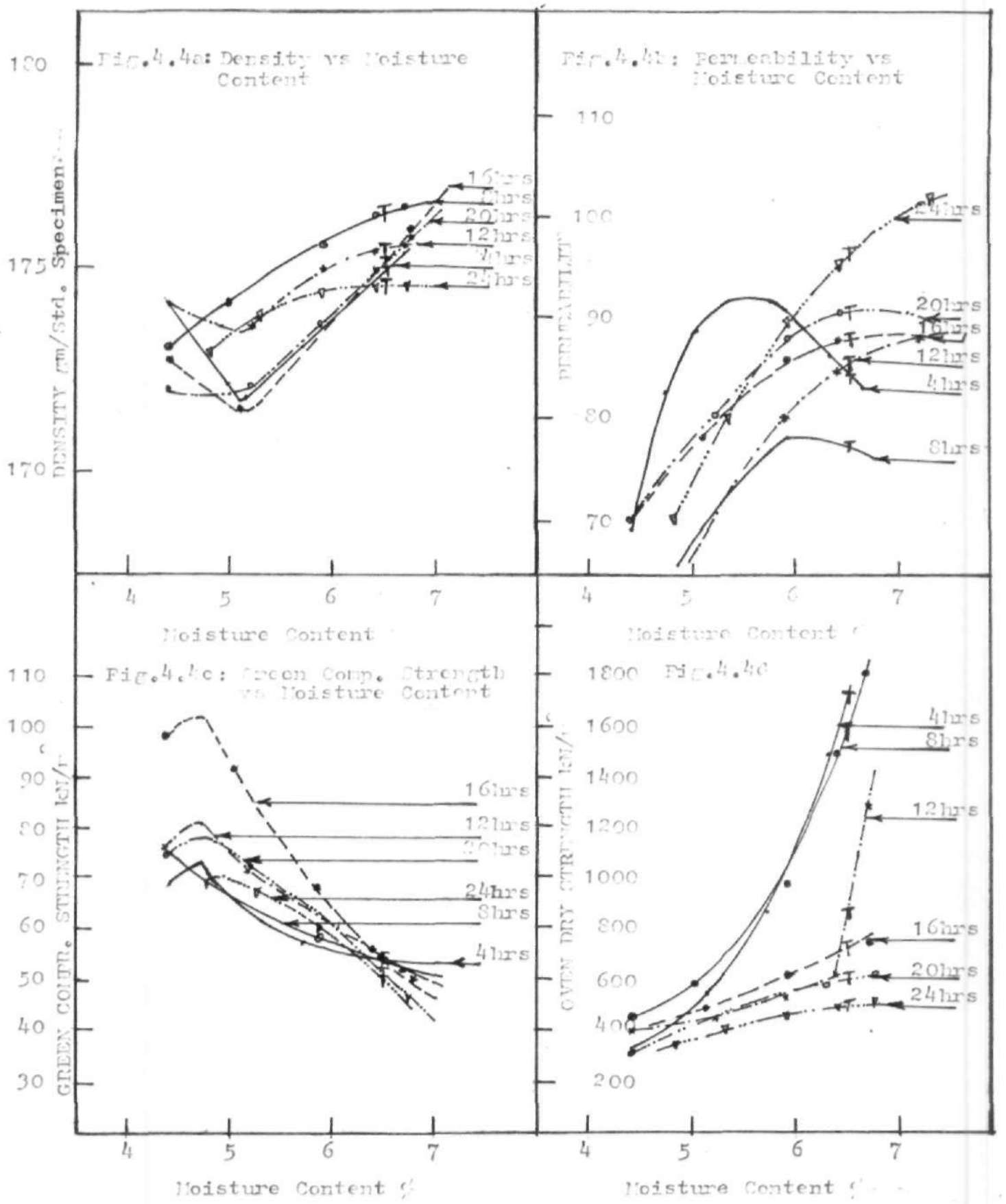


FIG. 4.4: EFFECT OF TEMPERING TIME ON DENSITY, PERMEABILITY, GREEN COMPR. STRENGTH AND OVEN DRY STRENGTH OF KANKARA CLAY SANDS.

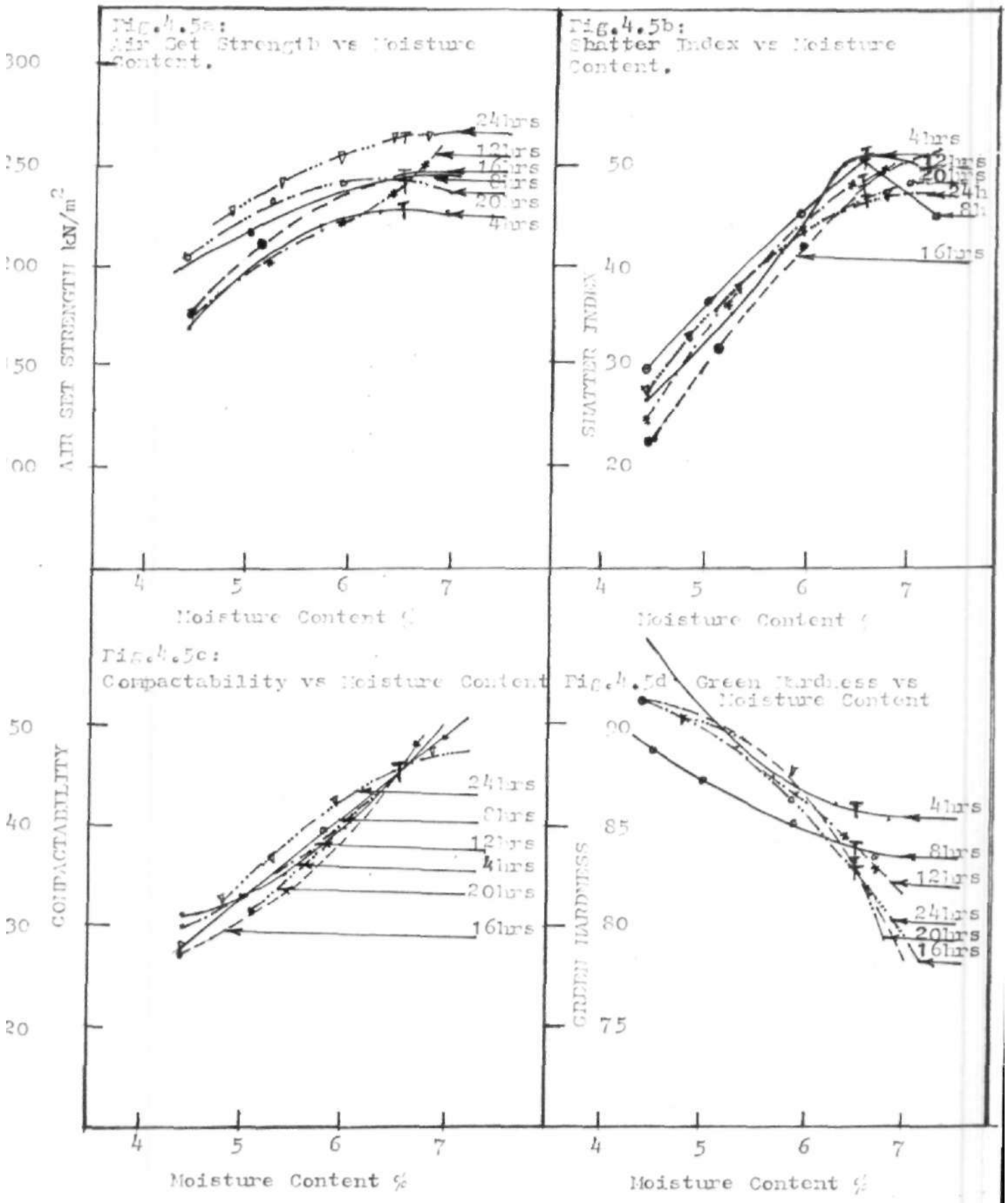


FIG. 4.5: EFFECT OF TEMPERING TIME ON AIR SET STRENGTH, SHATTER INDEX, COMPACTABILITY, GREEN HARDNESS OF KAINDARA CLAY SANDS.

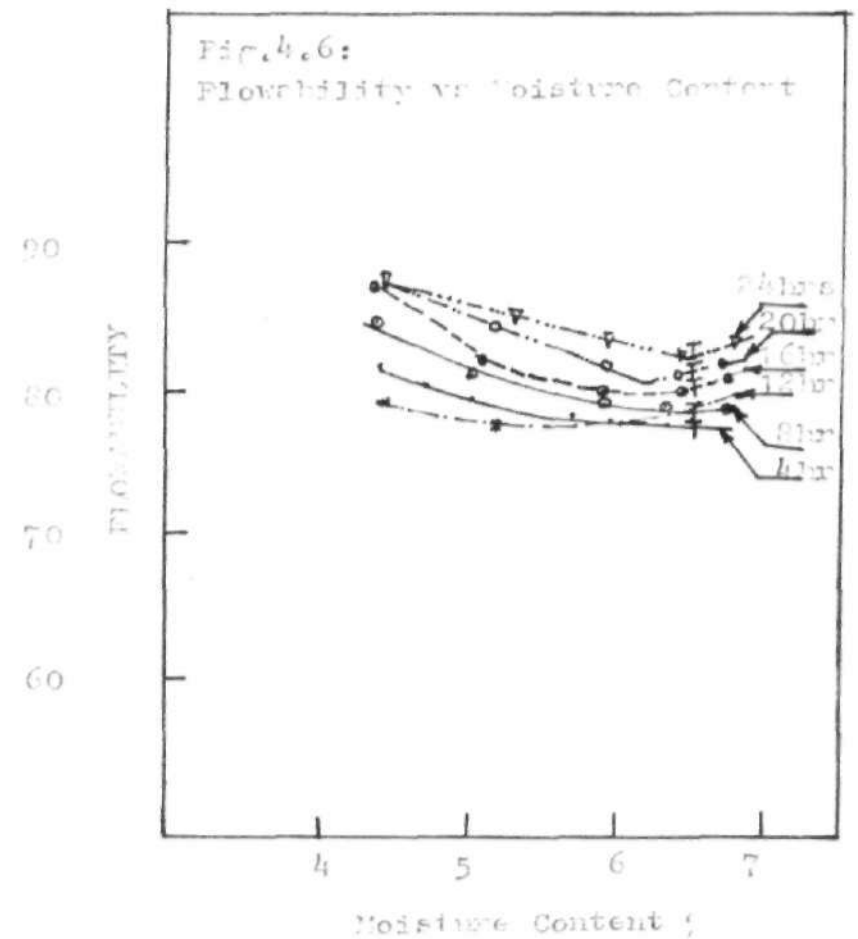


FIG. 4.6: EFFECT OF TEMPERING TIME ON FLOWABILITY OF KANDARA CLAY SANDS.

TABLE 4.1: VALUES OF PROPERTIES AT TEMPER POINTS FOR BATTATTI CLAY SANDS

Tempering Time (hours)	4	8	12	16	20	24
Moisture Content %	5.0	5.1	5.3	5.2	5.2	5.2
Density gm/std specimen	165.5	170.8	168.3	168.1	168.0	168.8
Permeability	149	79	130	132	99	98
Green Compression Strength (kN/m^2)	59	67	68	70	69	67
Oven Dry Strength (kN/m^2)	189	245	260	280	304	337
Air Set Strength (kN/m^2)	180	193	200	200	200	220
Shatter Index	50	52	55	54	54	54
Compactability	45	45	45	45	45	45
Green Hardness	80	85	85	87.8	87.8	89.3
Flowability	80.5	80	79	78.5	81	82

TABLE 4.2: VALUES OF PROPERTIES AT TEMPER POINTS FOR KANKARA CLAY SANDS

Tempering Time (hours)	4	8	12	16	20	24
Moisture Content %	6.5	6.5	6.5	6.5	6.5	6.5
Density gm/std specimen	175	176.5	175.5	175.2	175.1	174.8
Permeability	84	77	85.5	88	90.3	95.5
Green Compression Strength(kN/m^2)	54	54	54	53	52	50
Oven Dry Strength (kN/m^2)	1720	1560	860	720	600	500
Air Set Strength (kN/m^2)	230	235	240	244	250	262.1
Shatter Index	51	50	48.8	48	46.5	46
Compactability	45	45	45	45	45	45
Green Hardness	85.7	83.7	83.5	83	82.5	82
Flowability	77	77.5	78	80	81.5	82.5

4.4. Discussion of the Results

The results of the investigations are discussed below:

4.4.1 Moisture Requirement at Different Tempering Times:

As could be observed from the results, some sand properties change with the tempering time. The changes in other properties are not very significant especially after 12 hours of tempering time. The behaviour of Battatti and Kankara clay sands are different with changes in tempering time. The fact that the sand properties change with moisture content needs no mention as it is well known. The moisture requirement of a sand mixture will depend on its composition, degree of mulling etc.

In green sand moulding, as sands are brought to the correct degree of temper before moulding, it is always better to compare properties of different sand samples at the correct degree of temper or at the temper point. As discussed earlier in chapter three, compactability was used to assess the degree of temper of various sand mixtures and at 45 percent compactability the sand mixtures are considered to be at the correct degree of temper.

Figures 4.2c and 4.5c represent the compactability versus moisture content relationship of sand mixtures prepared from both Battatti and Kankara clays respectively at various tempering times. From these two figures, percentages of water required at various tempering times for sand mixtures to reach correct temper points (45 percent compactability) were obtained and shown in tables 4.1 and 4.2 respectively.

The letter "T" marked on compactability to moisture curves show the moisture content at temper points for different tempering times.

There was no noticeable change in water requirement (moisture content) at temper points of Kankara clay sands for all the tempering times tested. In case of Battatti clay sands, water requirement at temper point changed slightly but changes were not very significant. Water requirement of Battatti clay sands slightly increased from 5.1 percent at 4 hours tempering time to 5.3 percent at 12 hours tempering time and then maintained a value of 5.2 percent for 16, 20 and 24 hours tempering times.

4.4.2 Density

Mould strength partly depends upon effective compaction and partly, in the case of heavier castings, upon the mechanical support derived from the box bars and metal reinforcements. The general aim of compaction is to bring the bulk density from its loose value towards a value that will provide adequate mould strength. Thus the density or compactiveness of sand play important role in sand control work. Changes in density or compactiveness usually mean changes in some other properties like green strength, dry strength and permeability.

Davies (1950) in one of his works showed that as the density was increased, the green strength, green hardness and dry strength were all increased but the permeability decreased. Density also has considerable effect on thermal conductivity of

sands. A dense sand has a higher thermal conductivity and provides increased rate of solidification of the casting while a less dense or porous sand acts as an insulator and restricts heat flow.

Figures 4.1a and 4.4a show the density to moisture content relationship of Battatti clay and Kankara clay sand mixtures at various tempering times. The letter "T" marked on the curves show the density values at the temper points on these graphs and their values are given in tables 4.1 and 4.2. From table 4.1, it could be seen that the density of Battatti clay sand increased to some extent when the tempering time was increased from 4 hours to 8 hours. The mass of sand required for standard specimen increased from 165g to 170.8g. It then decreased to 168.3g for 12 hours tempering time and remained about this same level with further increase in tempering time. Also from Table 4.2, the mass of sand required for standard specimen for Kankara clay sands increased slightly from 175g at 4 hours tempering time to 176.5g at 8 hours tempering time. It then decreased to 175.5g for 12 hours tempering time and remained about the same level with further increase in tempering time.

4.4.3 Permeability

As discussed earlier in chapter two, permeability is an essential property of moulding sands which must be high enough in value to allow gas and steam evolved during casting to pass through the mould. This is important to protect the cast part against surface blows, gas holes and other similar defects.

The permeability to moisture content relationship at various tempering times are illustrated in figures 4.1b and 4.4b for Battatti and Kankara clay sands respectively. The letter "T" marked on the curves showed the permeability values at temper points for various tempering times and are also given in tables 4.1 and 4.2 respectively. For the two clay sands, there were drops in permeability values at temper points when the tempering time was increased from 4 hours to 8 hours. The drop in permeability of Battatti clay sand mixtures were more significant as it dropped from a value of 149 to 79. It increased again to 130 when the tempering time was increased to 12 hours. The drop in permeability values for Kankara clay sand mixtures was not so significant as it only dropped between a value of 84 and 77 when the tempering time was increased from 4 hours to 8 hours. It then increased to 85.5 for 12 hours tempering time and gradually to 95.5 as the tempering time was increased to 24 hours. The drop in permeability between 4 and 8 hours is likely to be due to increase in density values of these two clay sands between these tempering times. Increase in density values may be due to larger condensation of water usually noticeable on the container lids when the tempering time was increased from 4 hours to 8 hours. To verify these results and its authenticity, this particular aspeot was repeated about four times and almost the same set of readings were obtained.

The maximum values of permeability for the two clay sands occured almost at the temper points.

At temper points, clay is believed to be stiffest and keeps the sand grains further away from each other thereby increasing the permeability.

4.4.4 Green Compression Strength

The green compression strength is most widely used in sand tests. The green strength value increases with increase in moisture level to a maximum value after which further increase in moisture level brings about a decrease in green strength.

Figures 4.1c and 4.4c show the green compression strength to moisture content relationship for Battatti and Kankara clay sands for the tempering times investigated. The letter "T" marked on the curves indicate the green compression strength values at temper points and the values are shown in tables 4.1 and 4.2. From these tables, it can be seen that the green compression strength values at temper points are 59kN/m^2 for 4 hours tempering time, 67kN/m^2 for 8 hours, 68kN/m^2 for 12 hours and 70kN/m^2 for 16 hours tempering time. Increase in tempering time above 16 hours brought about a decrease in the green strength values. In the case of Kankara clay sands, the green compression strength was 54kN/m^2 for 4 hours, 8 hours and 12 hours tempering times and decreased from this value when the tempering time was increased gradually to 24 hours.

4.4.5 Oven Dry Strength

The dry strength helps to withstand erosive forces and pressures of liquid metals when poured into the mould. The low limit of the dry strength is set by the eroding power of the

metal. The chances of erosion are increased by the heaviness of metal, high speed of flow, sudden swerves and impingements. Dry strength is also required in green sand moulding to avoid friability should the mould dry out on standing before casting.

Figures 4.1d and 4.4d illustrate the oven dry strength to moisture content relationships for Battatti and Kankara clay sands at all tempering times investigated. The letter "T" marked on the curves indicate the oven dry strength values at temper points. These values are shown in tables 4.1 and 4.2 for Battatti and Kankara clay sands respectively. From these tables, it could be seen that the behaviour of the oven dry strength values of the two clay sands with respect to the tempering time is quite different. In the case of Battatti clay sands, the oven dry strength increased gradually from 189kN/m^2 for 4 hours to 337kN/m^2 for 24 hours tempering time (an increase of 78 percent). In the case of Kankara clay sands, the reverse is the situation. The oven dry strength of Kankara clay sands decreased gradually from 1720kN/m^2 for 4 hours to 500kN/m^2 for 24 hours tempering time (a decrease of 71 percent). The oven dry strength results for Kankara clay sands was initially thought to be due to experiemental error, but the results were found to be valid as similar results were obtained when these tests were repeated another four times. In anycase, increase in oven dry strength of Battatti clay sands with increase in tempering time is an advantage as Battatti clay sands generally has a low oven dry strength.

4.4.6 Air Set Strength

Green sand when left opened to the atmosphere can easily loose water and their surface edges become dry. If the sand does not have sufficient air set strength, the air dried sand becomes loose and can cause inclusions and dirt in the casting. Thus it is advantageous to check the air set strength to avoid the use of the sand with low air set strength.

Figures 4.2a and 4.5a show the air set strength to moisture content relationships for both Battatti and Kankara clay sands at various tempering times. The letter "T" marked on the curves indicate the air set strength values at temper points for all tempering times. These values are shown in tables 4.1 and 4.2 for Battatti and Kankara clay sands respectively. From these tables, it could seen that the air set strength values of Battatti and Kankara clay sands at temper points increased with increase in tempering time but the increases were not substantial. In the case of Battatti clay sands, the air set strength values at the temper points was 180kN/m^2 for 4 hours, 193kN/m^2 for 8 hours and 200 kN/m^2 for 12 hours tempering time. The air set strength after 12 hours tempering time did not show any improvement for 16 and 20 hours but at 24 hours tempering time, the value was 220kN/m^2. In the case of Kankara clay sands, the air set strength values at temper points increased gradually from 230kN/m^2 for 4 hours to 260kN/m^2 for 24 hours tempering

time.

In 'Sand Control' published by Harry W. Dietert & Co. a minimum air set strength of 140kN/m^2 for non - ferrous, light grey iron and malleable iron casting; 200kN/m^2 for medium and heavy casting; and 200 to 350kN/m^2 (depending on the size of the casting) for steel are suggested. This means that at all tempering times tested, the values of air set strength of Battatti clay sand was not high enough for medium and heavy castings. It is to be improved upon by some other means. Tempering time cannot help much in this case.

4.4.7 Shatter Index

The shatter index is a measure of toughness, the property which aid the satisfactory lift during pattern withdrawal. A low value indicates friability in pattern withdrawal and too high a value, where not needed, indicates unsatisfactory mould qualities sometimes from excessive clay or water content.

Figures 4.2b and 4.5b show the shatter index to moisture content relationships for Battatti and Kankara clay sands respectively for all the tempering times tested. The letter "T" marked on the curves indicate the shatter index at temper points for all the tempering times. These values are shown in tables 4.1 and 4.2 for Battatti and Kankara clay sands respectively. Looking through the tables, in the case of Battatti clay sands, the shatter index values

increased from 50 for 4 hours to 55 for 12 hours tempering time and then decreased to 54 for 16, 20 and 24 hours tempering times. The shatter index values of Kankara clay sands at temper points however did not show any considerable change in value with increase in tempering time, but a slight decrease can be noticed.

The effect of tempering time on shatter index as seen from the results for these two clay sands cannot be considered significant at all. Davies (1950) has shown in one of his works that shatter index of value 50 to 85 can be considered as mouldable range.

4.4.8 Green Hardness

In order to prevent the mould wall dialation and to withstand pressures of the molten metal during casting, the mould surface should have sufficient hardness. The relationship between green hardness and moisture content for various tempering times is shown in figures 4.2d and 4.5d for both Battatti and Kankara clay sands respectively. The letter "T" marked on the green hardness to moisture content curves indicate the green hardness values for the two clay sands at temper points. These values are shown in tables 4.1 and 4.2 respectively. From these tables, it can be seen that the behaviour of green hardness for the two clay sands with respect to the tempering time differs. While in the case of Battatti clay sands, a slight increase in green hardness from 80 at 4 hours to 89 at 24 hours tempering time was noticed, green hardness

values of Kankara clay sands at temper points decreased slightly from 85.7 for 4 hours to 82 for 24 hours tempering time. A low hardness is responsible for mould wall movement and erosion and this could be adjusted by increasing the amount of ramming or squeazing.

4.4.9 Flowability

The flowability of moulding sand is its ability to be compacted to a uniform density when ramming energy is applied. The greater the ease of flowing, the more readily will the various sand grains, comprising a mould, flow together until all the sand grains are in contact. Thus forming a continous uniform mould surface. The flowability of moulding sand has a very practical application in foundry.
It explains certain behaviour of moulding sands, and provide a means of improving casting quality and reducing the time of ramming. High flowability will improve smoothness of the casting surface while low flowability will contribute materially to a rough surface finish.

Figures 4.3 and 4.6 represent the flowability to moisture content relationships at all tempering times tested for Battatti and Kankara clay sands respectively. The letter "T" marked on the curves indicate the flowability values at temper points and these values are shown in tables 4.1 and 4.2 for Battatti and Kankara clay sands respectively.

From these tables, it can be seen that the tempering time does not have significant effects on flowability of the two clay sands except for Kankara clay sands that showed a slight increase with increase in tempering time.

4.5 Conclusions

The results of the experiments under consideration show that increase in tempering time does not necessarily bring about significant improvements on properties of foundry sands prepared from the two local clays (Battatti and Kankara clays respectively). However, slight changes in properties were noticed when the tempering time was increased from 4 hours to 24 hours. While some properties were slightly improved with increase in tempering time, some other properties were impaired. The type and extent of changes in properties depend on the property, the type of clay and length of tempering time for which the sand mixtures are stored or left to temper before use.

In the case of Battatti clay sands, properties like oven dry strength, air set strength, green hardness, green strength and shatter index generally showed slight improvements with increase in tempering time up to 12 hours, permeability however showed a sharp decrease in value when the tempering time was increased from 4 hours to 8 hours and increased again as the tempering time was further increased to 12 hours.

In the case of Kankara clay sands, air set strength and green compression strength showed slight improvements upto 12 hours tempering time. But green hardness, oven dry strength, shatter index decreased with increase in tempering time. Permeability, when the tempering time was increased from 4 hours to 8 hours, decreased slightly in value and then started to increase with further increase in tempering time. For the two clay sands, the property that changed most was the oven dry strength. Increase in the case of Battatti and decrease in the case of Kankara.

As the properties of sand mixtures prepared from these two clays changed slightly with increase in tempering time, the choice of tempering time to be used for storing sand mixtures prepared from both Battatti and Kankara clays should depend on the combination of properties required for a particular application. The author however considers a tempering time of about 12 to 16 hours suitable for storing sand mixtures preparod from these two clays for the following reasons:

1) At tempering time below 12 hours, the density of the two sands usually increase which in turn brings about sharp decrease in permeability. Permeability being one of the essential properties of moulding sands, the decrease therefore, cannot be over-looked as this may mean the cast parts (especially heavy

castings) may not be protected against blow holes, pin holes and other similar defects.

2) At tempering time above 16 hours, the improvements in some properties are only slight and as such further increase in tempering time with an eye on achieving more improvements on these properties will only amount to loss of time. Therefore it may be economically unwise for any continous production foundry to store sand mixtures prepared from these clays above 16 hours.

3) It is more convinient to prepare sand mixtures in the evening and store them overnight for a period of 12 to 16 hours before use to prepare moulds the following morning.

CHAPTER FIVE

CATION EXCHANGE TREATMENT OF LOCAL FOUNDRY MOULDING SANDS BY THE ADDITION OF Na_2CO_3

5.1 Introduction

The practice of adding chemicals to moulding sands is recent in foundry additives practice. It started a little more than a century ago. At that time little was known about the exact reasons for changes occuring to clay due to chemical additions. It was later discovered that changes in sand properties were due to cation exchange reaction taking place between clay particles and the solution in water of the chemicals added. It was thus found possible to change the properties of foundry sands through changes in the clay by use of chemicals.

Previous investigators like Booths (1948), Palvish (1950), Zang and Grooth (1954), Houseman (1958), Hofmann (1959), etc. have done a lot of work to show that sand properties and casting qualities may be changed by the use of chemicals added to the sand but the amount and type of change would depend on the type and amount of chemicals used.
Also, investigations by Mathew (1977) have shown that it is possible to improve Nigerian foundry sands by chemical treatment. Based on these previous investigations, it was decided to investigate the following:

(i) The response to chemical treatment of Nigerian foundry sands prepared from two local clays, Battatti and Kankara clays respectively.

(ii) The optimum amount of chemicals to be used for maximum improvements.

(iii) The relation of the amount of chemicals to be used and the cation exchange capacity of the foundry sands.

But before the details of the experimental investigations are dealt with, it is essential to have a background knowledge of the structure, other characteristics and bonding actions of clays to have theoretical assessment of the changes possible in sand properties due to chemical treatment.

5.2 Theoretical Background

5.2.1 Structure and Practical Significance of Clay Particles

Chemical analyses of clays show them to be composed essentially of silica, alumina, water, frequently with appreciable quantities of iron, alkalies and alkaline earths. The clay minerals are hydrated aluminium silicates i.e oxides of aluminium and silicon with smaller amounts of metal ions substituted within the crystal structure. Clay minerals generally consist of thin plate-like particles having large surface area. Non-clay fractions are normally granular, not flake-shaped like in clay minerals. The important properties of clays like bonding power and plasticity are believed to be closely related to the flake-shaped particles. The plate like particles of the clay minerals are crystalline in nature. The concept of crystalline nature of clay minerals was first introduced by Pauling (1930) and the atomic structure of most minerals have now been studied in considerable details, based

on Pauling's work, by numerous investigators. It is of great advantage to foundrymen if the crystalline nature of clay minerals they use are well understood.

Clay minerals are built up of two layers, a layer of silica tetrahedrons and another of aluminium octahedrons. The exact manner in which these layers are stacked together are different for different clay minerals. Three main groups of clay minerals commonly used in foundries are kaolinite, montmorillonite (Bentonite) and illite and the arrangement of component layers of these clay minerals are discussed below;

The Kaolinite Clay Mineral Group

The structure of kaolinite was first suggested in general by Pauling (1930). It was worked out in some details by Grunner (1932) and later revised by Brindley (1946). From their investigations, it was found that the structural unit of kaolinite crystal is formed by the joining together of a silicon tetrahedral layer and an aluminium octahedral (gibbsite) layer after the replacement of appropriate number of hydroxyl ions on one side of the octahedral layer by oxygen ions at the tip of the tetrahedral units of the tetrahedral layer. As this structural unit consists of one silica unit and one alumina unit, the kaolinite group is said to have a 1:1 lattice structure (fig. 5.1).

The bonding between structural units in kaolinite is rather strong and is due to hydrogen bonding between the hydroxyl ions of the alumina layer and the oxygen ions of the silica layer.

cations when wetted. For this reason, montmorillonite is said to have an expanding lattice. Due to the weak bonds between the structural unit of montmorillonite crystals, it may easily be fractured to give particles as small as individual structural units. The finer clay particles thus provide a larger effective surface area which in turn provides it a larger bonding power, plasticity, capacity for expansion on wetting and shrinkage on drying.

Illite Clay Mineral Group

The basic structural unit of the illite group is the same as that of montmorillonite except that some of the silicon in the tetrahedron are replaced by aluminium and the resultant charge deficiency is mainly balanced by potassium ions held between the structural units as shown in fig. 5.3.

These potassium ions provide a much stronger linkage between the structural units of illite than in montmorillonite and consequently water cannot enter between the units as easily as in the case of montmorillonite and therefore the illite crystals are less expansive than montmorillonite crystals. The illite crystals can also grow into bigger particles than montmorillonite particles. Hence the properties like hydration, cation adsorption (also cation exchange) swelling, shrinkage, bond strength, plasticity etc. develop less intensively in illite than in montmorillonite but more intensively than in kaolinite.

So, in general we can say that clay particles are made up of plate-like structural units and these structural units are held to one another with varying degrees of rigidity

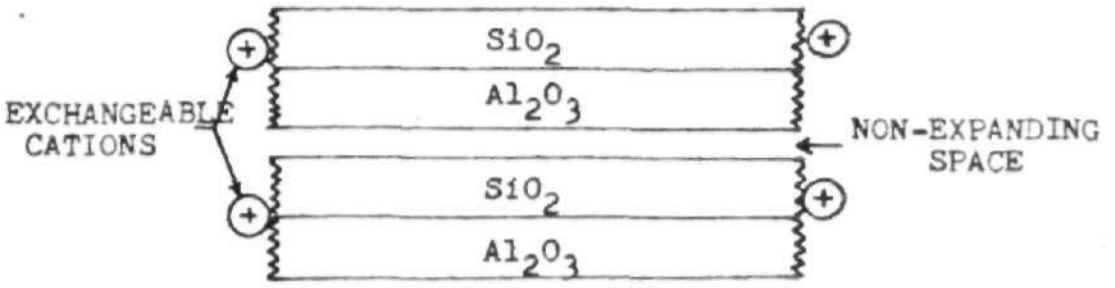


FIG.5.1: SCHEMATIC DIAGRAM SHOWING THE LATICE STRUCTURE OF KAOLINITE CLAY CRYSTAL

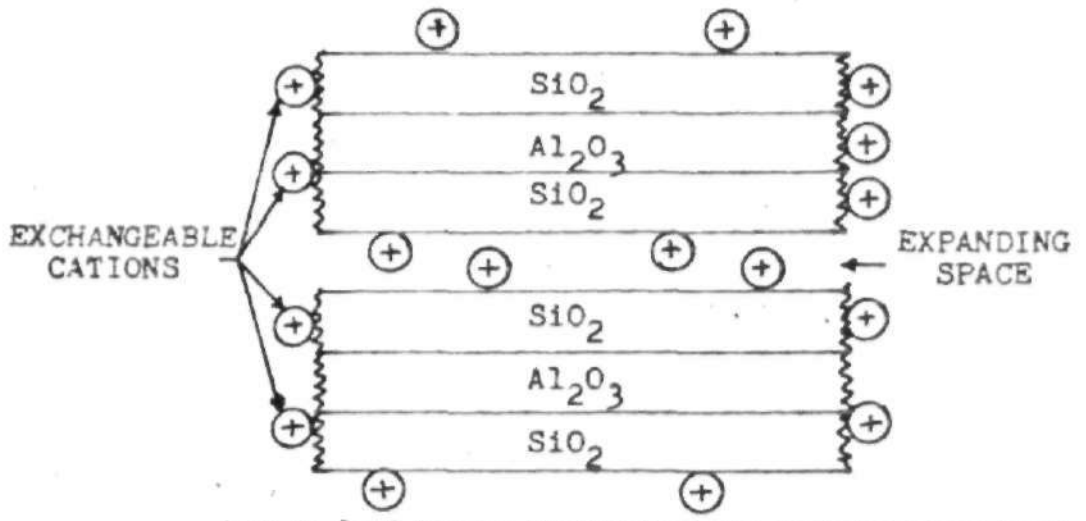


FIG.5.2: LATICE STRUCTURE OF MONTMORILLONITE CLAY CRYSTAL

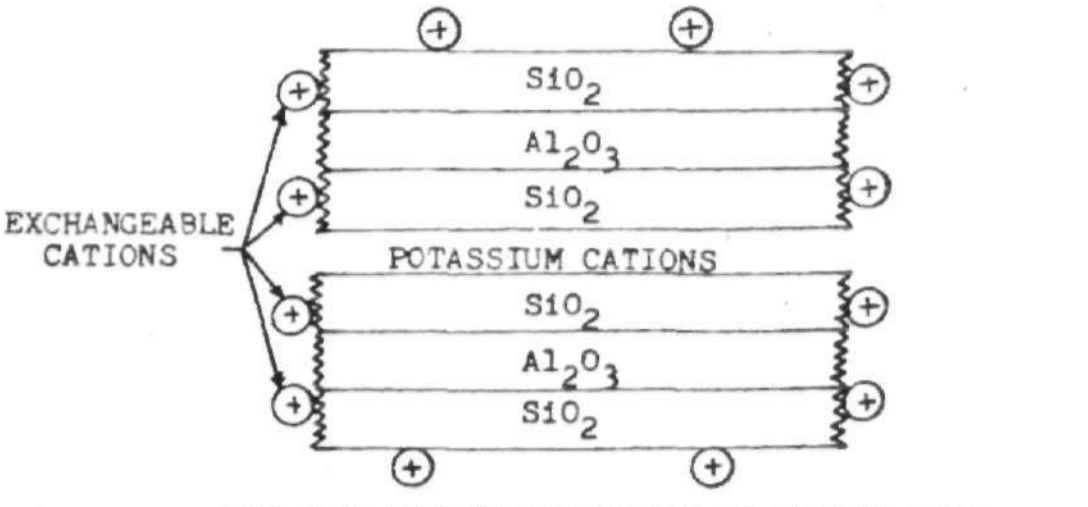


FIG.5.3: LATICE STRUCTURE OF ILLITE CLAY CRYSTAL

depending on the particular type of clay. In some cases, expansion between the structural units are possible upon wetting causing and overall swelling of the clay particles. In other types, plates are held more rigidly and little swelling occurs. All clay particles, because of their fineness of size, expose a large amount of external surface area. But the swelling type of clay (montmorillonite) has a much larger effective surface area because of its much finer particles size and active internal surfaces. Because of this reason, montmorillonite type of clay is superior to other types in bonding power and plasticity and therefore superior for foundry applications.

5.2.2 Cation Exchange

5.2.2.1 The Source of Negative Charge of the Clay Particle

Clay particles are negatively charged particles. The sources of negative charge of the clay varies from one type to another. In montmorillonite, it is mainly due to the ionic substitution or by the replacement of trivalent aluminium ion (Al^{3+}) by diavalent magnessium ion (Mg^{2+}) from the interstices of the alumina octahedral sheet. In illite, some of the quadrivalent silicon (Si^{4+}) ions in the tetrahedral sheets are replaced by the trivalent aluminium (Al^{3+}) leaving a negatively charged lattice. But a considerable amount of these negative charges is balanced by petassium ions which hold the structural units together. The main source of negative charges in the kaolinite group is believed to be due to the dissociation of hydrogen ions from the hydroxyls exposed on

the edges or surfaces of the clay particles and the unsatisfied charges at the broken edges of the silica and aluminium sheets.

5.2.2.2 Cation Exchange Of Clay Particles

It has been clearly explained above that clay particles are negatively charged particles being sorrounded by a large number of cations. But these cations are loosely held and are easily displaced by others. Therefore, they are called exchangeable cations and the process is called cation exchange.

This cation exchange is a reversible reaction, the cations surrounding the clay minerals going into the solution, and the cations present in the solution taking the place of the cations that move out from the surface into the surrounding solution. But the exchange capacity of the different cations are different.

5.2.2.3 Determination of Cation Exchange Capacity (C.E.C) And Exchangeable Cations.

Accurate determinations of cation exchange capacity in clay minerals is very difficult to accomplish. One method of measurement generally used is by saturating the clay with NH^{4+} and Ba^{2+} and determining the amount held at pH 7.

Measurement of cation exchange capacity is done in terms of milliequivalents per 100g. The term equivalent is defined as that quantity which is chemically equivalent to 1g of hydrogen (6.02×10^{23} atoms of hydrogen).

Determination of exchangeable cation composition is also a very difficult problem. It involves the complete replacement

of all exchangeable cations by some cation which is not present in the sample, accurate analysis of the solution obtained, and the determination of and suitable correction for the cations that pass into solution from any insoluble material in the sample.

The cation exchange capacities of the three main clay mineral groups as given by Grim (1968) are as follows:

(i) Kaolinite group - 3 to 15 milliequivalent/100g

(ii) Illite group - 10 to 40 milliequivalent/100g

(iii) Montmorillonite group - 80 to 150 milliequivalent/100g

5.2.2.4 Replaceability of Exchangeable Cations

Experiments carried out by previous investigators have shown that under a given set of conditions, various cations were not equally replaceable and did not have the same replacing power. Calcium has been shown to easily replace exchangeable sodium, butthe same amount of sodium does not replace much exchangeable calcium. As the cation exchange reaction was studied, it became obvious that there was no single universal replaceability series. The following order of replacing power of cations is generally accepted.

$$Li^+ < Na^+ < K^+ < NH_4^+ < Mg^{2+} < Ca^{2+} < Al^{3+} < H^+$$

Replaceability of exchangeable cations is influenced by the following:

(i) The valence of the cations

(ii) The size

(iii) The degree of hydration of the associated cations

(iv) Concentration of cations

The valence of the cation has been found to have a dominant influence on the case of replacement. The higher the valence of the ion, the greater is its replacing power and the more difficult it is to displace when already present on a clay. Hydrogen however is an exception since for the most part, it behaves like a diavalent or trivalent ion.

It was pointed out by Kelley (1948) that the replacing power increases qualitatively with atomic number in ions of the same valence. Also in ions of the some valence, the replacing power tends to increase as the size of the ion increases, i.e the smaller ions are less tightly held than the larger ions. Alten and Kurmies (1931) presented strong evidence that all the common cations are hydrated and that hydration is important in exchange reaction.

The effect of concentration on cation exchange capacity was investigated by Kelley and Cummis (1921). They found that replacement of Ca^{2+} and Mg^{2+} is possible by increasing the concentration of Na^{+} in the solution. Gedroiz (1932) pointed out that the replacement of Ca^{2+} and Mg^{2+} by NH_4^{+} increased as the concentration of NH_4^{+} increased. Thus from the foregoing discussion, it can been seen that the valence of cations, size, degree of hydration of the associated ions and concentration have high influence on replaceability of exchangeable cations. Figure 5.4 shows a schematic representation of cation exchange reaction.

5.2.3 Bonding Actions of Clays in Foundry Sands and the Effect of Type and Amount of Cations

5.2.3.1 Bonding Between Clay Particles

Dry sand does not provide the necessary bond to hold sand grains firmly together; bond is developed only when clay particles are hydrated. In the presence of water molecules, which tend to hydrolyse according to the reaction.

$$H_2O \rightleftharpoons H^+ + OH^- ,$$

Clay particles preferentially absorb hydroxyl (OH^-) ions, owing to unsatisfied valence bond at the surface of the clay crystal, and the clay-water particles become negatively charged. These negative charges are balanced by positive charges (cation) and as such a clay particle can be considered as being surrounded by an electrical double layer. The second layer, the layer of cation, is not sharply defined in thickness and it extends some distance into the liquid medium, thus clay particle is said to comprise of a double diffuse layer. A hydrated clay particle surronded by its double diffuse layer is called a clay micelle. This is shown schematically in Figure 5.5.

When two clay particles come together, there will be attraction between unlike charges and repulsion between like charges and this brings about a rearrangement of the ions. The rearrangement of the ions causes localized concentrations of anions and cations, and, therefore the clay micelles become dipoles (Dipoles are molecules which are neutral but in which the centres of positive and negative charges are separated) as shown in Figure 5.6 with forces of attraction between the unlike

ions and repulsion between like ions still existing.
The magnitude of the force of attraction is represented in Figure 5.7 as a function of intermicellar distance.
The dotted curve represents the net micellar force between two micelles and this net intermicellar force is one of attraction. The maximum intermicellar attraction force is at a distance x as seen in the figure. When the distance between the micelles decreased from the critical distance, the repulsion forces increase more rapidly than the attraction forces. Similarly to the right of point x both attraction and repulsion forces decrease and therefore the net attraction force between the micelles is less. In green sand, there will be a net-work of micellar dipoles as shown in Figure 5.8.

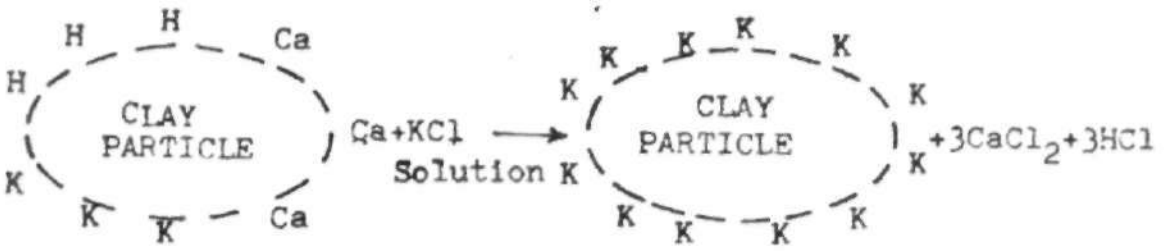


FIG.5.4: SCHEMATIC REPRESENTATION OF CATION EXCHANGE REACTION

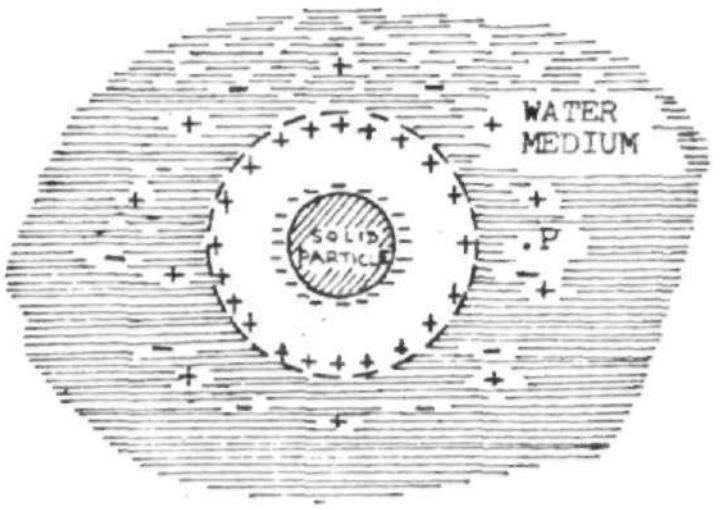


FIG.5.5: SCHEMATIC REPRESENTATION OF A CLAY MICELLE WITH ITS DOUBLE DIFFUSE LAYER

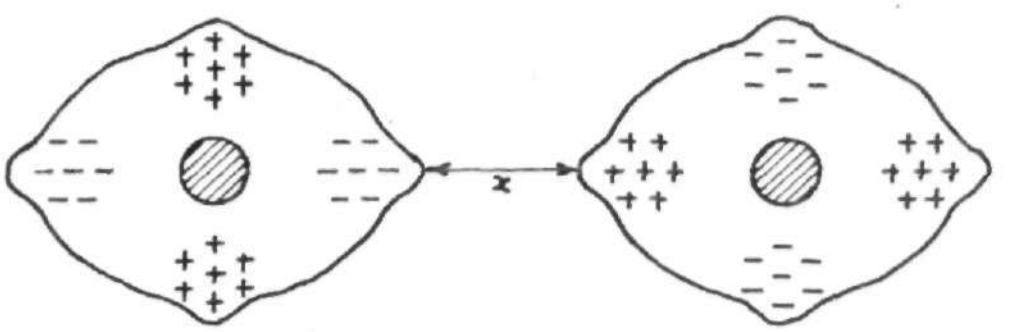


FIG.5.6: SCHEMATIC REPRESENTATION OF CLAY DIPOLES

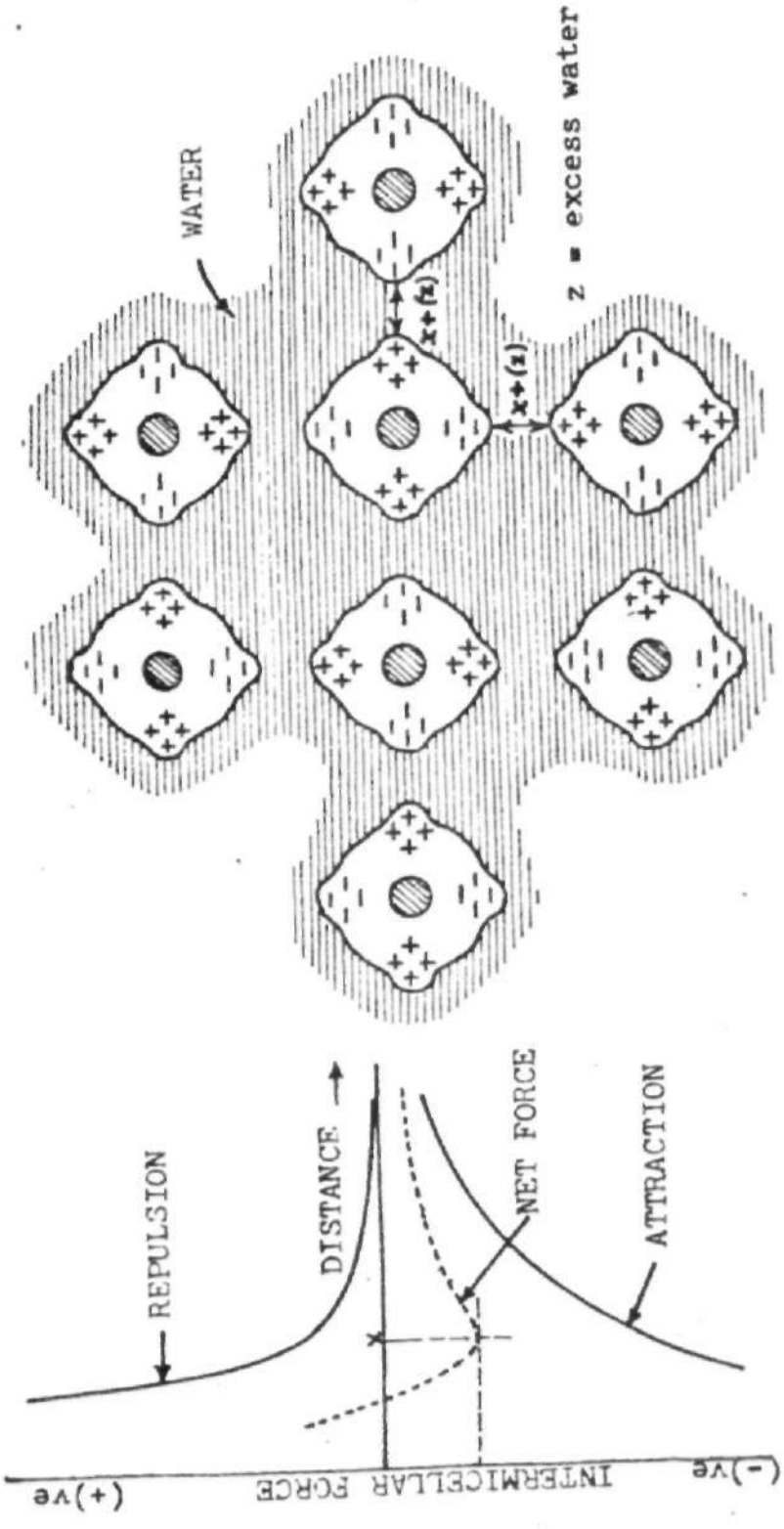


FIG.5.8: SCHEMATIC ILLUSTRATION OF CLAY DIPOLES AS IN GREEN SAND

FIG.5.7: THE MAGNITUDE OF ATTRACTION AND REPULSION FORCES AS A FUNCTION OF INTERMICELLAR DISTANCE

5.2.3.2 Bonding in Foundry Sand Mixtures

Sand grains (quartz) also exhibit bond between themselves just as clay particles, but to a very small extent. Diran and Taylor (1952) say that there are unsatisfied positive and negative valence bonds at the free surface of quartz crystals. Hydrated quartz preferably absorbs hydroxyl (OH^-) ions from water and thus have a layer of negative charges. To contaract these negative charges, it absorbs a layer of cations and thus a double diffuse layer is formed around the quartz grains just like in the case of clay particles. Particles of sand (quartz) thus also form micelles with intermicellar force between them, but it is so low that it cannot form a strong bond except a binder is added.

When foundry sands are prepared, a quartz - clay - water system is formed and there will be forces of attraction between quartz and clay micelles and clay and clay micelles. The sand particles can be considered bonded together mainly by:

(i) Intermicellar force between quartz and clay, and clay and clay.

(ii) The clay dipole forming a continous network around sand particles (Fig. 5.9) and holding particles together mainly because of the net attraction between the clay particles.

Depending on the type of clay, a certain degree of hydration is required to develop the micellar dipoles through the clay water medium in a sand - clay - water system. This is why the green strength of clay bonded sand would

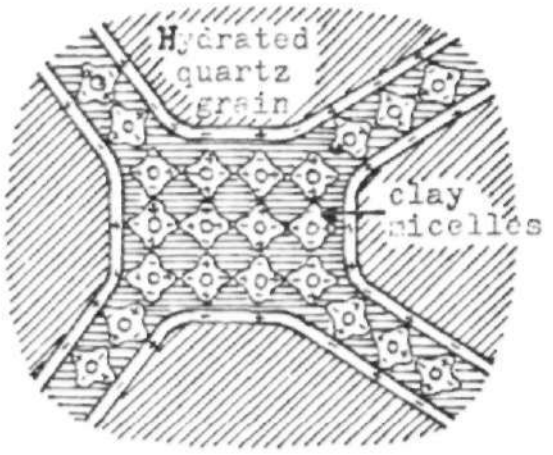


FIG.5.91 NETWORK OF CLAY PARTICLES AROUND SAND GRAINS

initially increase with increase in moisture content to a maximum after which further increase in moisture content brings about a decrease in green strength. This is because after this maximum value, further addition of water will cause water to enter the spaces between the dipoles and to increase the separation between the dipoles decreasing the net intermicellar force hence a decrease in green strength.

5.2.3.3 Dry Strength in Foundry Moulding Sands

In green sand moulding, the amount of water added is usually higher than the one required for critical distance 'x' for maximum attraction (Fig. 5.7). This is because there is a minimum amount of water required to provide complete hydration of all the clay particles. But this minimum amount will be more than the amount required to provide the critical intermicellar distance. Using less amount of water means some clay may not be hydrated hence may not take part in the bonding process. When the moulding sands are dried, the water is lost and the quartz and clay particles are brought closer together until the distance for maximum intermicellar force is reached hence the strength is higher and after this distance is reached, further drying may not have any effect on the dry strength.

5.2.3.4 Clay Properties and the Type of Adsorbed Cations

In the presence of water, clay particles and cations attract water and get hydrated. Thus a water hull is formed around the clay particles and cations. The thickness of this water hull will depend on the type of cation. Cations like Na^+ and Li^+ form bigger water hulls around it while K^+ and Ca^{2+}

are considered the smallest and least hydrated ions. When these less hydrable cations are used, they can approach the inner layer of negative ions closely and neutralise some of the negative charges reducing the repulsive forces (usually called Zeta potential) between clay particles and enabling the particles to approach each other closely to form large particles. The large particles due to their combined weight settles down leaving the clear water on top. This phenomenon is called flocculation.

On the other hand, when cations attached to the clay micelles are the highly hydrable type like Na^+ and Li^+, they can not approach closely to the inner negative charges because of the large water hulls (large size). Thus there is less neutralization of the negative charges and therefore the repulsive forces (Zeta potential) between the clay micelles is higher. This prevents close approach of clay particles and hence clay particles are left in dispersed state without settling. This phenomenon is called Deflocculation.

From the foregoing discussion, it could be seen that the type of cations present in the diffuse layer of clay have an important bearing on the moulding sand properties.
The flocculation/deflocculation ability of different cations are as follows:

Na K Ca Mg Al H

← →

Deflocculation Flocculation

As hydrogen has the highest flocculating ability as seen above, there is higher net intermicellar attraction force between clay particles if the cations adsorbed in them are hydrogen ions. For Na^+, the reverse is the case as the repulsive forces are higher and the intermicellar attraction forces will be less. Thus hydrogen clay will give the highest green strength in the group while Na clay will give the lowest. But in the case of dry strength, the effect is opposite. Na clay will give the highest dry strength while H clay produces the lowest. This is explained to be due to deflocculation of clay in the presence of Na^+ which will make the clay more slippery and it will provide a proper coating around the sand grains giving a closely knit network of clay micelles around the sand particles and on drying, these closely knit network of clay provides very high dry strength values.

Investigations have further shown that not only the green and dry strength values of moulding sands are changed due to adsorbed cations but also other physical properties. But the exact manner in which the properties are going to change can only be ascertained by experimental investigations involving cation exchange treatment.

5.3 Experimental Investigations

5.3.1 Selection of Chemicals for the Cation Exchange Treatment

Previous investigators have shown that foundry sands would have better characteristics when the clay content present in sand is in a deflocculated state. For deflocculation, chemicals containing sodium are considered better as they are

The Cation Exchange Capacities (C.E.C.) of the two clays were determined by Mathew (1977) in his work at the Soil Science Laboratory, Institute of Agricultural Research, Ahmadu Bello University, Zaria and the values obtained are as follows:

(i) Battatti clay - 6.2 milliequivalent/100g

(ii) Kankara clay - 3.4 milliequivalent/100g

It was thus decided to prepare and test sands containing 0 percent, 0.05 percent, 0.1 percent, 0.2 percent, 0.3 percent and 0.5 percent Na_2CO_3. The maximum of 0.5 percent was fixed for the following reasons:

(1) The Cation Exchange Capacity of Battatti clay is about 6.2 meq./100g and that of Kankara clay is 3.4 meq./100g. 0.5 percent Na_2CO_3 content actually represents 9.44 meq. for Na per 100g. This amount is about 1.5 times C.E.C of Battatti clay and 2.8 times that of Kankara clay and there is no doubt that this will be more than adequate. Therefore at this level of Na_2CO_3, the clay in the sands may be in a flocculated state and further additions may increase the flocculation still further.

(2) Larger addition of Na_2CO_3 would lower the refractoriness of the sand as the melting point of Na_2CO_3 is only 852°C.

For the two reasons given above, higher amounts of Na_2CO_3 (above 0.5 percent) were not tried. Two kilograms of sand mixtures (15 percent clay + 85 percent sand) were prepared at five moisture levels for each Na_2CO_3 percentage tried.

The following sand samples were used for the test;

(1) Five 2000g samples each of 15 percent Battatti and Kankara clay. In the case of each clay, each sample was tempered to a different moisture level with 0 percent Na_2CO_3.

(2) Five 2000g samples each of 15 percent Battatti and Kankara clay. In the case of each clay each sample was tempered to a different moisture level with 0.05 percent Na_2CO_3.

(3) Five 2000g samples each of 15 percent Battatti and Kankara clay. In the case of each clay, each sample was tempered to a different moisture level with 0.1 percent Na_2CO_3.

(4) Five 2000g samples each of 15 percent Battatti and Kankara clay. In the case of each clay, each sample was tempered to a different moisture level with 0.2 percent Na_2CO_3.

(5) Five 2000g samples each of 15 percent Battatti and Kankara clay. In the case of each clay, each sample was tempered to a different moisture level with 0.3 percent Na_2CO_3.

(6) Five 2000g samples each of 15 percent Battatti and Kankara clay. In the case of each clay, each sample was tempered to a different moisture level with 0.5 percent Na_2CO_3.

A total of about 60 samples were prepared from these two types of clays and tested. Samples were prepared in a Ridsdale Laboratory Sand Muller by mulling 2 minutes dry, and

5 minutes wet after adding a calculated amount of water containing different percentages of Na_2CO_3. Distilled water was used for the preparation of all the samples as it is generally considered better than ordinary tap water, for investigations involving the use of chemicals.

At the end of the preparation i.e mulling, sand mixture sample were stored in airtight containers andwere left to temper for about 12 hours before they were tested. The following properties of the sands were tested:

(1) Moisture Content
(2) Density
(3) Permeability
(4) Green Compression Strength
(5) Oven Dry Strength
(6) Air Set Strength
(7) Shatter Index
(8) Compactability
(9) Green Hardness
(10) Flowability

5.3.3 Results

The results of the tests are presented graphically in Figures 5.10 to 5.15. The letter "T" marked on the curves show the properties at temper points for different percentages of Na_2CO_3.

The different properties at temper points of Battatti and Kankara clay sands treated with various percentages of Na_2CO_3 are presented graphically in Figures 5.16 and 5.17.

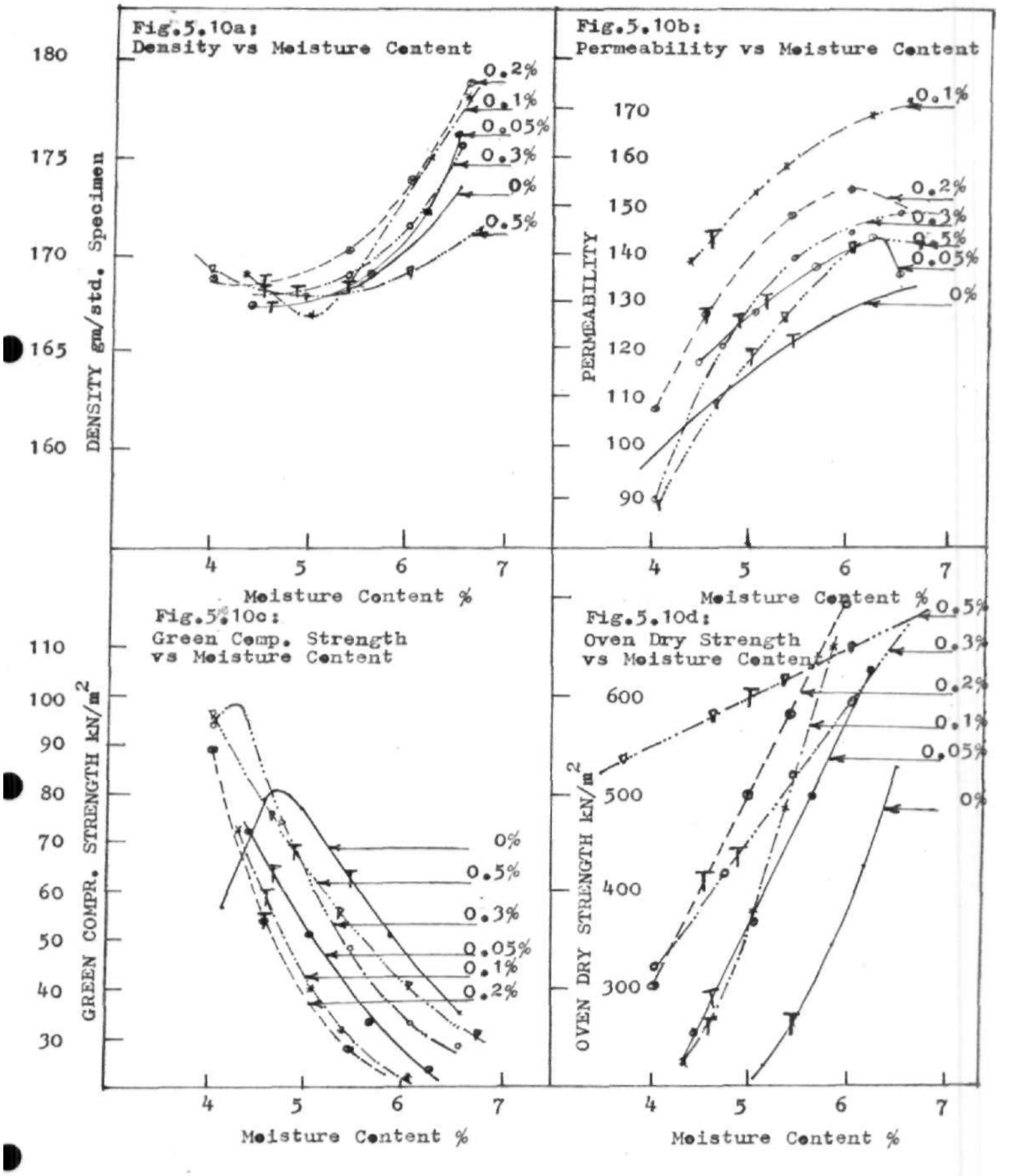


FIG. 5.10: EFFECT OF Na_2CO_3 ADDITION ON DENSITY, PERMEABILITY, GREEN COMPR. STRENGTH AND OVEN DRY STRENGTH OF BATTATTI CLAY SANDS.

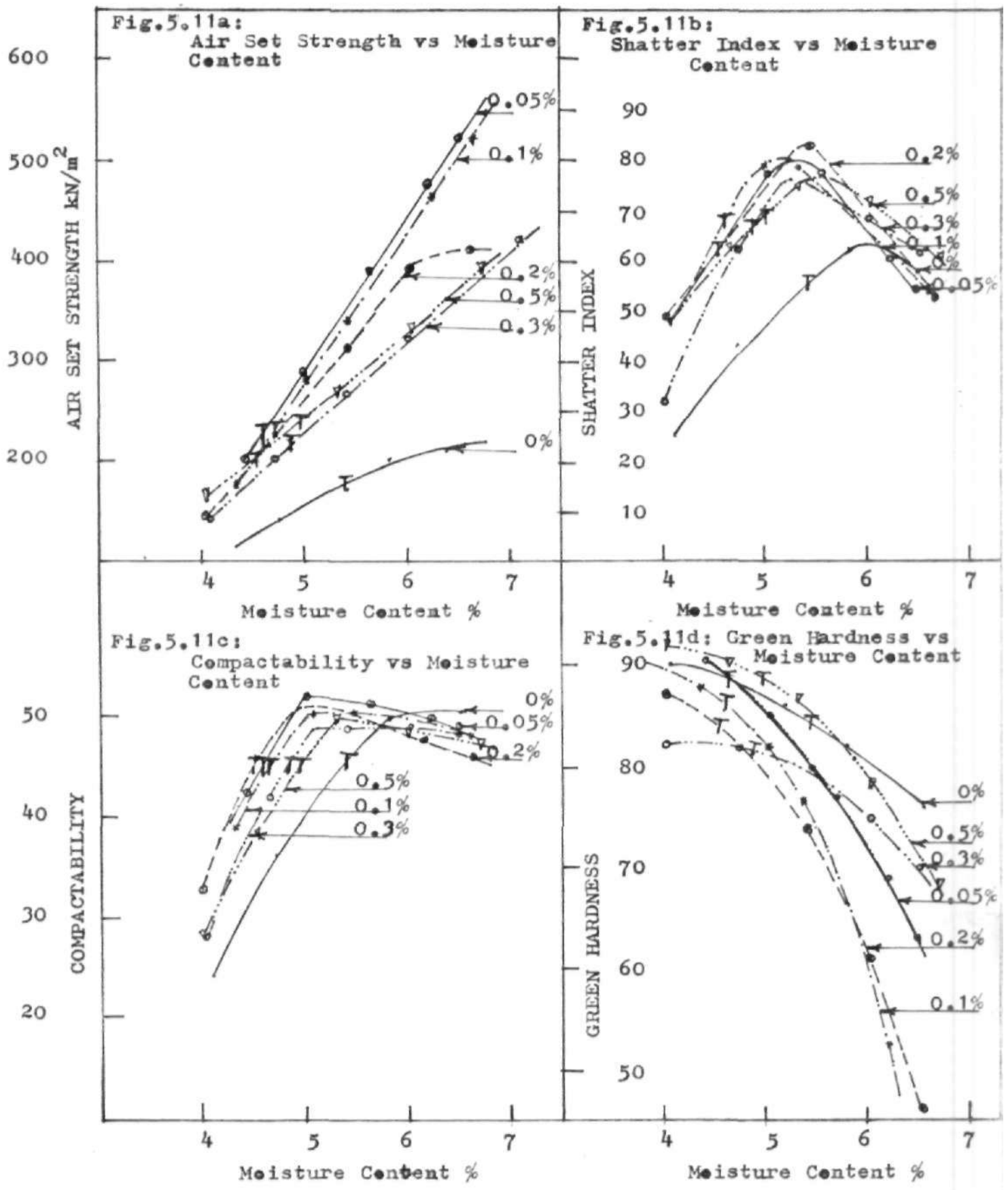


FIG. 5.11: EFFECT OF Na_2CO_3 ADDITION ON AIR SET STRENGTH, SHATTER INDEX, COMPACTABILITY AND GREEN HARDNESS OF BATTATTI CLAY SANDS.

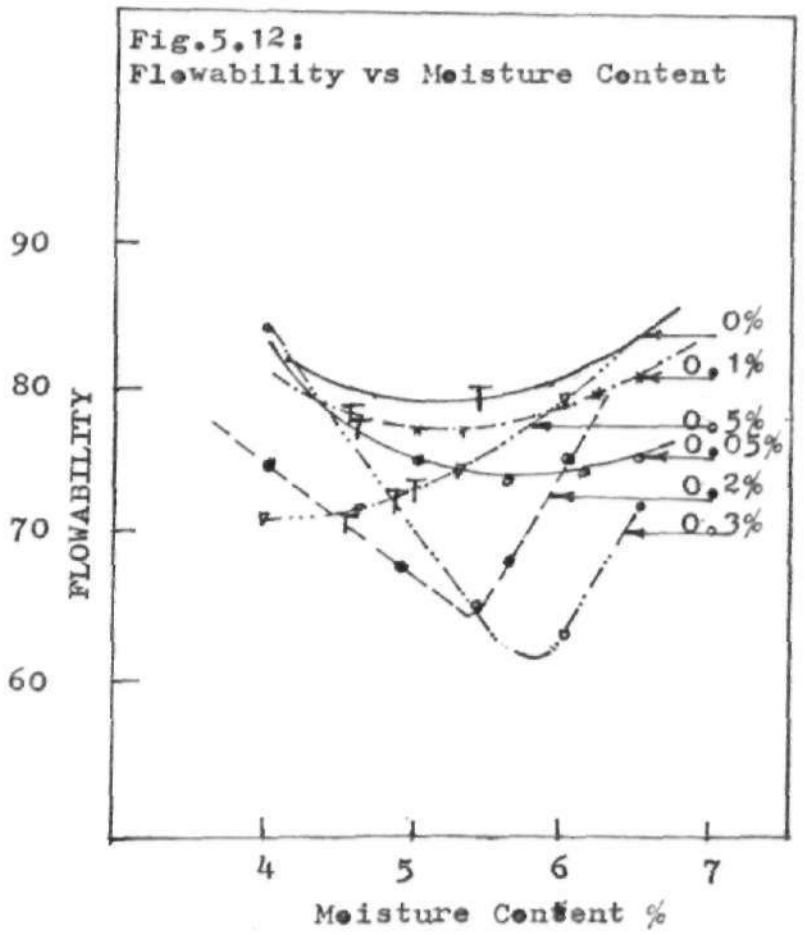


FIG. 5.12: EFFECT OF Na_2CO_3 ON FLOWABILITY OF BATTATTI CLAY SANDS.

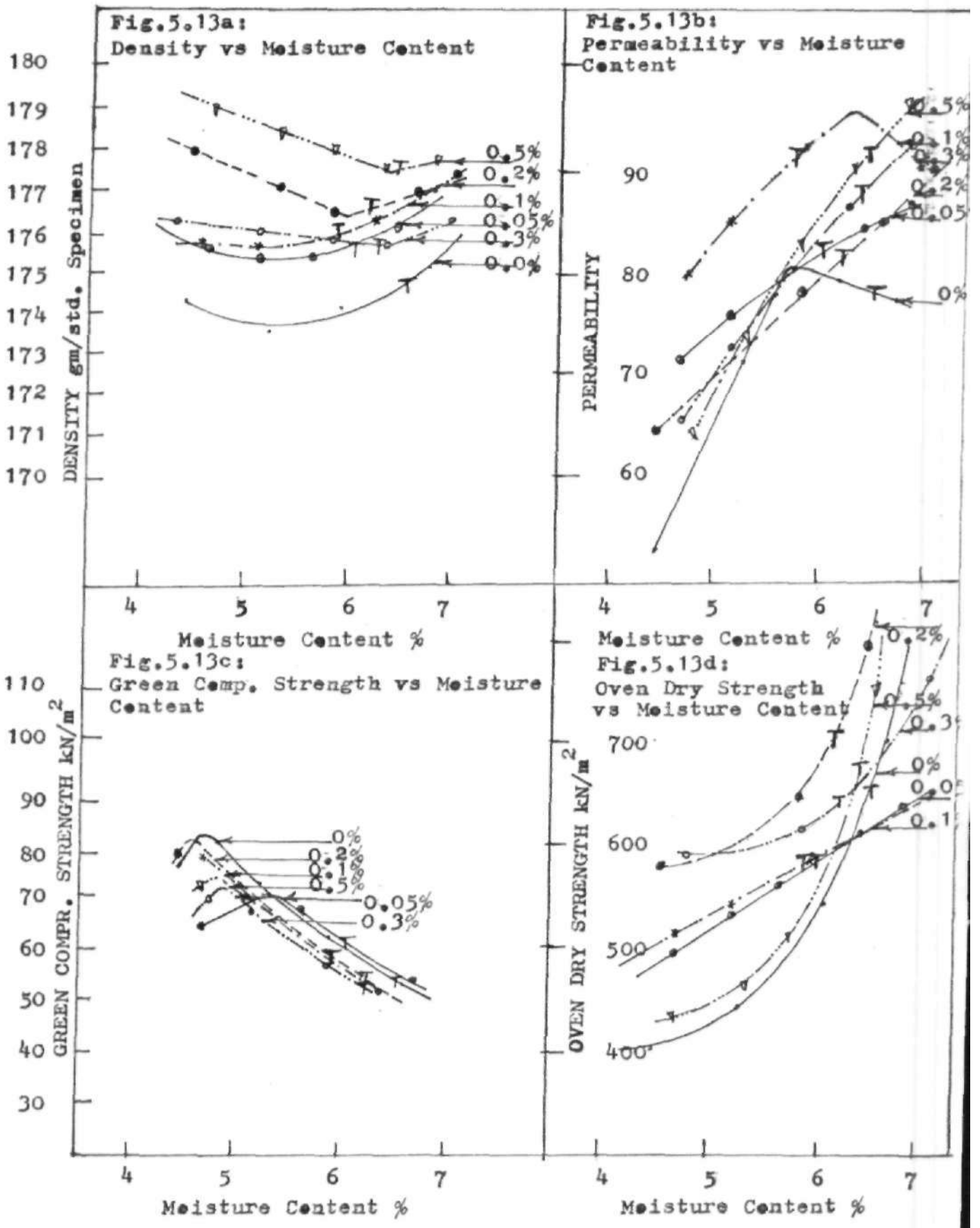


FIG. 5.13: EFFECT OF Na_2CO_3 ADDITION ON DENSITY, PERMEABILITY, GREEN COMPR. STRENGTH AND OVEN DRY STRENGTH OF KANKARA CLAY SANDS.

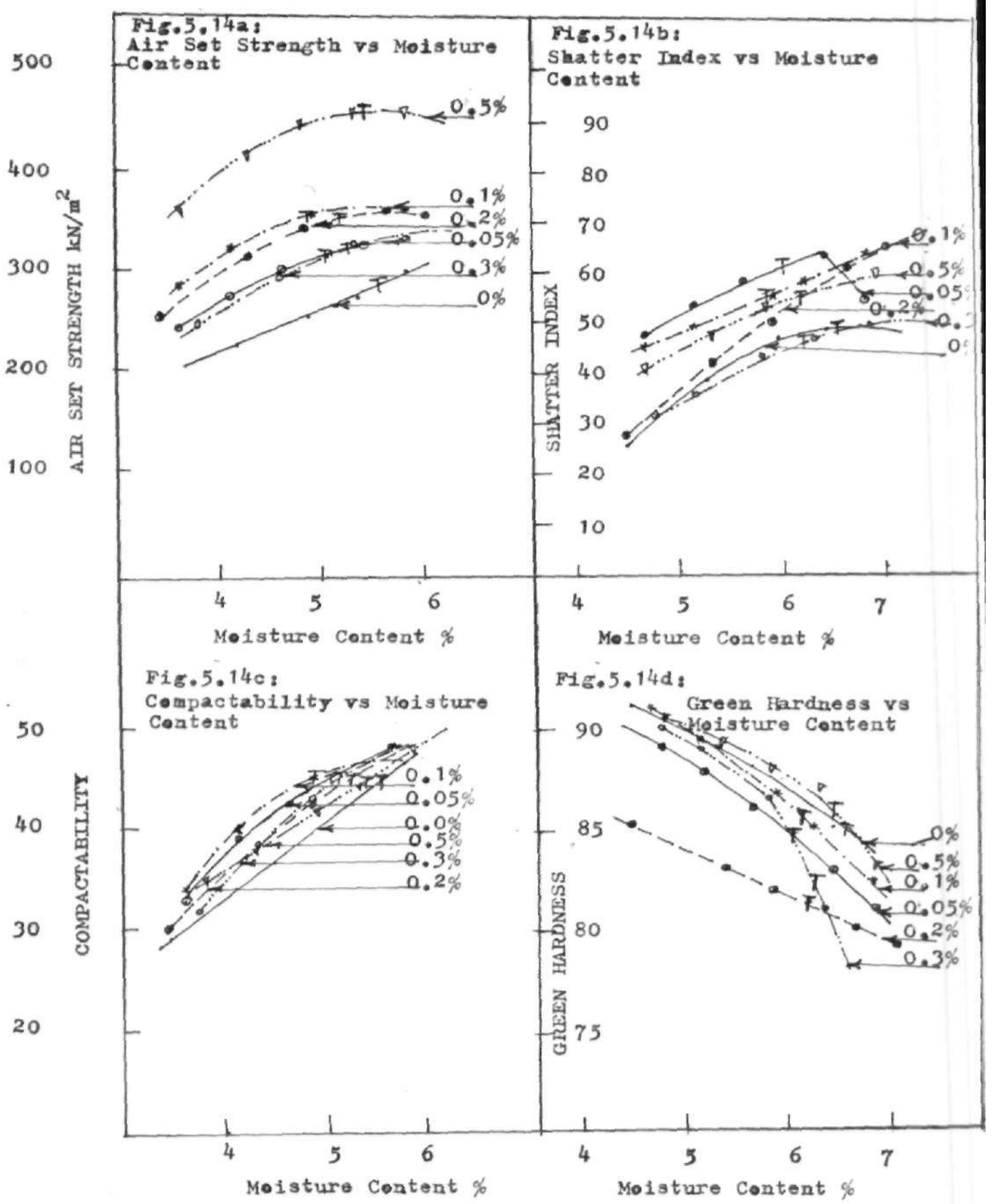


FIG. 5.14: EFFECT OF Na_2CO_3 ADDITION ON AIR SET STRENGTH, SHATTER INDEX, COMPACTABILITY AND GREEN HARDNESS OF KANKARA CLAY SANDS.

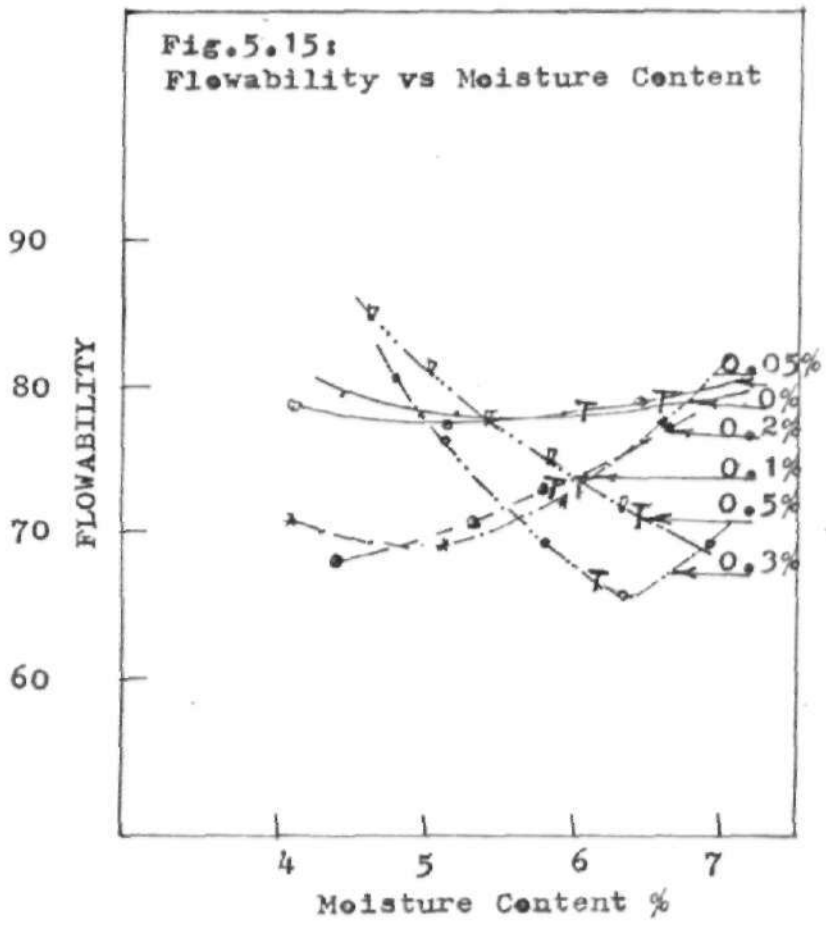


FIG. 5.15: EFFECT OF Na_2CO_3 ADDITION ON FLOWABILITY OF KANKARA CLAY SANDS.

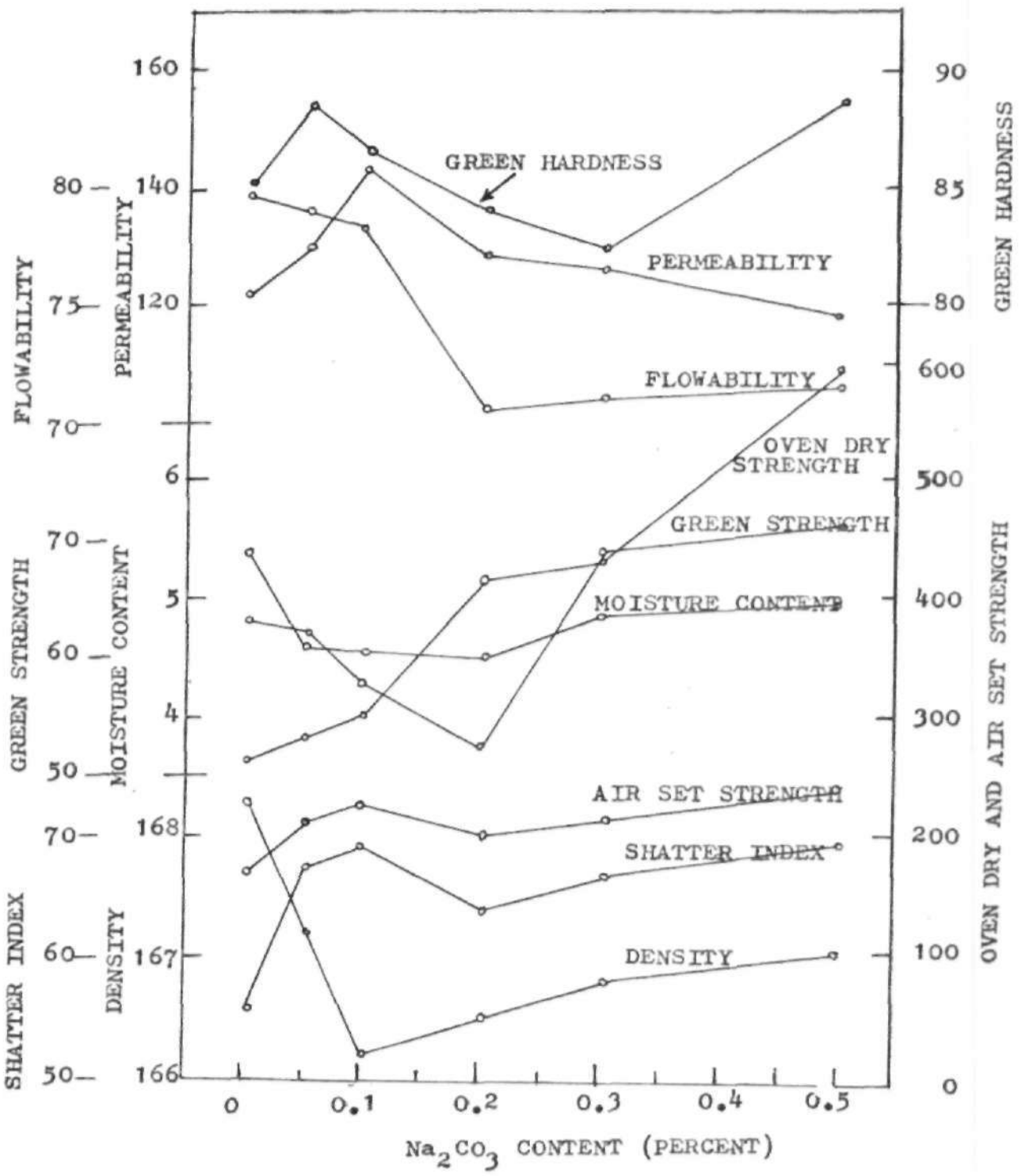


FIG. 5.16: PROPERTIES OF 15 PERCENT BATTATTI CLAY SANDS AT TEMPER POINTS vs Na_2CO_3 CONTENT.

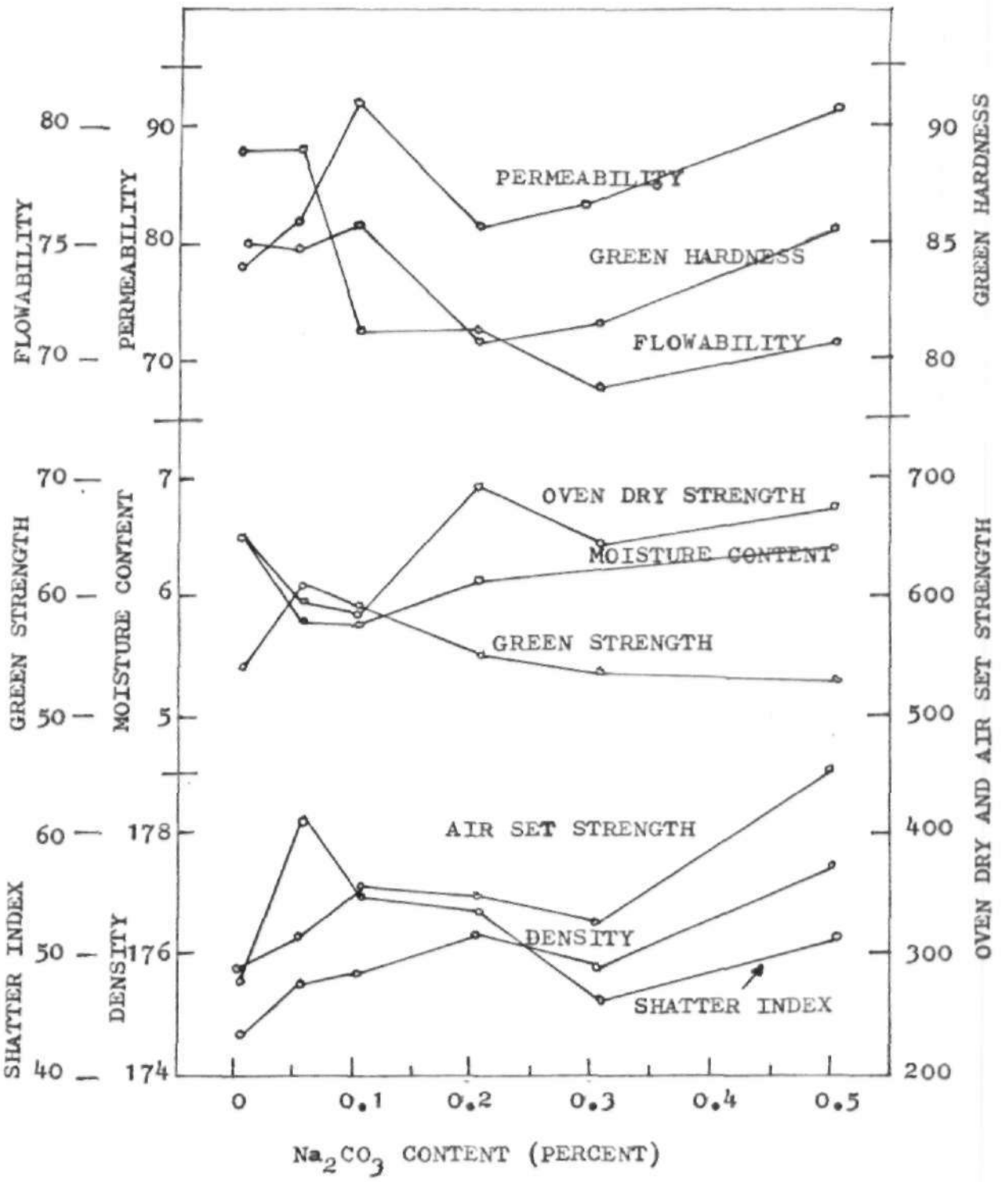


FIG. 5.17: PROPERTIES OF 15 PERCENT KANKARA CLAY SANDS AT TEMPER POINTS vs Na_2CO_3 CONTENT.

5.3.4 Discussion of the Results

Looking through the graphs, it can be seen clearly that the changes in the properties of Battatti clay sands are much more significant than the changes in the properties of Kankara clay sands. The larger changes in Battatti clay sands could be attributed to its larger Cation Exchange Capacity. Changes in each property will now be discussed one by one.

5.3.4.1 Water Requirement

As could be seen from the graphs, most sand properties change with the amount of Na_2CO_3 added and the amount of water present. As discussed earlier in chapter three, compactability was used to assess the degree of temper of sand mixtures for various percentages of Na_2CO_3 added and at 45 percent compactability, the sand mixtures were considered to be at correct degree of temper. Therefore from figures 5.11c and 5.14c, it is possible to find the water requirement or the amount of water needed to bring the two sands at different Na_2CO_3 contents to the correct degree of temper. These values are represented graphically against percent Na_2CO_3 in Figures 5.16 and 5.17.

From these graphs, it is clear that the amount of water required to bring the two sands to the correct degree of temper decreased with small additions of Na_2CO_3. For both Battatti and Kankara clay sands, the maximum decrease occured at 0.1 percent Na_2CO_3 addition after which further increase in Na_2CO_3 brought about an increase in water requirements. Battatti clay sands showed a greater decrease of 0.85 percent while Kankara clay sands showed a decrease of 0.63 percent in

the water content at temper point.

The decrease in water requirements is due to the higher water adsorption capacity of Na^+ ions. When a small amount of Na_2CO_3 is added, Na^+, which is more hydrable than H^+, Al^{3+}, Ca^{2+}, Mg^{2+} etc. surrounding the clays, replaces some of these ions and therefore the clays get hydrated and feel more wet with smaller amounts of water. Hence the sand mixtures feel wet enough with smaller amounts of moisture content. As the Na^+ content is further increased, some of the Na^+ may not be adsorped by the clay particles. These excess Na^+ remain in the clay-water system and absorb water, get hydrated and therefore part of the water needed by the clay is lost to these ions. For this reason sand mixtures would need more water to feel wet enough when the Na_2CO_3 added is high.

5.3.4.2 Density

Density values of both Battatti and Kankara clay sands changed with the addition of Na_2CO_3 but the manner the changes occured were different for the two types of sands.
Figures 5.10a and 5.13a represent the density to moisture content relationships for both sands at different percentages of Na_2CO_3. The letter "T" marked on the curves indicate the density values at temper points. Graphs representing these values against percentages of Na_2CO_3 are shown in figures 5.16 and 5.17. From these graphs, it can be seen that the density values of Battatti clay sands at temper points decreased up to 0.1 percent Na_2CO_3 addition after which further increase in Na_2CO_3 percentage brought about an increase in density values

and approached the value for 0 percent Na_2CO_3 content for 0.5 percent Na_2CO_3 addition. Addition of upto 0.2 percent Na_2CO_3 generally increased the density values at temper points for Kankara clay sands. The density value then decreased with further increase in Na_2CO_3.

The decrease in density may be due to improved coating of sand grains with clay which does not allow the sand particles come close to one another.

5.3.4.3 Permeability

The permeability values of the two clays have a substantial increase with the addition of small amounts of Na_2CO_3. Figures 5.10b and 5.13b show the permeability to moisture content relationships at various percentages of Na_2CO_3 for Battatti and Kankara clay sands respectively. As before, the letter "T" marked on the curves indicate the permeability values at the correct degree of temper. Graphs of permeability versus Na_2CO_3 percent addition are represented in figures 5.16 and 5.17. From the figures it can be seen that the maximum permeability values at temper points occured at 0.1 percent Na_2CO_3 addition for the two clay sands.

The permeability increased in an orderly manner from a value of 121 (at the temper point) at 0 percent Na_2CO_3 to 143 at 0.1 percent Na_2CO_3 (at the temper point). Further increase in percentage of Na_2CO_3 brought about a decrease in permeability; the permeability value of 0.5 percent Na_2CO_3 addition being 118 which is less than the value for 0 percent Na_2CO_3.

In the case of Kankara clay sands, the permeability changes were not so orderly. The permeability value increased from 77.5 to 93.5 at 0.1 percent Na_2CO_3 and decreased as percentage Na_2CO_3 addition increased to 0.2 percent. An increase in permeability of Kankara clay sand could still be noticed as the Na_2CO_3 percentage was increased from 0.2 to 0.5 percent but in no case was it higher than the value for 0.1 percent Na_2CO_3 addition.

Substantial increase in permeability with addition of small percentage of Na_2CO_3 as seen from the results shows that the permeability of a fine sand can be increased when treated with small amounts of Na_2CO_3 and thus can be used for heavier casting to obtain a good surface finish.

5.3.4.4 Green Compression Strength

The green strength values of Battatti clay sands were highly affected by Na_2CO_3 addition but changes in Kankara clay sands were not very high. Battatti clay sands showed a decrease in green strength value in an orderly manner as the Na_2CO_3 content was increased from 0 percent to about 0.2 percent after which further increase in Na_2CO_3 content brought about an increase in green strength values. The green strength at temper point of Battatti clay sands decreased in an orderly manner from 63.5kN/m^2 at 0 percent Na_2CO_3 to 52.3kN/m^2 at about 0.2 percent Na_2CO_3 (a decrease of about 17 percent) and increased from this value to 71kN/m^2 at 0.5 percent Na_2CO_3 which in actual fact is greater than the value for 0 percent Na_2CO_3 addition. For Kankara clay sands, at temper points, small addition of 0.05 percent Na_2CO_3 increased the green strength value and then decreased gradually as the Na_2CO_3 percentage was increased.

The decrease in green strength value of moulding sand mixtures treated with small amount of ions having deflocculating ability like Na^+ ions (as explained earlier in this chapter) is that there is less neutralization of negative charges and hence the repulsive force (Zeta Potential) between the clay micelle is higher and intermicellar attration force is reduced leading to a decrease in green strength. On the other hand, if there are excess Na^+, the decrease in green strength will be less or there may even be an increase because of the reduction in the repulsive forces due to excess amount of positive ions. The results of the experiment with Battatti clay sands are clearly in support of the theory, but changes in Kankara clay sands are not very conclusive.

5.3.4.5 Oven Dry Strength

Figures 5.10d and 5.13d represent the oven dry strength to moisture relationships for Battatti and Kankara clay sands respectively. The letter "T" marked on the curves indicate the oven dry strength values at temper points for different percentages of Na_2CO_3. The values are plotted against percent Na_2CO_3 and are shown in figures 5.16 and 5.17.

From the graphs, the oven dry strength of Battatti clay sands is seen to show substantial improvement with the addition of Na_2CO_3. Oven dry strength at temper point of Battatti clay sand increased from 265kN/m^2 at 0 percent Na_2CO_3 to 595kN/m^2 at 0.5 percent Na_2CO_3 (it is not very clear why the increase in oven dry strength values still continued upto 0.5 percent Na_2CO_3 addition).

In any case, the increase in oven dry strength is beneficial to Battatti clay sand which has a low oven dry strength. In the case of Kankara clay sand, there is a drop in oven dry strength between 0 percent Na_2CO_3 (650kN/m^2) and 0.05 percent Na_2CO_3 (595kN/m^2) addition after which the oven dry strength increased to a maximum (695kN/m^2) when 0.2 percent Na_2CO_3 was added.

It can thus be seen that the increase in oven dry strength values of Battatti and Kankara clay sands treated with Na_2CO_3 actually proved the theory that the replacement of less hydrable ions by higher hydrable ions brings about an increase in dry strength as discussed earlier in this chapter.

5.3.4.6 Air Set Strength

The air set strength values of both Battatti and Kankara clay sands showed substantial increase with small addition of Na_2CO_3. Figures 5.11a and 5.14a show the grpahs of air set strength to moisture content relationships for various percentages of Na_2CO_3. The letter "T" marked on the curves indicate the values at temper points and these values are plotted graphically against percent Na_2CO_3 as seen in figures 5.16 and 5.17.

For the two sands, the maximum values of air set strength at temper points were obtained when 0.1 percent Na_2CO_3 was added. (Though there were still increase at 0.5 percent which is thought to be due to increase in water requirements). The air set strength of Battatti clay sands increased from a value 171kN/m^2 at 0 percent Na_2CO_3 to 226kN/m^2 at 0.1 percent Na_2CO_3 (an increase of 32 percent) and decreased as the percentage

of Na_2CO_3 is increased to 0.2. Similarly, the air set strength of Kankara clay sands increased from 285kN/m^2 at 0 percent Na_2CO_3 to 355kN/m^2 at 0.1 percent Na_2CO_3 and then decreased as percentage of Na_2CO_3 is further increased.

The increase in air set strength of both clay sands at low percentages of Na_2CO_3 addition further proves the theory that the replacement of less hydrable ions in clay by more hydrable ions like Na^+ brings about a substantial increase in dry strength.

5.3.4.7 Shatter Index

Na_2CO_3 addition to the two sands brought about significant increase in shatter index values of both Battatti and Kankara clay sands. The relationships between shatter index and moisture content are clearly reflected in figures 5.11b and 5.14b. The letter "T" marked on the curves indicate the values of the shatter index at temper points and are plotted against percent Na_2CO_3 as shown in figures 5.16 and 5.17 for the two sands.

From the graphs, it can be seen that the maximum increase in shatter index at temper points of Battatti clay sand occured at 0.1 percent Na_2CO_3. Addition of 0.1 percent Na_2CO_3 increased the shatter index of Battatti clay sands from 56 to 69; an increase of about 23 percent. The shatter index values with addition of higher percentage of Na_2CO_3 was equally high. It may be due to the fact that the shatter index is extremely sensitive to water content of the sand and it increases rapidly with increase in percentage of water to a maximum value after which increase in water content brings about a

decrease in shatter index. Thus it can be said that addition of Na_2CO_3 helps to improve the toughness of Battatti clay sand if the moisture is not above certain range.

However, in the case of Kankara clay sands, the maximum increase in shatter index occured at 0.05 percent Na_2CO_3. Addition of 0.05 percent of Na_2CO_3 increased the shatter index of Kankara clay sands from 48 to 61, an increase of 27 percent after which further increase in Na_2CO_3 percentage decreased the shatter index. At 0.3 percent, it is found to be even lower than that at 0 percent.

The increase in toughness of sands due to the addition of smallamounts of Na_2CO_3 can be attributed to the capacity of Na^+ ions to disperse the clay particles and make them to coat the sand grains more thoroughly. A more thorough coating of sand grains with clay allows the sand to deform more readily under load or, in other words, increases the toughness of the sands. Increase in toughness of both Battatti and Kankara clay sands by Na_2CO_3 is a great advantage as the toughness of these sands are generally not high enough.

5.3.4.8 Green Hardness

Figures 5.11d and 5.14d represent the green hardness to moisture content relationships for various percentages of Na_2CO_3 for the two clay sands. The letter "T" marked on the curves represent the green hardness values at temper points and these values are plotted against percent Na_2CO_3 in figures 5.16 and 5.17.

Generally, the green hardness for both Battatti and Kankara clay sands decreased appreciably with increase in Na_2CO_3 percentage upto about 0.2 percent of Na_2CO_3 addition and then start to increase with further increase in the amount of Na_2CO_3. At 0.5 percent Na_2CO_3, the green hardness value for Battatti clay sand is 88.7 and that of Kankara is 86. These values in actual fact are greater than the values at 0 percent Na_2CO_3 addition which is 85 for both clay sands.

5.3.4.9 Flowability

Flowability of the two sands generally showed a decrease with Na_2CO_3 addition. The flowability to moisture content relationships for both Battatti and Kankara clay sands are shown in figures 5.12 and 5.15 respectively. The letter "T" marked on the curves indicate the flowability values at correct degree of temper for various percentages of Na_2CO_3. These values were plotted against percentages of Na_2CO_3 addition and are shown in figures 5.16 and 5.17 respectively. From these graphs, it can be seen that the flowability values for Battatti clay sand decreased from 79 at 0 percent Na_2CO_3 to 71 at 0.2 percent Na_2CO_3 addition (a decrease of 9 percent) after which further increase in Na_2CO_3 percentage brought about an increase in flowability. Similarly, flowability of Kankara clay sands decreased from 78 at 0 percent Na_2CO_3 to 67.5 at 0.3 percent Na_2CO_3 addition (a decrease of 13 percent) and further increase in Na_2CO_3 increased the flowability.

The decrease in flowability is attributed to increase in toughness as it is a well known fact that a tough sand does not flow well.

5.3.4.10 Choice of Adequate Amount of Na_2CO_3 for Foundry Moulding Sands Prepared from Battatti and Kankara Clays

From the foregoing discussions, it is clear that addition of Na_2CO_3 to a foundry sand prepared from these two local clays brings about a lot of changes in their properties. While some properties are improved, some are however impaired, the extent of changes strongly depending on the amount of Na_2CO_3 added and of course also on the type of clay.

As the extent to which these properties changed depend on the amount of Na_2CO_3, the choice of the amount of Na_2CO_3 to be added should depend on the combination of properties needed for a particular application.

However, as the general improvements in properties occured at about 0.1 percent Na_2CO_3 addition, the use of 0.1 percent Na_2CO_3 is suggested for Battatti and Kankara clay sands to get the best combination of improvements in properties.

5.3.5 Conclusions

(1) It is possible to change the properties of foundry moulding sands prepared from the two local clays (Battatti and Kankara) by subjecting the sand mixtures to cation exchange treatment with Na_2CO_3.

(2) Cation exchange treatment of sands with Na_2CO_3 brings about improvements in certain properties while some other properties however are impaired.

(3) A combination of improvements in properties of foundry moulding sands could be achieved with the addition of small amounts of Na_2CO_3 to the foundry sands. The use of 0.1 percent Na_2CO_3 is recommended for the sand prepared from these two local clays as this amount gives a general maximum change. (Higher amount than 0.1 percent may bring more improvements in some properties but this will also lower the refractoriness of the sand).

(4) Changes in Battatti clay sands are more significant than changes in Kankara clay sands. The larger change may be attributed to its higher Cation Exchange Capacity than that of Kankara clay.

(5) Water requirements of moulding sands prepared from these two clays are decreased when small amounts of Na_2CO_3 is added.

(6) Permeability of the two sands are increased by the addition of small amounts of Na_2CO_3.

(7) Addition of small amounts of Na_2CO_3 to sands decrease their green strength. This is more noticeable in Battatti clay sands.

(8) The oven dry strength of the two sands are improved substantially by sodium carbonate addition. Improvement is more noticeable in Battatti clay sand and this is advantageous

as Battatti clay sands generally has low oven dry strength.

(9) The air set strengths (upto 0.1 percent Na_2CO_3 addition) show significant improvement for the two sands.

(10) Green hardness and flowability generally decreased with addition of Na_2CO_3. The decrease is more at lower percentages of Na_2CO_3.

CHAPTER SIX

THE COMBINED EFFECTS OF METHOD OF PREPARATION AND CATION EXCHANGE REACTIONS BROUGHT ABOUT BY Na_2CO_3 ADDITION ON PROPERTIES OF MOULDING SANDS

6.1 Introduction

The importance of proper mixing to improve some sand properties have been known to foundrymen for long. It has been found that the use of an efficient muller or increase in mulling time can lead to a thorough coating of the sand grains by bonding materials. A sand mixture which is thoroughly coated with bonding materials is capable of giving high strength and toughness and some improvements on other properties. Investigations carried out by Mathew (1977) have shown that improvements on properties of local foundry sands are possible by special preparation techniques.

Also as mentioned in chapter five, it is possible to change the sand properties and casting qualities by the use of chemicals. Investigations carried out as discussed in chapter five on foundry sands prepared from local materials showed that it is quite possible to improve the properties of Nigerian foundry sands by the use of chemicals.

Mathew (1977) has also indicated that the properties of local sands could be further improved by a combination of an improved method of preparation and Na_2CO_3 addition. Based on these previous investigations, it was decided to investigate

into the details of how foundry sands would behave when a combination of improved method of preparation and Na_2CO_3 addition is used to prepare the sand mixtures. Mathew (1977) investigated to see the behaviour of certain properties of moulding sands when the sand mixtures are prepared using improved method of preparation with 0.05 percent Na_2CO_3 addition to the sand mixtures. In this particular work, it was decided to investigate the effects of four other methods of preparation for sands treated with six different percentages of Na_2CO_3 additives.

6.2 Experimental Investigations

In experiments discussed in chapter five, a method of preparation in which the ingredients, sand and clay, were mixed for 2 minutes dry and for 5 minutes wet after adding calculated amounts of water in which desired percentages of Na_2CO_3 have been dissolved was used for preparation of the samples. This method is considered as the normal method and can be called method 1. After the experiments with the sand samples prepared by this method, it was decided to investigate to see what will happen if sand mixtures containing 0 percent, 0.05 percent, 0.1 percent, 0.2 percent, 0.3 percent and 0.5 percent are prepared by four other methods of preparation (methods 2, 3, 4 and 5) as described below.

Method 1: Mixing the ingredients (sand and clay) for 2 minutes dry and for 5 minutes wet after adding calculated amount of water (normal method).

Method 2: Mixing the ingredients (sand and clay) for 2 minutes dry and for 10 minutes wet continously (i.e increase in mulling time).

Method 3: Mixing the ingredients for 2 minutes dry and for 5 minutes wet with 5 percent water, airdrying the mixtures, then remulling one minute dry and for 5 minutes wet. (Two stage mulling without using excess water during the initial mulling).

Method 4: Mixing the ingredients for 2 minutes dry and 5 minutes wet with 7.5 percent water, airdrying the mixtures, then remulling one minute dry and 5 minutes wet (Two stage mulling with slight excess water during the initial mulling).

Method 5: Mixing the ingredients for 2 minutes dry and 5 minutes wet with 10 percent water, airdrying the mixtures, then remulling one minute dry and 5 minutes wet (Two stage mulling with excess water during the initial mulling).

The excess amount of water used during the initial mulling would make the mulling more efficient and thorough by activating the clay to provide its binding capacity and plasticity. The two factors that help in making the mulling more efficient and thorough in these cases are increase in mulling time (due to double mulling) and excess water used during the first mulling. Water contents above 10 percent were not tried for initial mulling as such higher amounts of water were making the sand too

wet and sticky thereby making its removal from the muller difficult.

For each of the methods of preparation, five 2000 g of sand at 5 different moisture levels (after the final mulling) were prepared for each amount of Na_2CO_3 addition. 30 samples were prepared for each type of clay and for each method of preparation. Thus, a total of about 240 samples were prepared for these investigations. As usual the sand samples were prepared in a Ridsdale Laboratory Mill with rotating wheels. Distilled water was used throughout the investigations. After the preparations, samples were stored in airtight containers for about 12 hours before being tested.

The following usual sand properties were tested:

(1) Moisture content

(2) Density

(3) Permeability

(4) Green Compression Strength

(5) Oven Dry Strength

(6) Air Set Strength

(7) Shatter Index

(8) Compactability

(9) Green Hardness

(10) Flowability

6.2.1 Results

The results of the investigations using methods 2, 3, 4 and 5 with different percentages of Na_2CO_3 were plotted (i.e properties versus moisture content relationships) for

different properties graphically. The graphs as they were too many are not included in this thesis in order not to make the thesis bulky. However, values of properties at temper points for each sand sample prepared using these methods including method 1 at different percentages of Na_2CO_3 were obtained from these graphs and were used to plot the graphs shown in figures 6.1 to 6.18 in which the properties at temper points were plotted against Na_2CO_3 percent addition for the different preparation methods. This was done because in green sand moulding, sands are brought to the correct degree of temper before moulding.

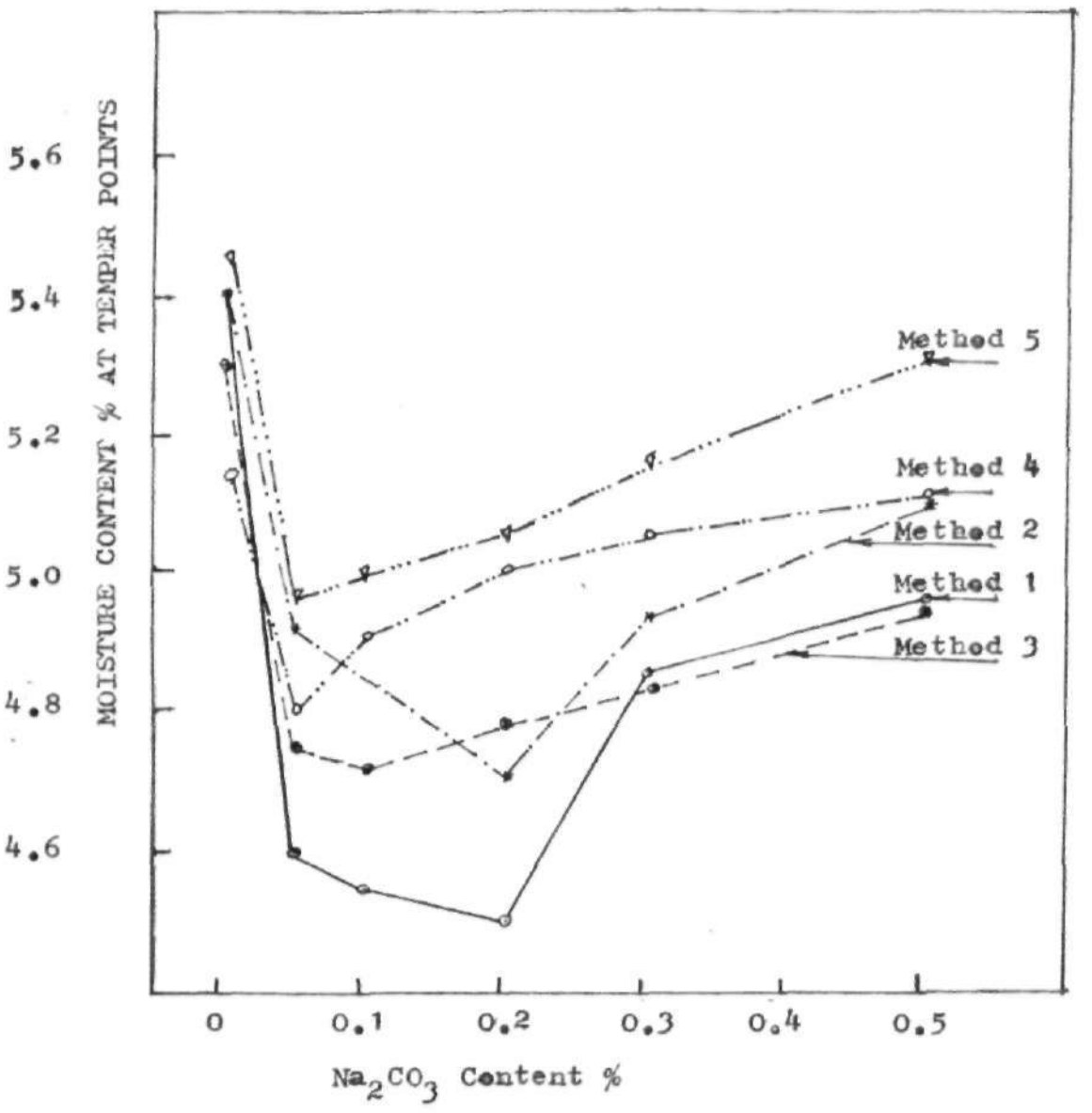


FIG. 6.1: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON WATER REQUIREMENTS AT TEMPER POINTS OF BATTATTI CLAY SANDS.

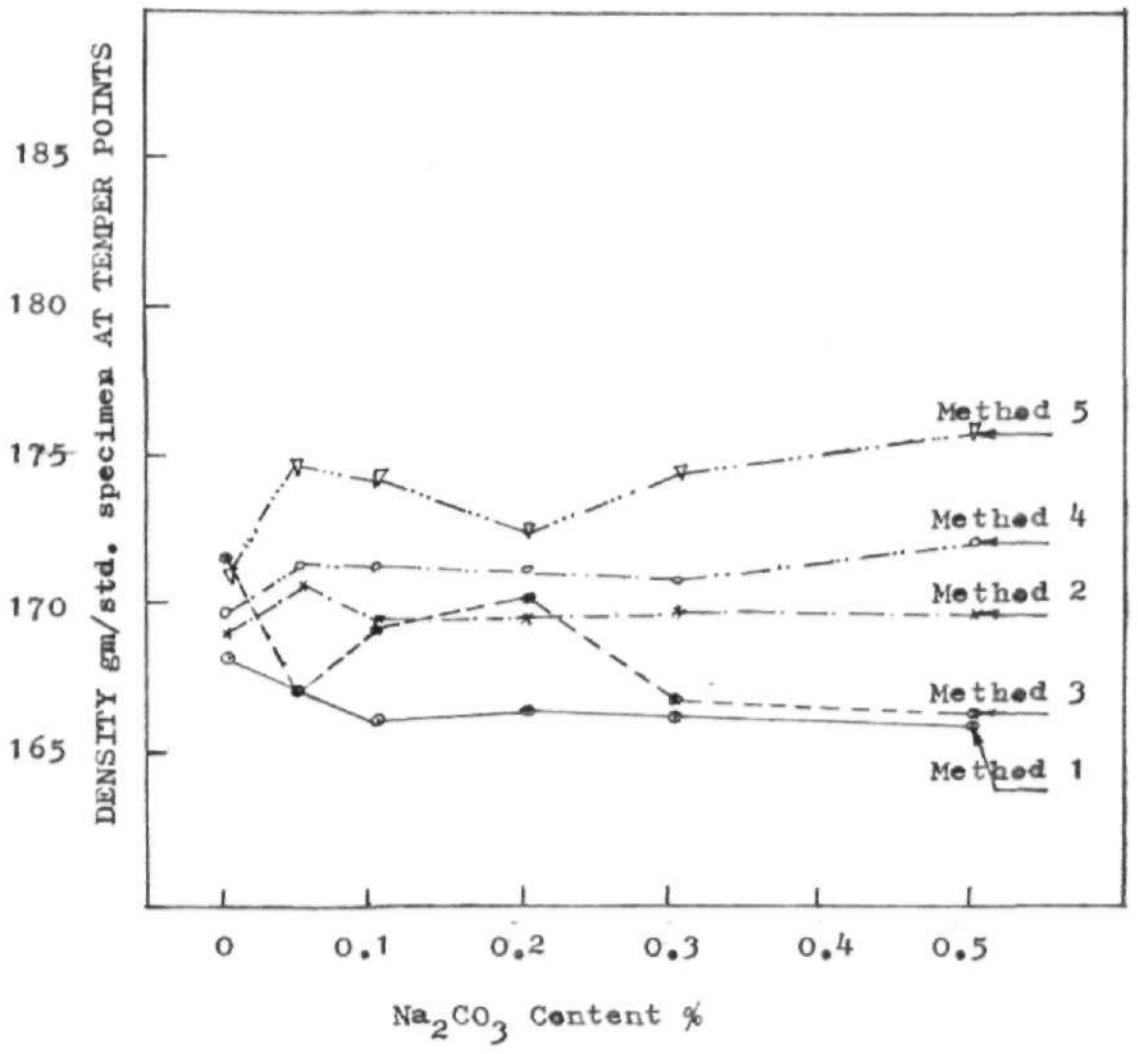


FIG. 6.2: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON DENSITY AT TEMPER POINTS OF BATTATTI CLAY SANDS.

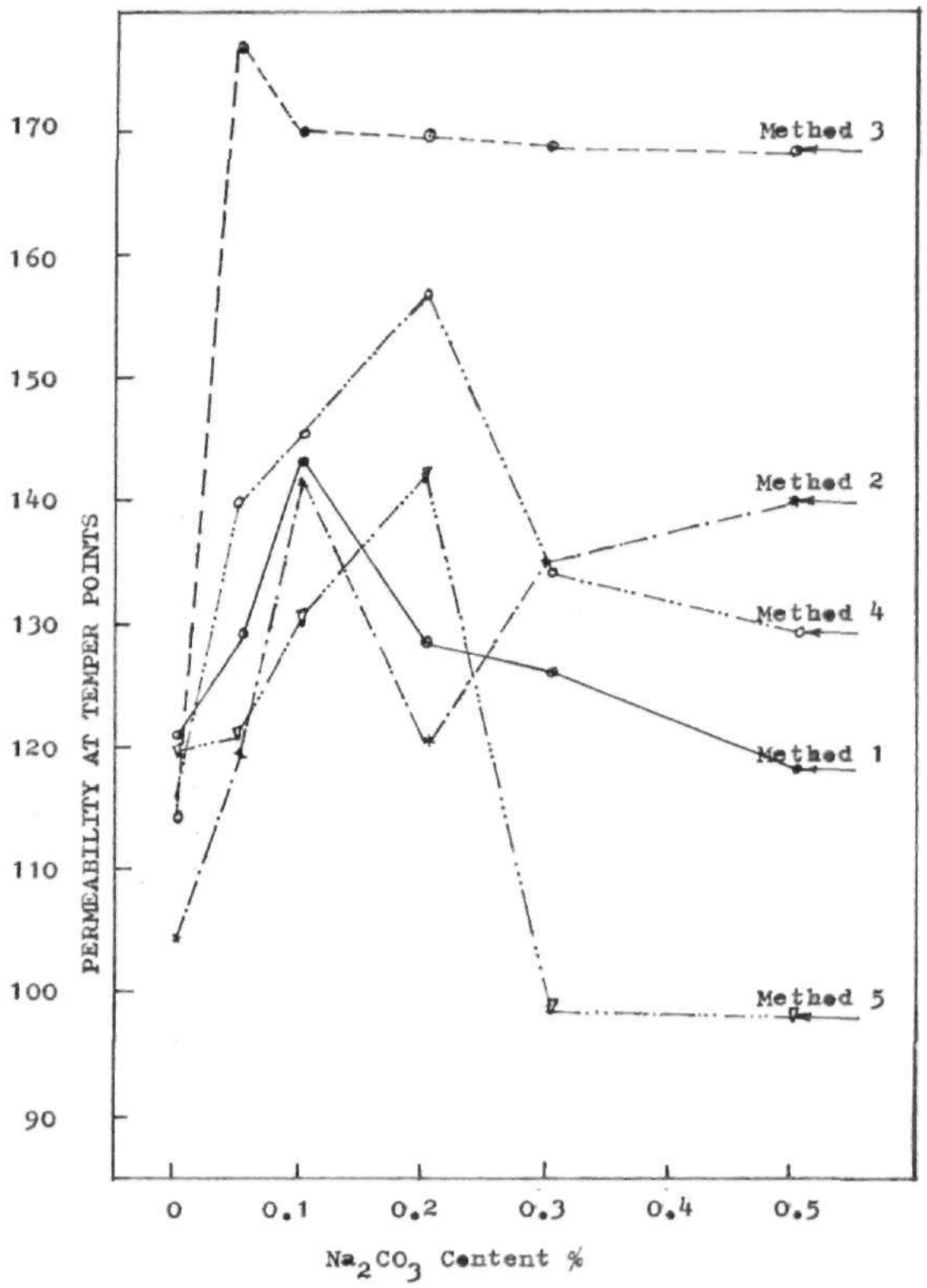


FIG. 6.3: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON PERMEABILITY AT TEMPER POINTS OF BATTATTI CLAY SANDS.

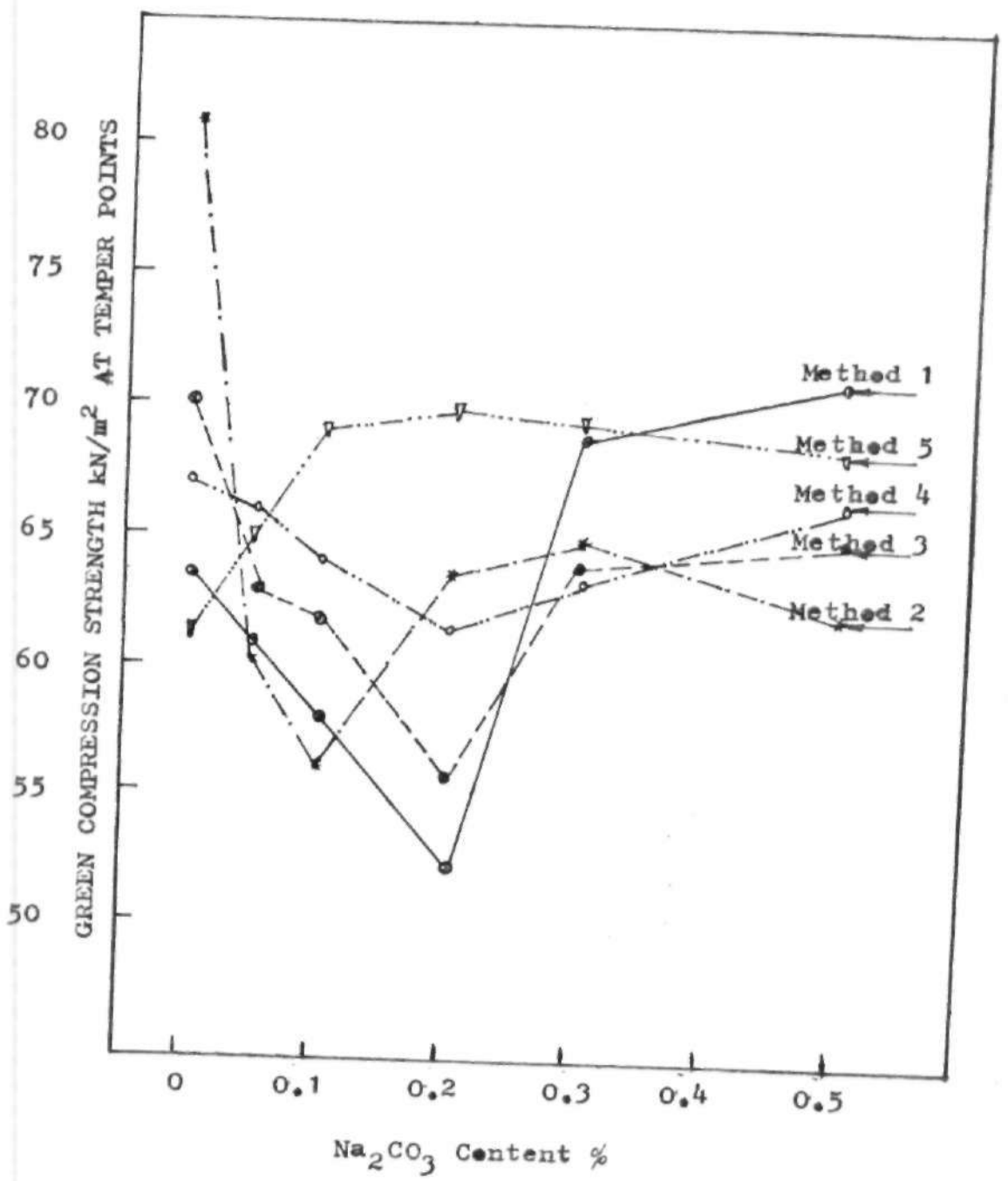


FIG. 6.4: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON GREEN COMPR. STRENGTH AT TEMPER POINTS OF BATTATTI CLAY SANDS.

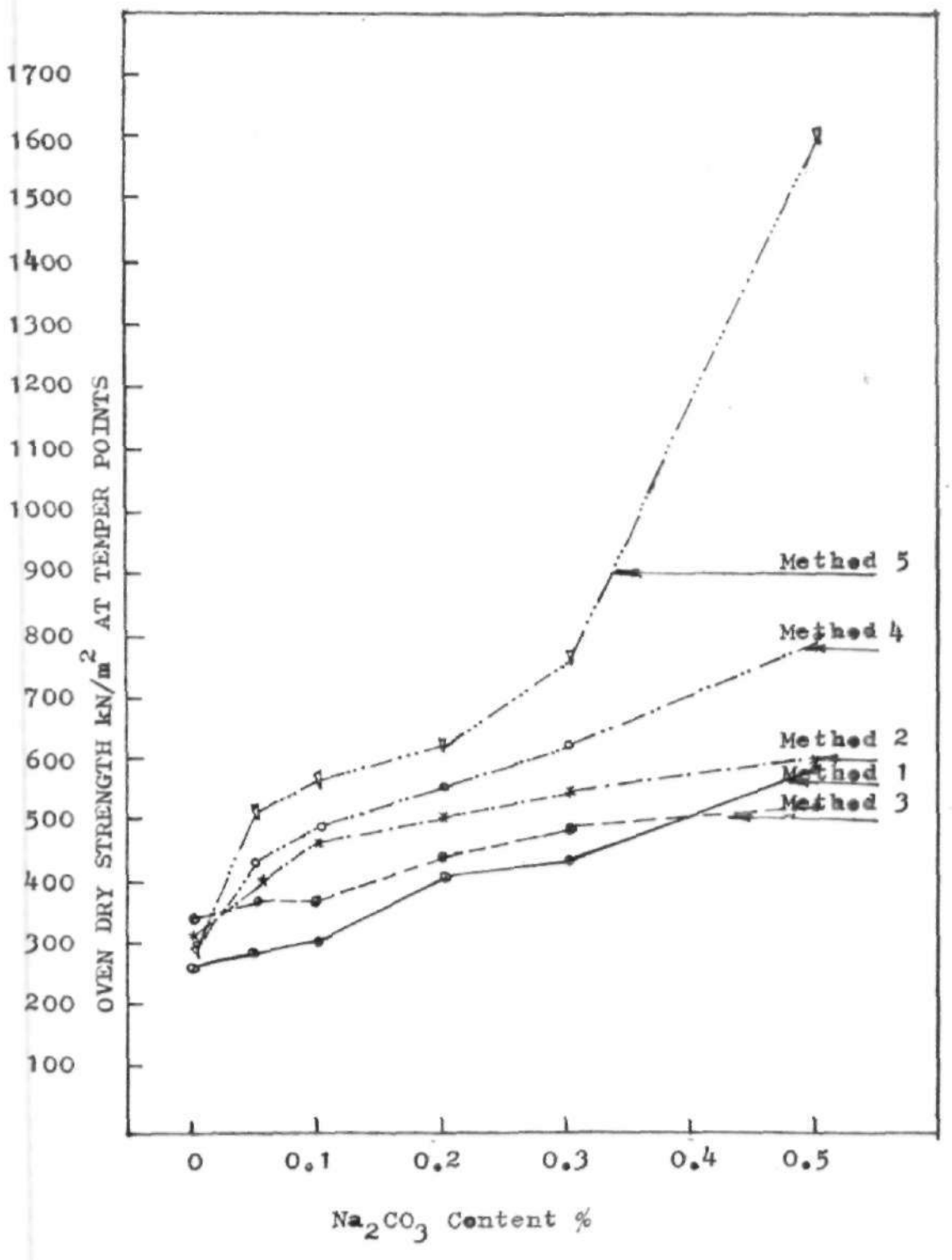


FIG. 6.5: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON OVEN DRY STRENGTH AT TEMPER POINTS OF BATTATTI CLAY SANDS.

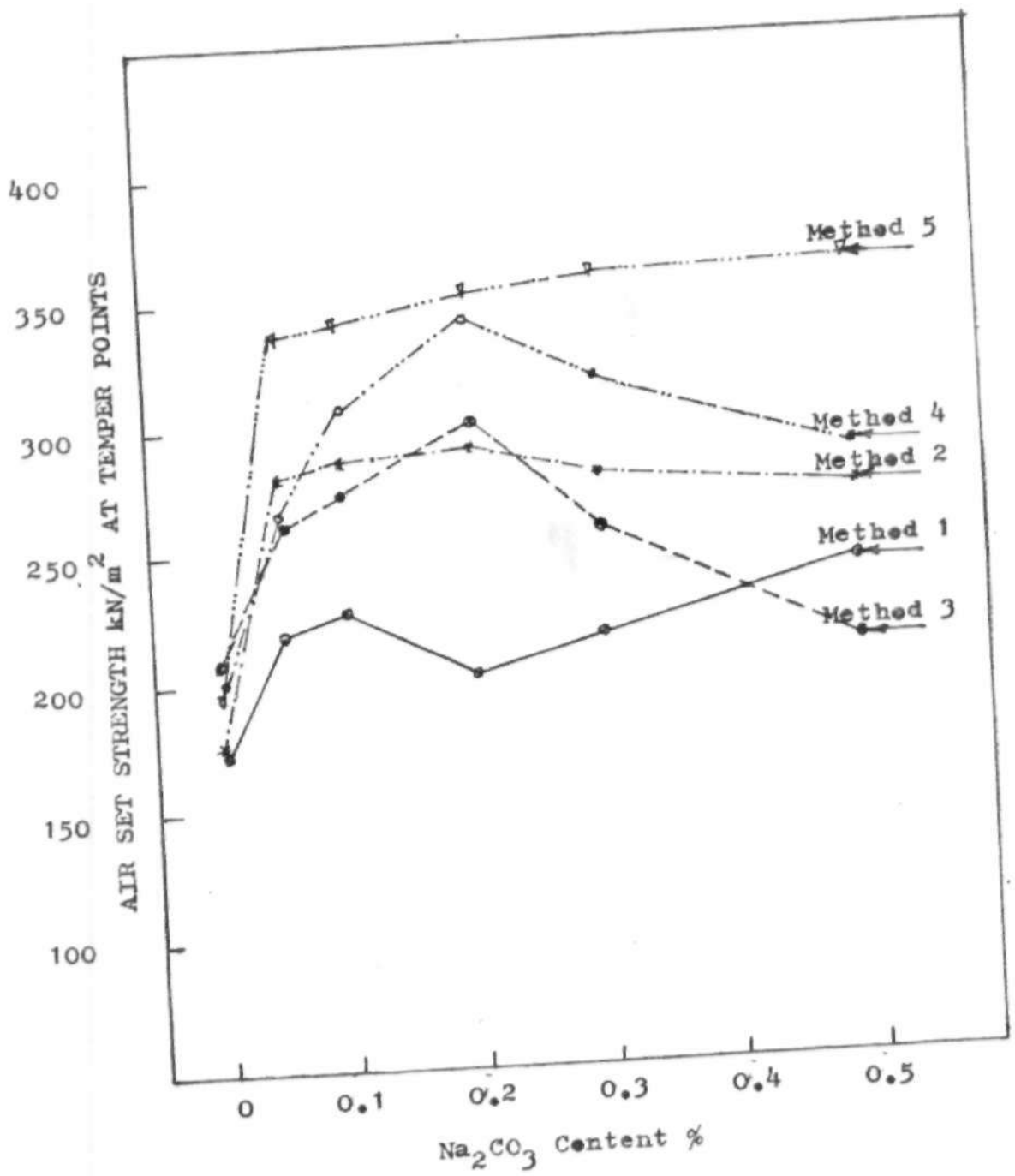


FIG. 6.6: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON AIR SET STRENGTH AT TEMPER POINTS OF BATTATTI CLAY SANDS.

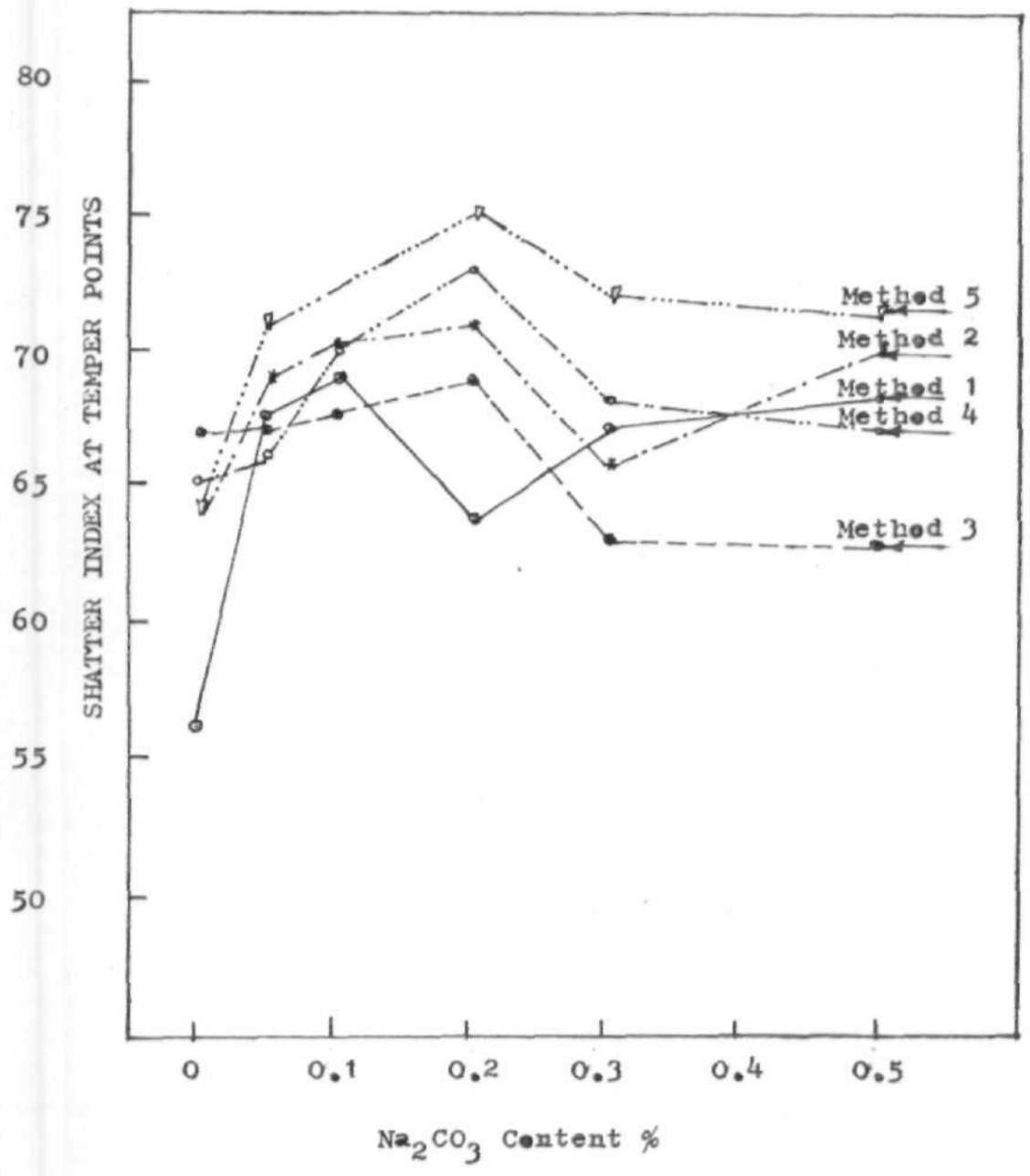


FIG. 6.7: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON SHATTER INDEX AT TEMPER POINTS OF BATTATTI CLAY SANDS.

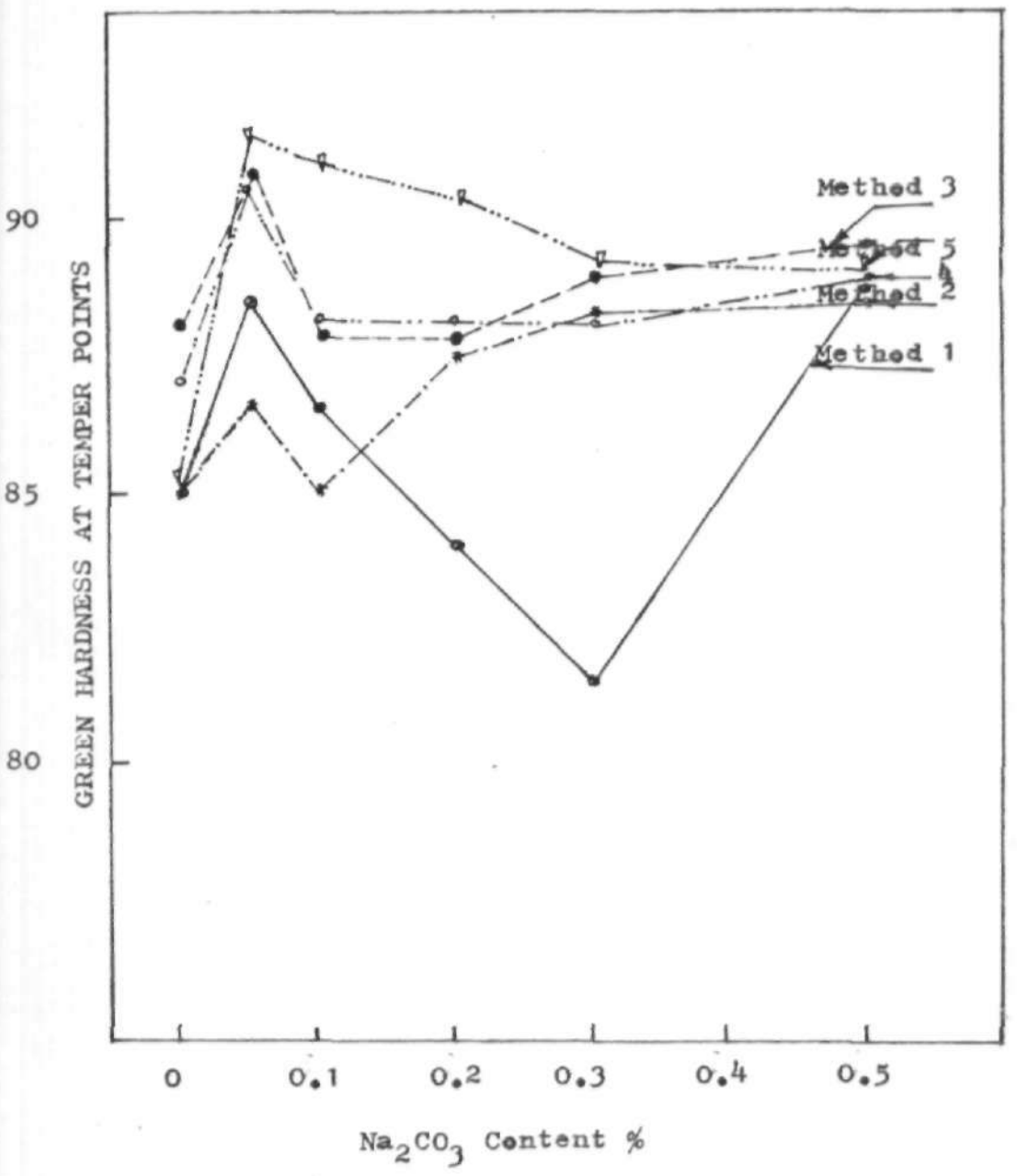


FIG. 6.8: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON GREEN HARDNESS AT TEMPER POINTS OF BATTATTI CLAY SANDS.

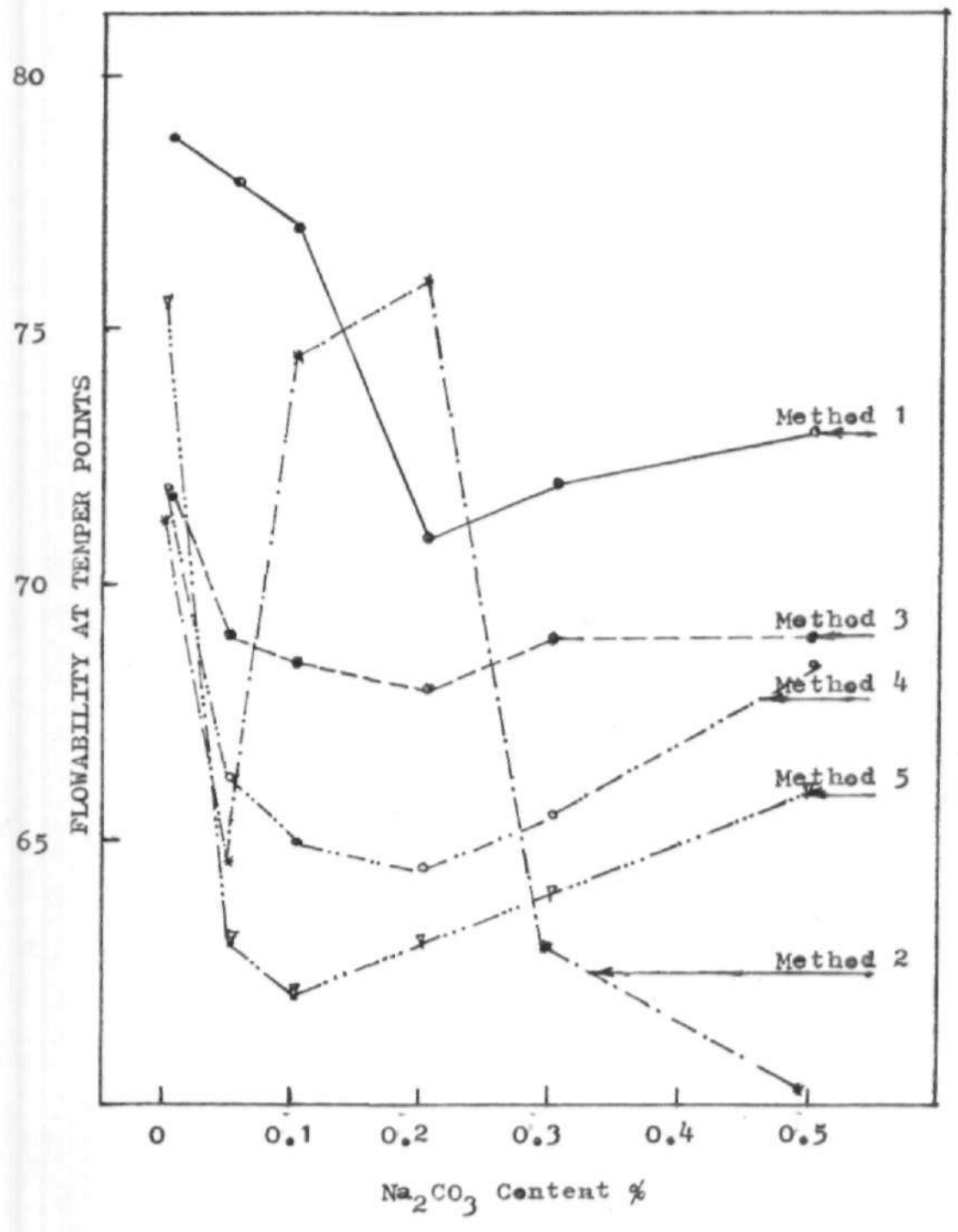


FIG. 6.9: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON FLOWABILITY AT TEMPER POINTS OF BATTATTI CLAY SANDS.

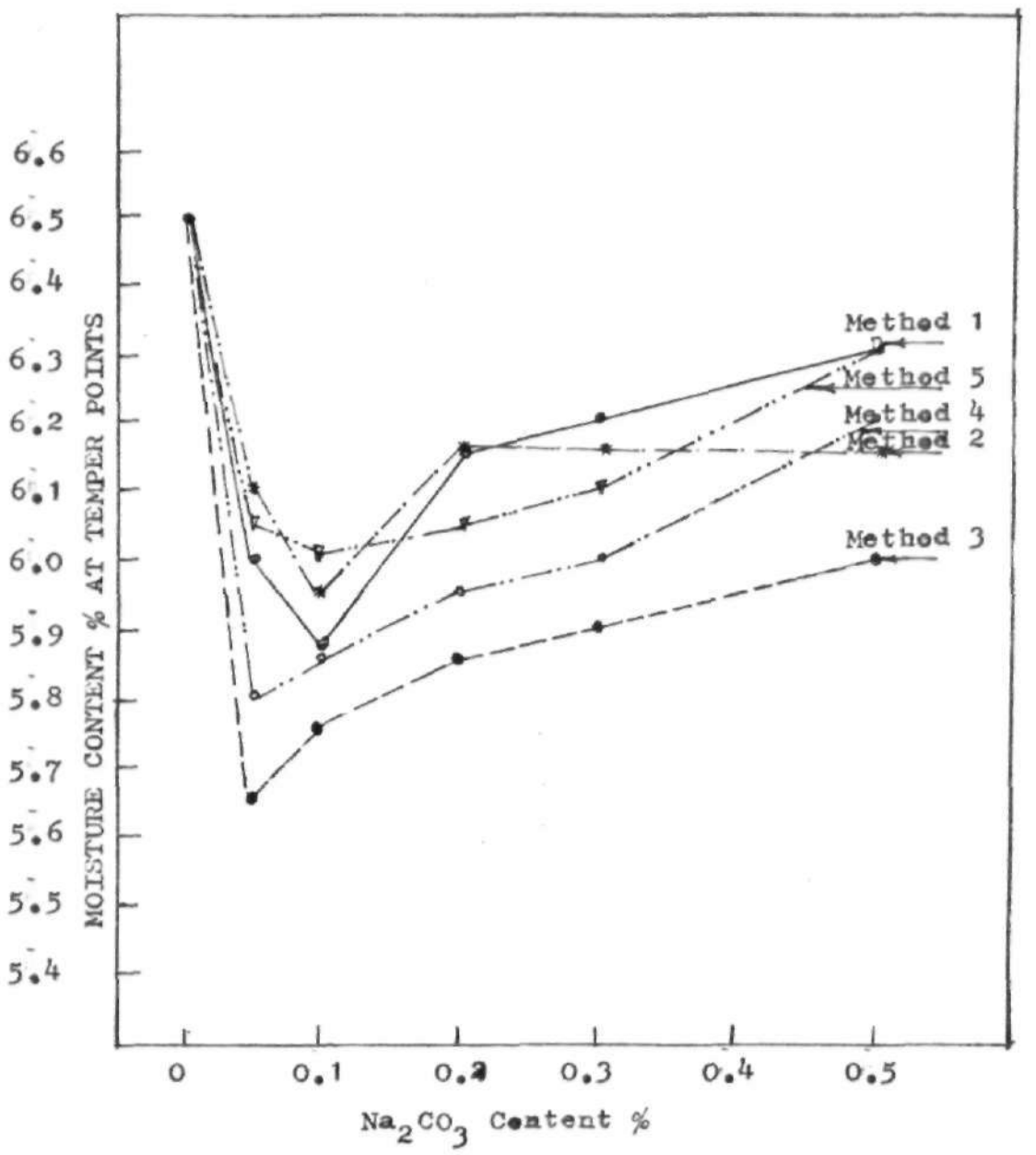


FIG. 6.10: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON WATER REQUIREMENTS AT TEMPER POINTS OF KANKARA CLAY SANDS.

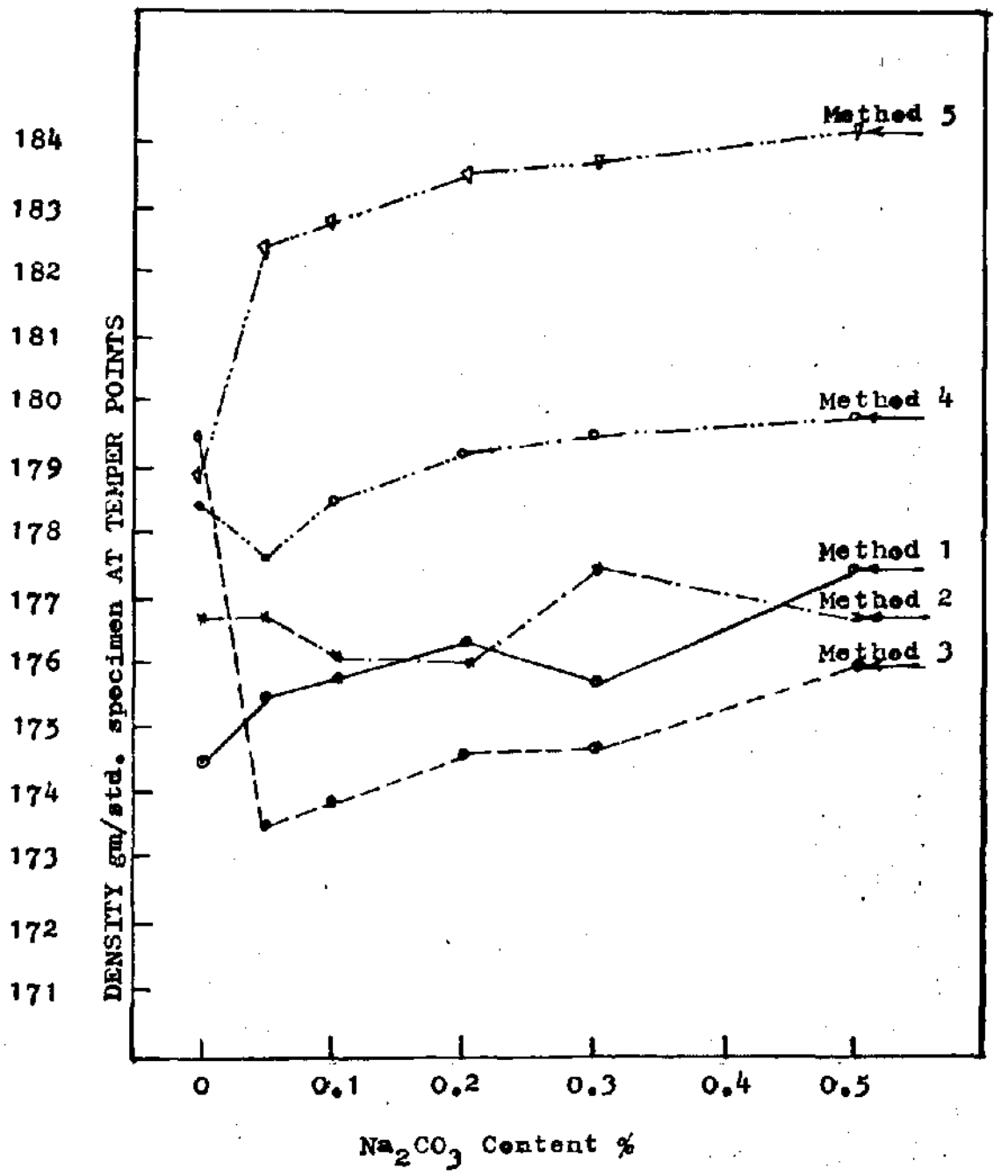


FIG. 6.11: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON DENSITY AT TEMPER POINTS OF KANKARA CLAY SANDS.

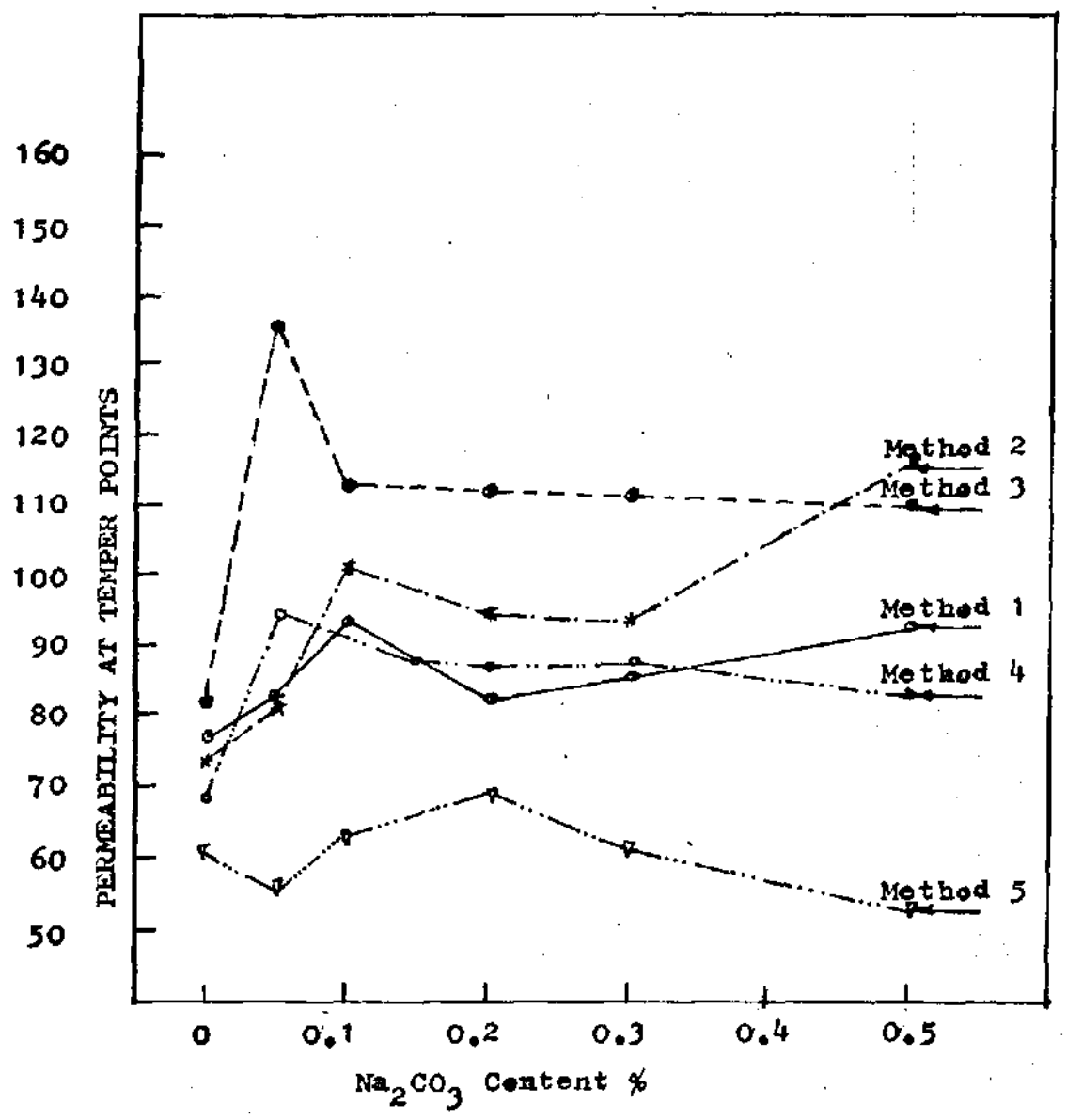


FIG. 6.12: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON PERMEABILITY AT TEMPER POINTS OF KANKARA CLAY SANDS.

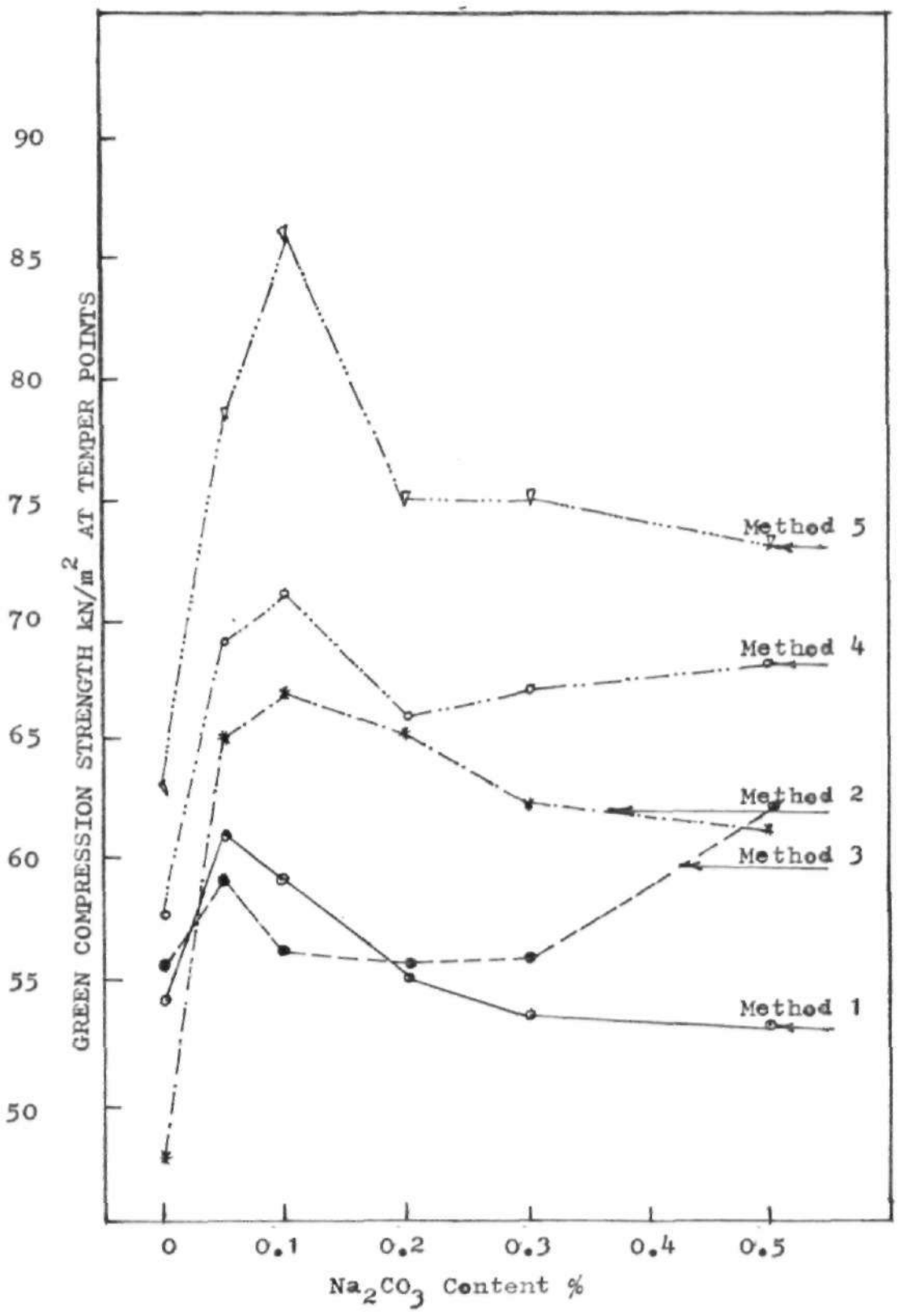


FIG. 6.13: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON GREEN COMPR. STRENGTH AT TEMPER POINTS OF KANKARA CLAY SANDS.

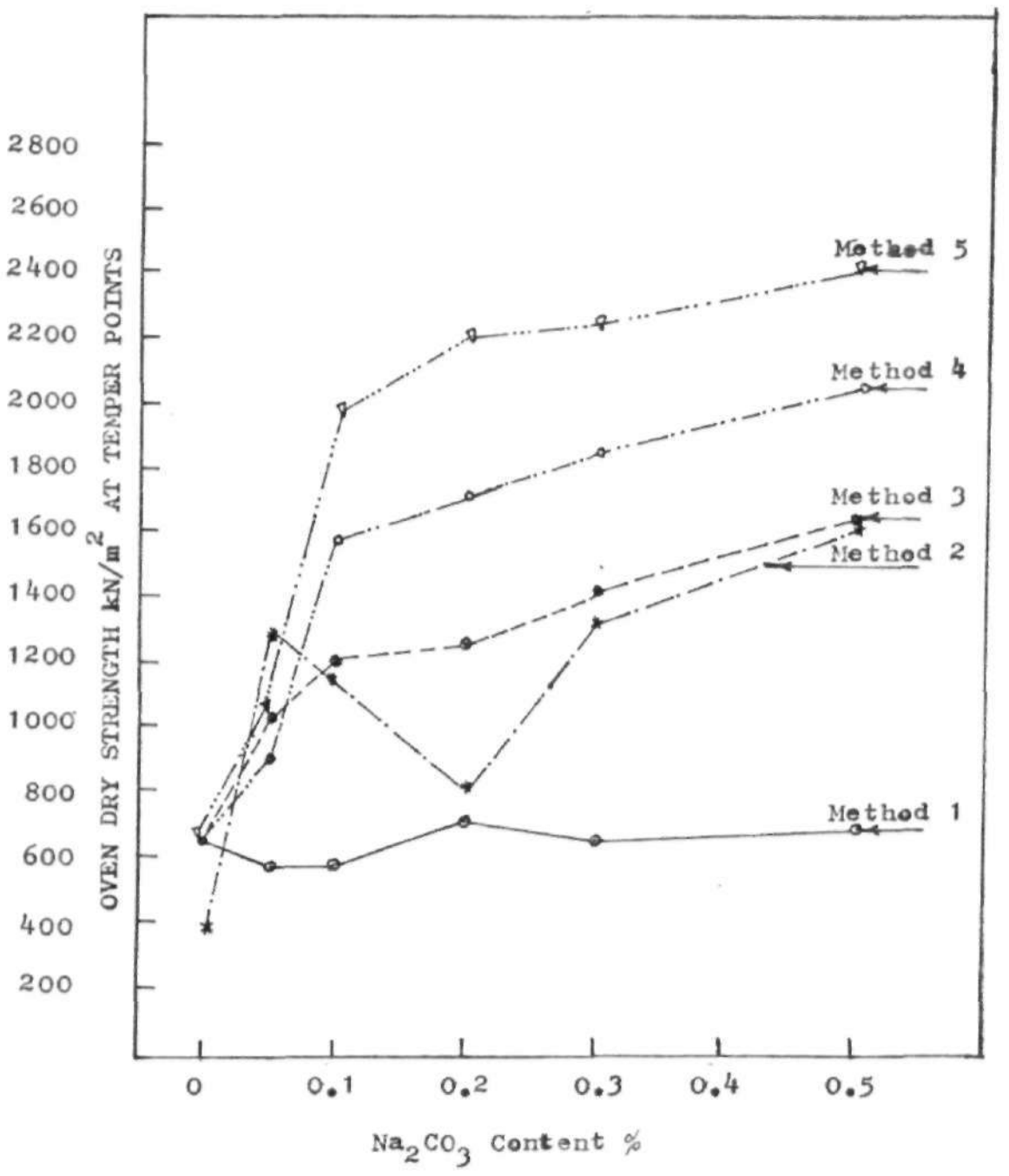


FIG. 6.14: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON OVEN DRY STRENGTH AT TEMPER POINTS OF KANKARA CLAY SANDS.

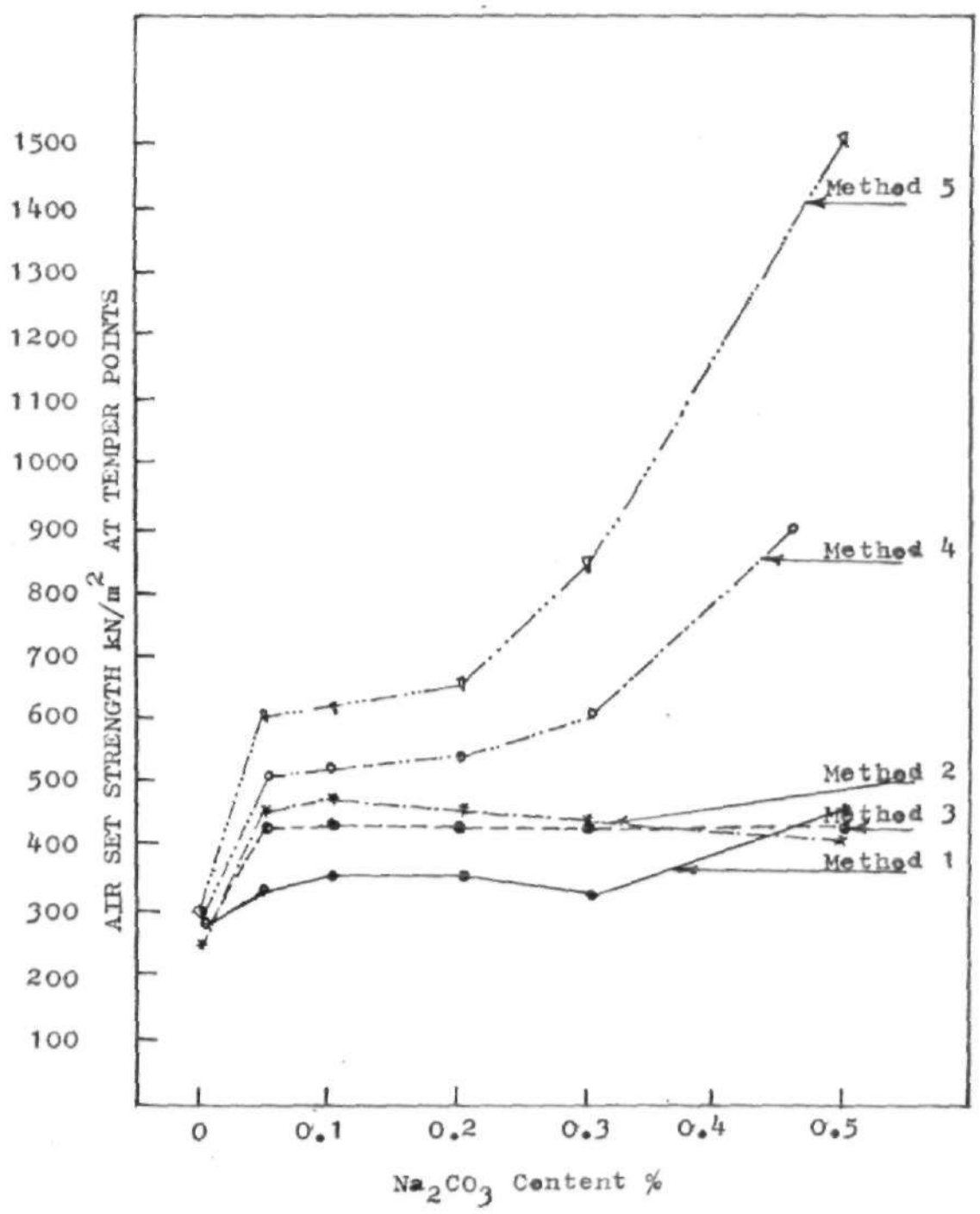


FIG. 6.15: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON AIR SET STRENGTH AT TEMPER POINTS OF KANKARA CLAY SANDS.

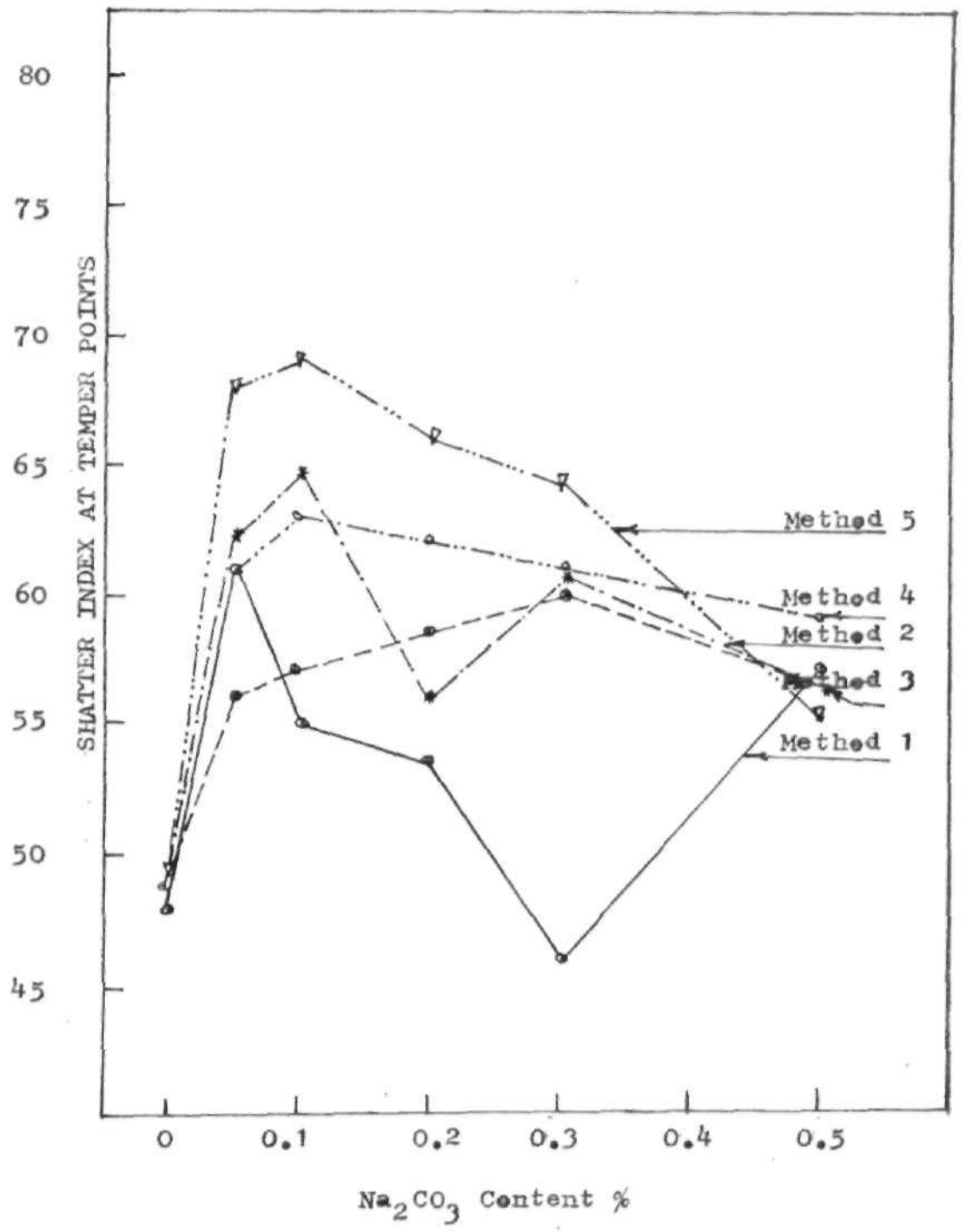


FIG. 6.16: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON SHATTER INDEX AT TEMPER POINTS OF KANKARA CLAY SANDS.

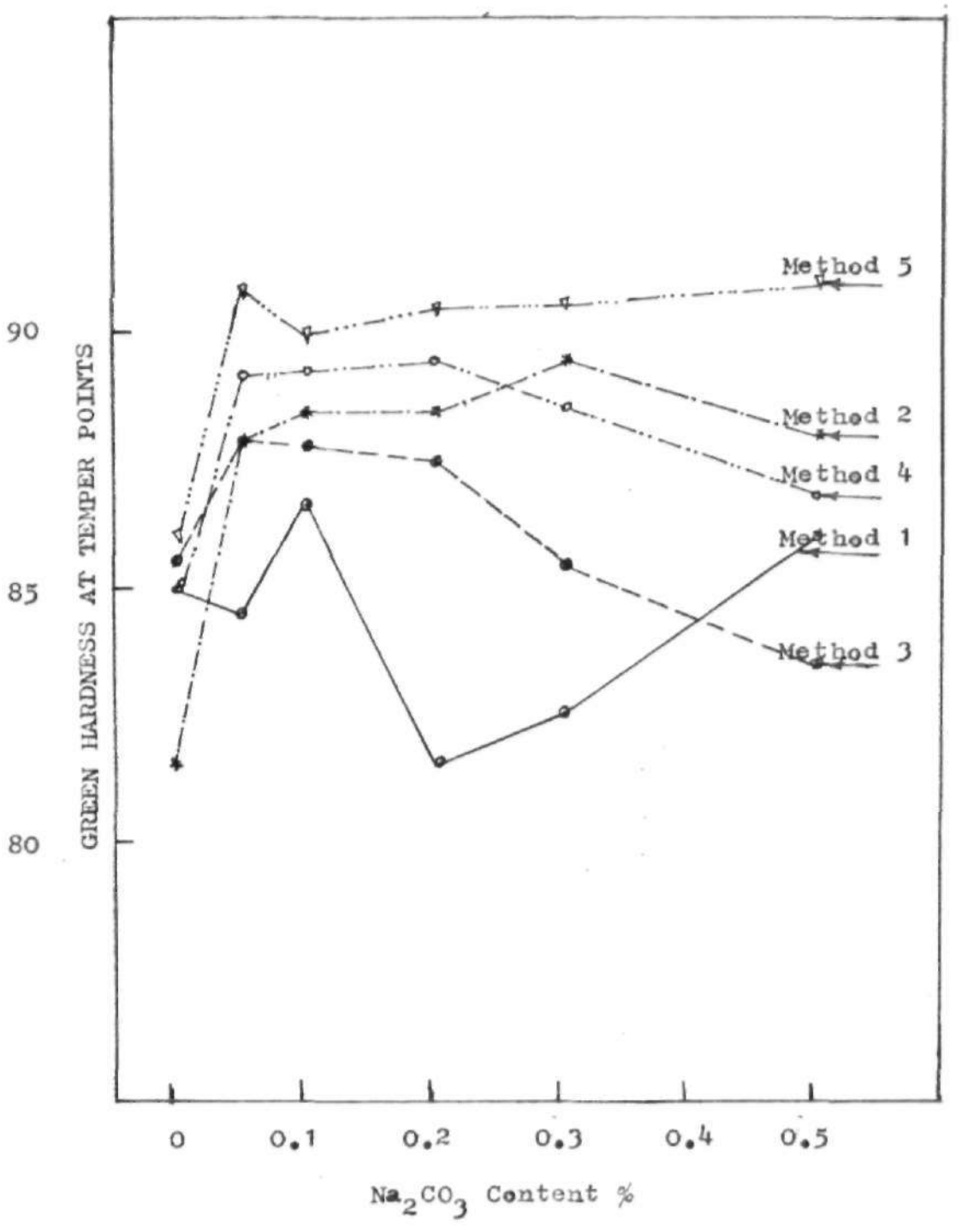


FIG. 6.17: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON GREEN HARDNESS AT TEMPER POINTS OF KANKARA CLAY SANDS.

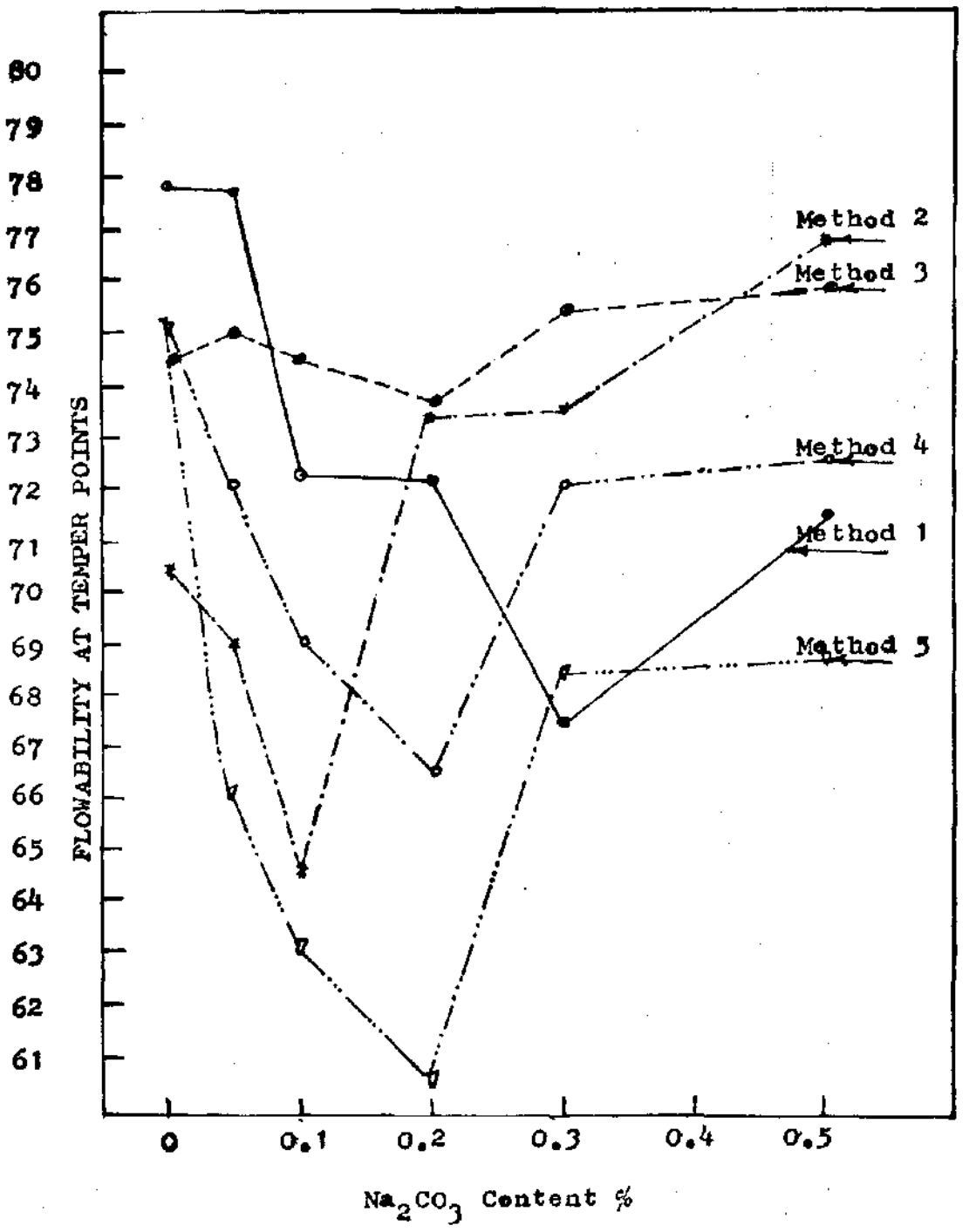


FIG. 6.18: COMBINED EFFECTS OF METHOD OF PREPARATION AND Na_2CO_3 ADDITION ON FLOWABILITY AT TEMPER POINTS OF KANKARA CLAY SANDS.

6.2.2 Discussion of the Results

Glancing through the graphs in figures 6.1 to 6.18, it can be seen that changes in properties of sand mixtures possible by treatment with Na_2CO_3 addition can be greatly enhanced when the high preparation methods under investigation (methods 2, 3, 4 and 5) are used to prepare the sand mixtures. The extent to which these properties are changed depends on the type of clay, the amount of Na_2CO_3 added and the method of preparation. Changes in properties with different percentages of Na_2CO_3 and with different methods of preparation will now be discussed one by one.

6.2.2.1 Water Requirement

Addition up to a certain amount of Na_2CO_3 (0.2 percent for Battatti clay sand and 0.1 percent for Kankara clay sand) decreases the amount of water required to bring the sand samples to the same compactability level. Further increase in Na_2CO_3 content will increase the amount of water required from the minimum value to bring the sand to the same compactability value. When the method of preparation was changed from the normal to the high preparation methods, moisture required to bring the sands to the same compactability level increased. Method 5 increased the moisture requirement more than the other methods for all levels of Na_2CO_3 content.

Figures 6.1 and 6.10 show the moisture contents at temper points of sand mixtures prepared using methods 1, 2, 3, 4 and 5 with respect to percent Na_2CO_3 addition for Battatti and Kankara clay sands respectively.

From these figures, it can be seen that for all the methods of preparation used, the amount of water required to bring the sand mixtures to temper points initially decreased with small addition of Na_2CO_3 and then increased with further increase in Na_2CO_3 content.

6.2.2.2 Density

Changing the method of preparation from the normal to one of the high preparation methods generally increased the density values except in the case of method 3. Method 5 gave the highest increase in density values. With this method, increase in Na_2CO_3 content has a substantial effect on the density values.

6.2.2.3 Permeability

For all methods of preparation, addition of small amounts of Na_2CO_3 increased the permeability substantially. Further increase in the amount of Na_2CO_3 decreased the permeability from the maximum value. The reason for increase in permeability due to small additions of Na_2CO_3 may be attributed to the clays, being in a deflocculated state, providing a better coating on the sand grains. Because of this better coating, the grains are prevented from coming very close to each other. This provides larger voids between the sand grains which increases the permeability of the sands.

Figures 6.3 and 6.12 illustrate the permeability values at temper points versus percent Na_2CO_3 addition relationships for sand mixtures prepared using both Battatti and Kankara clay sands for all the methods of preparation (i.e methods 1, 2, 3, 4 and 5).

From these graphs, it can be seen that permeability values at temper points were further changed with changes in the method of preparation. When the permeability values at temper points of sands containing 0.1 percent Na_2CO_3 and prepared by different methods were compared, it was found that in the case of Battatti clay sands, the value was 143 for method 1, 142 for method 2, 170 for method 3, 145 for method 4 and 130 for method 5. In the case of Kankara clay sands, the value was 93 for method 1, 100 for method 2, 112 for method 3, 91 for method 4 and 62 for method 5.

Thus for the two clay sands, method 3 gave the highest improvements on permeability. The values are lower for some methods. For method 5, it is lowest. The reason for method 3 having the highest permeability is thought to be due to complex behaviour of sand mixtures when a combination of Na_2CO_3 addition and high preparation techniques are used to prepare the sand mixtures. Normally, the permeability of sands is increased with small Na_2CO_3 addition. The permeability of sands are however decreased with increased preparation (i.e decrease from method 1 to 2 to 3 to 4 to 5). Therefore when a combination of Na_2CO_3 addition and high preparation techniques are used to prepare the sand mixtures, at an intermediate stage, the permeability shows the highest values due to a high degree of deflocculation of the clay.

For heavier castings, the increase in permeability for the two sands is an advantage. For lighter castings, high permeability is not required. Therefore when fine sand is used, and if permeability is low, a high substantial improvement in

permeability can be achieved when method 3 is used to prepare the sand mixtures after adding a small amount of Na_2CO_3.

6.2.2.4 Green Compression Strength

The green compression strength for Battatti and Kankara clay sands behaved differently when small amount of Na_2CO_3 was added to sand mixtures. In the case of Battatti clay sands, addition of upto 0.1 percent of Na_2CO_3 to sand mixtures prepared using all the methods of preparation generally decreased the green strength to a minimum value. It was then increased with further increase in Na_2CO_3 addition. Method 5 however did not show any decrease but a slight increase for small amounts of Na_2CO_3 added to the sand mixtures. In the case of Kankara clay sands, addition of small amounts of Na_2CO_3 generally brought about an increase in green strength values to a maximum value after which further increase in Na_2CO_3 addition decreased the green strength values for all the methods of preparation.

Figures 6.4 and 6.13 illustrate the green compression strength values at temper points versus percent Na_2CO_3 addition relationships for sand mixtures prepared from both Battatti and Kankara clays using all the methods of preparation (methods 1, 2, 3, 4 and 5). When the green compression strength at temper points were compared at 0.1 percent Na_2CO_3, in the case of Battatti clay sands, for method 1 the value was 58 kN/m^2; for method 2, 56 kN/m^2; for method 3, 62 kN/m^2; for method 4, 64 kN/m^2 and for method 5, 69 kN/m^2.

For Kankara clay sand mixtures, with 0.1 percent Na_2CO_3 content, the green compression strength value at temper points for method 1 was 59 kN/m^2; for method 2, 67 kN/m^2; for method 3, 56 kN/m^2; for method 4, 71 kN/m^2 and for method 5, 85 kN/m^2. Thus for the two clay sands, method 5 gave the highest improvements in green compression strength of the sand mixtures.

The results clearly show that when Na_2CO_3 is added, the changes in green compression strength of the sands will depend on the type of clay present, the amount of Na_2CO_3 added and method of preparation used to prepare the sand mixtures. That is why some previous investigators obtained different results; in some cases increases in green strength and in some cases decreses. Booth (1949) noticed both increases and decreases in green strength values of sands due to the addition of Na_2CO_3. Hofmann (1959) noticed an increase in the green strength values for Bentonite bonded sands at higher moisture contents due to the addition of Na_2CO_3. It is, however, not clear whether the amount used by these investigators was higher than the amount needed to cause a decrease in green strength values.

6.2.2.5 Oven Dry Strength

Addition of Na_2CO_3 (oven upto 0.5 percent) generally increased the oven dry strength of the two clay sands. When higher preparation techniques (i.e methods 2, 3, 4 and 5) were used to prepared the sand samples containing upto 0.5 percent Na_2CO_3, the oven dry strength was found to increase still further as compared with that of sand mixtures prepared

using method 1. The extent to which the oven dry strength was thus improved depended on the type of clay, amount of Na_2CO_3 added and the preparation technique used in preparing the sand mixtures.

Figures 6.5 and 6.14 represent the oven dry strength values at temper points versus percent Na_2CO_3 relationships for sand mixtures prepared from Battatti and Kankara clays using all the methods of preparation (methods 1, 2, 3, 4 and 5). When the oven dry strength values at temper points of sands containing 0.1 percent Na_2CO_3 and prepared by different methods of preparation were compared, in the case of Battatti clay sands, the value was 300 kN/m^2 for method 1, 460 kN/m^2 for method 2 (an increase of 53 percent), 370 kN/m^2 for method 3 (an increase of 23 percent), 490 kN/m^2 for method 4 (an increase of 63 percent) and 560 kN/m^2 for method 5 (an increase of 87 percent). In the case of Kankara clay sands, prepared by different methods of preparation, when the oven dry strength values at temper points of sands containing 0.1 percent Na_2CO_3 were compared, the value was 560 kN/m^2 for method 1, 1150 kN/m^2 for method 2 (an increase of 105 percent), 1200 kN/m^2 for method 3 (an increase of 114 percent), 1560 kN/m^2 for method 4 (an increase of 179 percent) and 1970 kN/m^2 for method 5 (an increase of 252 percent).

Thus from the foregoing discussions, the results of the investigations showed that the oven dry strength of Battatti and Kankara clay sands could be improved substantially when a

combination of improved method of preparation and Na_2CO_3 addition was used to prepare the sand mixtures. Among the methods of preparation investigated, method 5 gave the highest values of the oven dry strength for the two clay sands both at temper points and other moisture contents. The increase in oven dry strength is extremely beneficial to Battatti clay sands which generally has a low oven dry strength.

6.2.2.6 Air Set Strength

The air set strength of both Battatti and Kankara clay sands were generally improved with the addition of Na_2CO_3 (even upto 0.5 percent Na_2CO_3 addition). When better methods of preparation (i.e methods 2, 3, 4 and 5) were used to prepare the sand samples containing upto o.5 percent Na_2CO_3, the air set strength was found to increase still further as compared with sand mixtures prepared using method 1. The extent to which the air set strength was improved depended on the type of clay, amount of Na_2CO_3 and the method of preparation used.

Figures 6.6 and 6.15 represent the air set strength values at temper points versus percent Na_2CO_3 relationships for the two clay sands respectively using methods 1, 2, 3, 4 and 5. When the air set strength values at temper points of sands containing 0.1 percent Na_2CO_3 and prepared by different methods of preparation were compared, the air set strength value at temper point for Battatti clay sands was 225 kN/m^2 for method 1, 285 kN/m^2 for method 2 (an increase of 27 percent), 273 kN/m^2 for method 3 (an increase of 21.3 percent), 305 kN/m^2 for method 4

(an increase of 36 percent) and 341 kN/m^2 for method 5 (an increase of 51 percent). In the case of Kankara clay sands, the air set strength values at temper points was 350 kN/m^2 for method 1, 450 kN/m^2 for method 2 (an increase of 29 percent), 425 kN/m^2 for method 3 (an increase of 21 percent), 520 kN/m^2 for method 4 (an increase of 49 percent) and 605 kN/m^2 for method 5 (an increase of 73 percent).

So the results of the investigations show that the air set strength of both Battatti and Kankara clay sands can be improved substantially when a combination of better method of preparation and Na_2CO_3 addition is used. In this case also, method 5 provided the most effective way of improving the air set strength of the two clay sands. As in the case of the oven dry strength, the increase in air set strength of Battatti clay sand is an advantage as it generally has a low air set strength.

6.2.2.7 Shatter Index

When small amounts of Na_2CO_3 (about 0.1 percent) were added to sand mixtures prepared from Battatti and Kankara clays, improvements in shatter index values were obtained. With higher amounts of Na_2CO_3, above 0.2 percent for Battatti clay sand and 0.1 percent for Kankara clay sand, decreases in shatter index were noticed for the two clay sands. When higher preparation techniques (i.e methods 2, 3, 4 and 5) were used to prepare the sand mixtures containing different percentages of Na_2CO_3, further improvements in shatter index

were obtained as compared to values obtained using method 1. The improvements obtained were more substantial for Kankara clay sands than Battatti clay sands. In the case of shatter index also, the extent to which changes in its value occured depend on the type of clay used, the amount of Na_2CO_3 and the method of preparation used to prepare the sand mixtures.

The shatter index values at temper points versus percent Na_2CO_3 addition relationships for all the methods of preparation are shown in figures 6.7 and 6.16 for Battatti and Kankara clay sands respectively. When the shatter index values were compared for sand mixtures containing 0.1 percent Na_2CO_3 for all the methods of preparation (methods 1, 2, 3, 4 and 5), in the case of Battatti clay sands, the shatter index value was 69 for method 1, 70 for method 2, 67.5 for method 3, 70.5 for method 4 and 72 for method 5. In the case of Kankara clay sands also, the shatter index values at temper points were 55 for method 1, 64.5 for method 2, 57 for method 3, 63 for method 4 and 69 for method 5.

Again the results show that shatter index, i.e toughness of the sand mixtures prepared from the two clays could be further improved when a combination of better method of preparation and Na_2CO_3 addition is used. Here again, method 5 provided the most effective way of obtaining the highest shatter index values for the two clay sands. Further increase in toughness of both clay sands is a great advantage as the toughness of the sands are generally not high enough.

6.2.2.8 Green Hardness

The green hardness of both Battatti and Kankara clay sands generally showed decrease in values when small amounts of Na_2CO_3 were added to the sand mixtures. When the amount of Na_2CO_3 was gradually increased above 0.1 percent, the green hardness showed an increase, the values thereby approaching those values obtained when no Na_2CO_3 was added. When different methods of preparation (i.e methods 2, 3, 4 and 5) were used to prepare the sand mixtures containing Na_2CO_3, both decrease and increase were obtained. The type of decrease or increase in green hardness values depended on the amount of Na_2CO_3 added and the methods of preparation used.

The green hardness at temper points versus percent Na_2CO_3 addition relationships for Battatti and Kankara clay sands are illustrated in figures 6.8 and 6.17 respectively for different methods of preparation used. When the values of green hardness at temper points were compared for sand mixtures containing 0.1 percent Na_2CO_3, in the case of Battatti clay sands, the green hardness values at temper points were 86.5 for method 1, 85 for method 2, 87.8 for method 3, 88.2 for method 4 and 91 for method 5. Similarly in the case of Kankara clay sands, the green hardness values at temper points were 86.7 for method 1, 88.5 for method 2, 87.8 for method 3, 89.3 for method 4 and 90 for method 5.

The results of the investigations, again showed that the green hardness of Battatti and Kankara clay sands could be improved when a combination of better method of preparation

and Na_2CO_3 is used to prepare the sand mixtures. Also in this case, method 5 gave the highest green hardness values for the two clay sands. Increase in green hardness is a great advantage as resistance to metal penetration of moulds would be increased and the chances of having mould dialation is reduced.

6.2.2.9 Flowability

The addition of small amounts of Na_2CO_3 generally decreased the flowability values of Battatti and Kankara clay sands to a minimum value after which further increase in Na_2CO_3 percentage increased the flowability. When higher preparation techniques (i.e methods 2, 3, 4 and 5) were used to prepare the sand mixtures containing different percentages of Na_2CO_3, further decrease in flowability values as compared with values obtained using method 1 were noticed for the two clay sands.

Figures 6.9 and 6.18 show the flowability values at temper points versus percentage Na_2CO_3 addition graphs for all the methods of preparation tried (i.e methods 1, 2, 3, 4 and 5). When the flowability values were compared for sands containing 0.1 percent Na_2CO_3, in the case of Battatti clay sands, the values at temper points were 77 for method 1, 74.5 for method 2, 68.8 for method 3, 65 for method 4 and 62 for method 5. In the case of Kankara clay sands, the decrease in flowability was not too orderly. It can be seen that methods 2, 4 and 5 have lower flowability values than the value obtained for method 1 but method 3 showed a

slightly higher value of flowability than the value obtained for method 1.

The decrease in flowability was not unexpected as the toughness of the sands were further improved due to a combination of better method of preparation and Na_2CO_3 addition. It is a well known fact that a tough sand does not flow well.

From the foregoing discussions it has been seen that substantial improvements on properties of sand mixtures prepared from Battatti and Kankara clays can be obtained when combination of better methods of preparation and Na_2CO_3 addition are used. Among the methods of preparation investigated, method 5 gave more improvements in the properties of sand than other methods. Subsequently, it was decided to plot graphs of the important properties like permeability, green compression strength, oven dry strength and shatter index for method 5 and method 1 when 0 percent and 0.1 percent Na_2CO_3 were added to the sand mixtures prepared using these methods. The graphs are shown in figures 6.19 to 6.22 to provide a good comparison of the results.

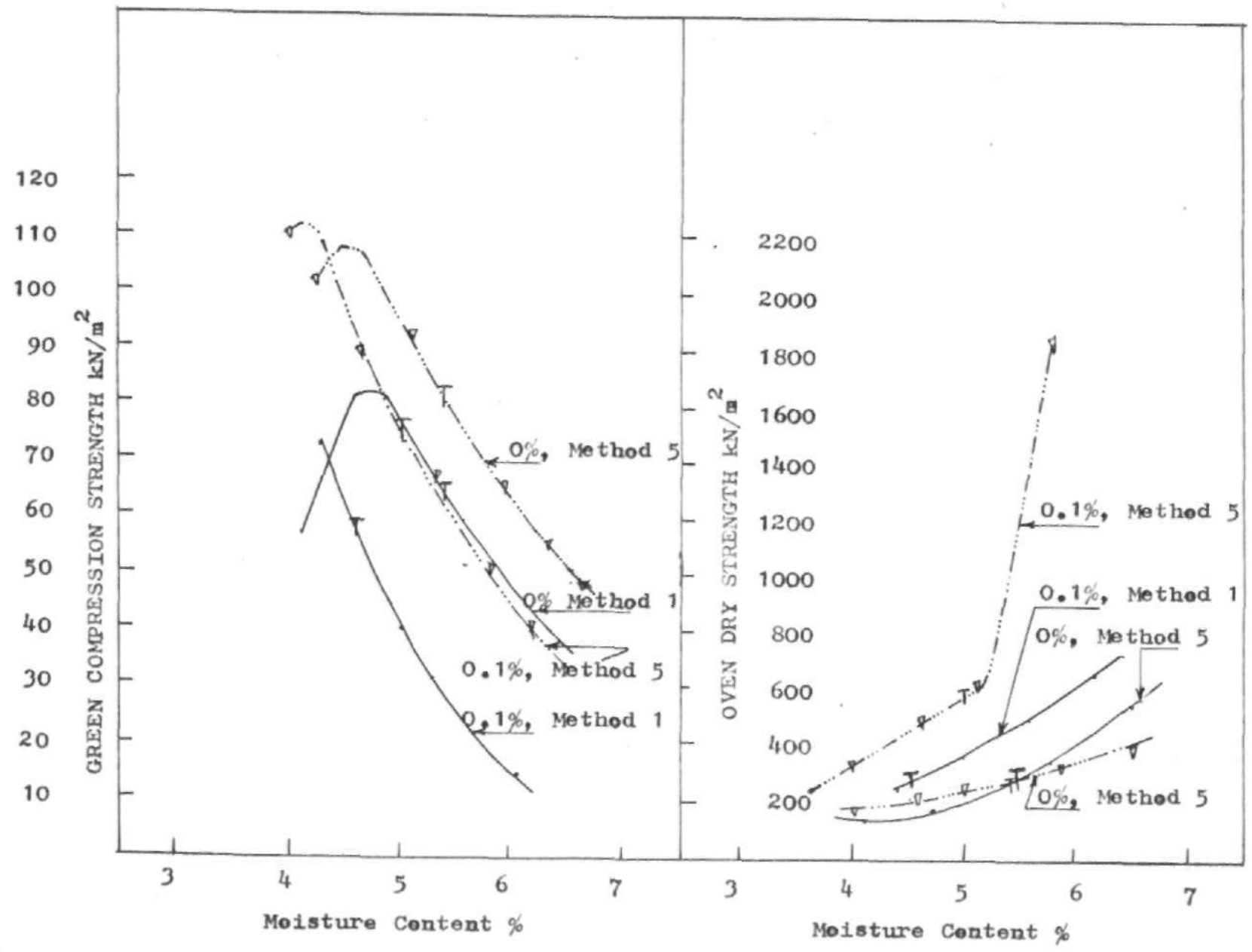


FIG. 6.19: EFFECT OF 0 PERCENT AND 0.1 PERCENT Na_2CO_3 ADDITION ON GREEN COMPR. STRENGTH AND OVEN DRY STRENGTH OF BATTATTI CLAY SANDS PREPARED BY METHODS 1 AND 5.

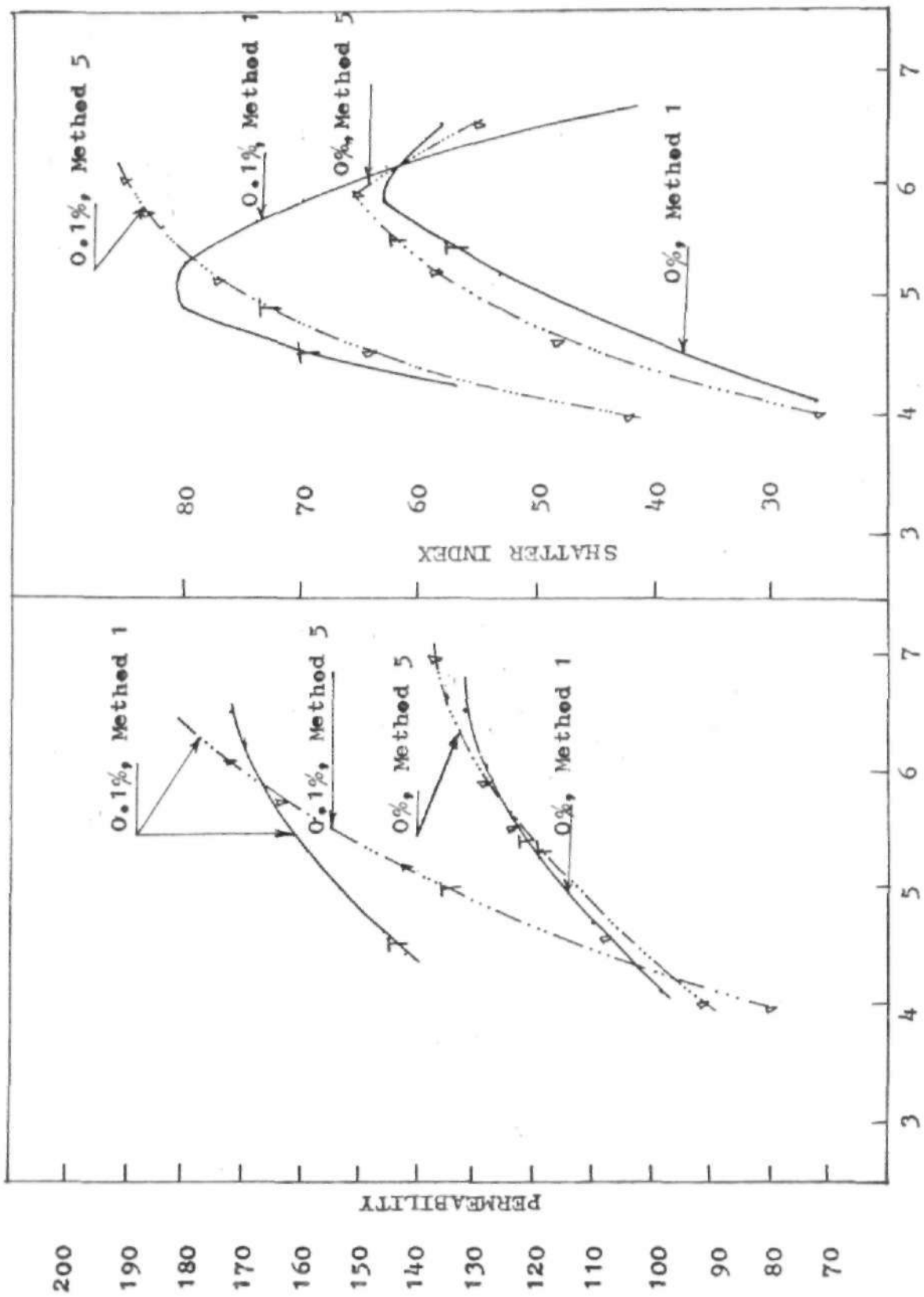


FIG. 6.20: EFFECT OF 0 PERCENT AND 0.1 PERCENT Na_2CO_3 ADDITION ON PERMEABILITY AND SHATTER INDEX OF BATTATTI CLAY SANDS PREPARED BY METHODS 1 AND 5.

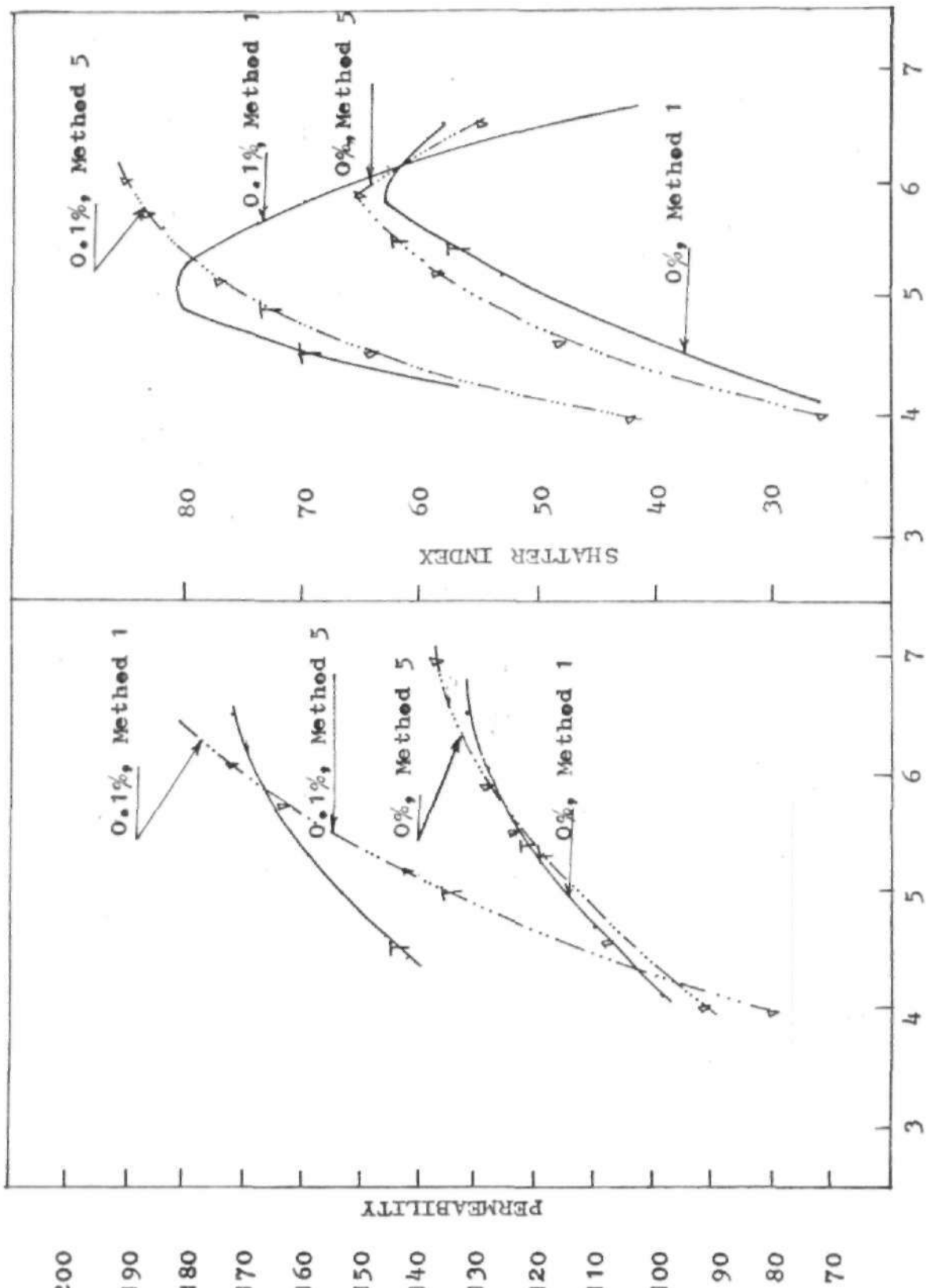


FIG. 6.20: EFFECT OF 0 PERCENT AND 0.1 PERCENT Na_2CO_3 ADDITION ON PERMEABILITY AND SHATTER INDEX OF BATTATTI CLAY SANDS PREPARED BY METHODS 1 AND 5.

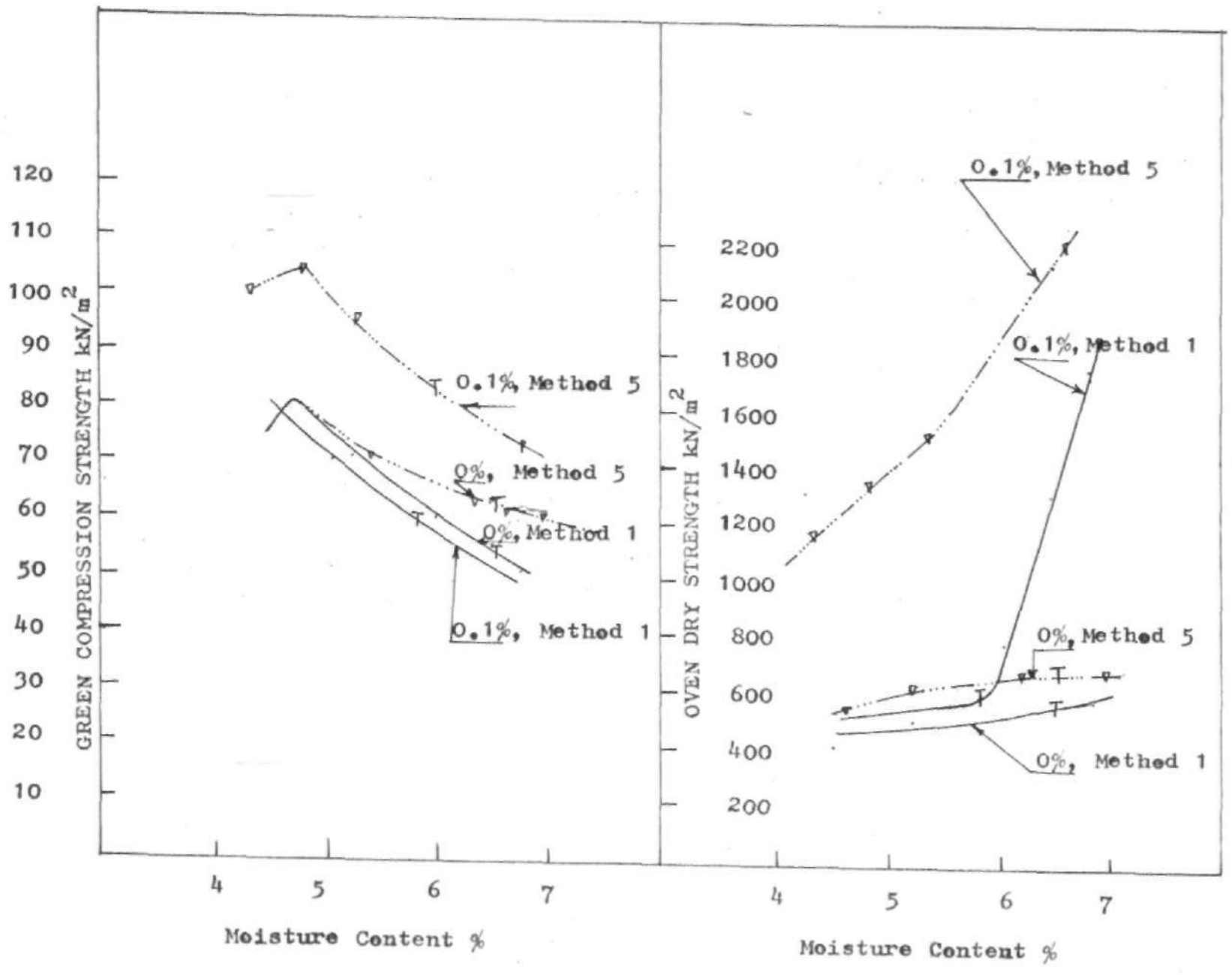


FIG. 6.21: EFFECT OF 0 PERCENT AND 0.1 PERCENT Na_2CO_3 ADDITION ON GREEN COMPR. STRENGTH AND OVEN DRY STRENGTH OF KANKARA CLAY SANDS PREPARED BY METHODS 1 AND 5.

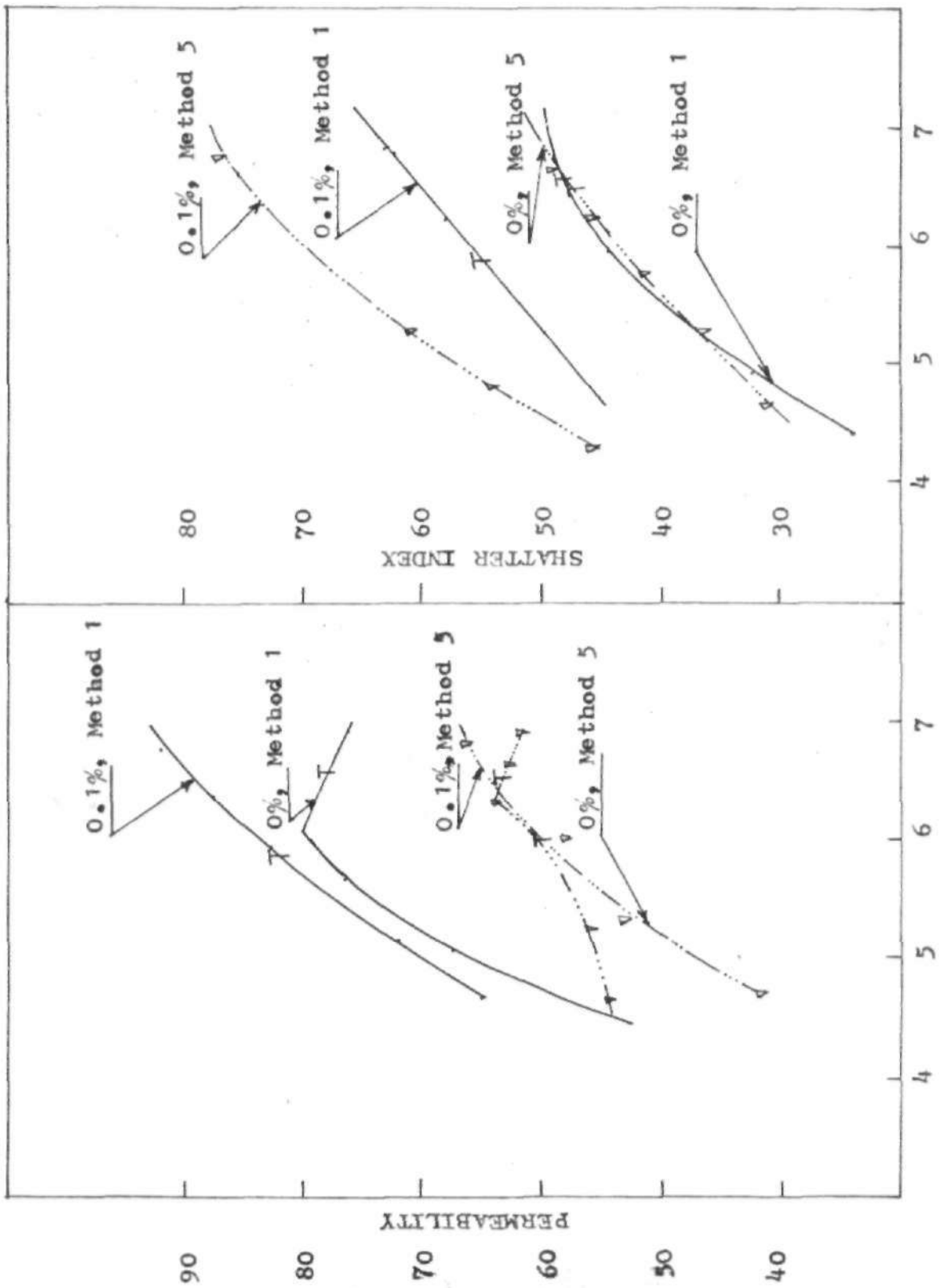


FIG. 6.22: EFFECT OF 0 PERCENT AND 0.1 PERCENT Na_2CO_3 ADDITION ON PERMEABILITY AND SHATTER INDEX OF KANKARA CLAY SANDS PREPARED BY METHODS 1 AND 5.

6.2.3 Test Castings

Six small aluminium test castings were produced from 15 percent Battatti and 15 percent Kankara clays using sand mixtures containing 0 percent and 0.1 percent Na_2CO_3 prepared using two methods of preparation. The water content was almost near the temper points. The castings obtained are shown in Plate XII. Castings B_1 and K_1 were produced from Battatti and Kankara sand moulds containing 0 percent Na_2CO_3 with the sand mixtures prepared using the normal method (method 1). Castings B_2 and K_2 were produced from Battatti and Kankara clay moulds containing 0.1 percent Na_2CO_3 with the sand mixtures prepared using the normal method (method 1). Castings B_3 and K_3 were produced from Battatti and Kankara clay moulds containing 0.1 percent Na_2CO_3 with sand mixtures prepared using two stage mulling with 10 percent water added during the initial mulling (method 5).

It was found that the castings produced from the two clay sand moulds containing 0.1 percent Na_2CO_3, prepared using two stage mulling with 10 percent water added during the initial mulling (i.e method 5) were much better than the ones produced from moulds prepared using method 1. The castings produced from Battatti sand moulds were better than those of Kankara sand moulds. The castings had good surface finish and shinning appearances. In general the results of the casting tests are very encouraging though all the castings produced were of relatively small size. As there were no large furnaces in the department, it was difficult to make bigger

castings. But the results of the laboratory tests clearly show that the moulds produced from local sand clay materials could be successfully made use of for different casting jobs when a combination of improved method of preparation and Na_2CO_3 addition (especially method 5) is used to prepare the sand mixtures. The results of the casting tests support the findings of the laboratory tests.

PLATE XXI: SMALL ALUMINIUM TEST CASTINGS PRODUCED FROM BAITATTI AND MAIDUNA SAND MOULDS TREATED WITH 0 PERCENT AND 0.1 PERCENT Na_2CO_3 WITH SAND MIXTURES PREPARED USING METHODS 1 AND 5.

6.2.4 Conclusions

The following conclusions could be drawn from the results of the investigations:

(1) Substantial changes in foundry sand properties can be achieved by a combination of better method of preparation and Na_2CO_3 addition to the sand mixtures prepared from Battatti and Kankara clays. This may be true for sand mixtures prepared using other clays as well.

(2) While most of the properties of the two clay sand mixtures were substantially improved by a combination of high preparation techniques and Na_2CO_3 addition, some properties were impaired.

(3) Improvements in most of the properties of the two foundry sands could be achieved by adding about 0.1 percent Na_2CO_3 to sand mixtures prepared using better methods of preparation. More improvements in some properties like oven dry strength and air set strength could still be achieved by increasing the amount of Na_2CO_3 above 0.1 percent (upto 0.5 percent) but this will also lower the refractoriness of the sand as the melting point of Na_2CO_3 is only 852°C.

(4) Changes in the properties of Battatti clay sands were more orderly and significant than changes in the properties of Kankara clay sands. This may be attributed to the higher Cation Exchange Capacity (C.E.C) of Battatti clay than that of Kankara clay.

(5) Water requirements of the sand mixtures generally decreased with the addition of small amounts of Na_2CO_3 for all the methods of preparation. When the sand mixtures containing 0.1 percent Na_2CO_3 prepared using different methods of preparation (i.e methods 1, 2, 3, 4 and 5) were compared, method 5 was observed to have the highest water requirements and method 1 has the lowest.

(6) Substantial changes in permeability were noticed when a combination of improved methods of preparation and Na_2CO_3 addition were used to prepare the sand mixtures. Method 3 (i.e Two stage mulling without using excess water during the initial mulling) gave the most effective way of improving the permeability values of the two clays.

(7) The green compression strength of the two clay sands behaved differently when small amounts of Na_2CO_3 (about 0.1 percent) were added to the sand mixtures prepared using the five methods of

preparation. While the green compression strength of Battatti clay sands decreased with small additions of Na_2CO_3, the green compression strength of Kankara clay sands increased. Among the five methods of preparation investigated, method 5 gave the best way of improving the green compression strength of the two sand mixtures.

(8) The oven dry strength of the two clay sands were improved substantially when a combination of better methods of preparation and Na_2CO_3 addition were used to prepare the sand mixtures. Method 5 gave the most effective way of improving the oven dry strengths of these clay sands. This is extremely beneficial to Battatti clay sands which generally has a low oven dry strength.

(9) The air set strength of the two clay sands were improved substantially when a combination of Na_2CO_3 addition and high preparation techniques were used to prepare the sand mixtures. Among the five methods of preparation investigated, method 5 gave the best way of achieving the highest improvements in air set strength.

(10) The shatter index, i.e the toughness of the sands was improved for both Battatti and Kankara clay sands when a combination of high preparation

techniques and Na_2CO_3 addition were used to prepare the sand mixtures. The improvement in shatter index was more substantial for Kankara clay sands than for Battatti clay sands. In this case also, method 5 gave the highest values of all the five methods investigated.

(11) The green hardness of both Battatti and Kankara clay sands showed considerable improvements when the sand mixtures were prepared using a combination of Na_2CO_3 addition and high preparation techniques.
Here again, method 5 gave the highest green hardness values for the two clay sands.

(12) The flowability of the sand mixtures were generally decreased when sand mixtures were prepared using a high preparation method after adding Na_2CO_3. The decrease in flowability depended on the type of clay, method of preparation used and the amount of Na_2CO_3 added to sand mixtures. Even though, there were decreases in flowability values, in no case was it critically low.

(13) Small test castings produced from sand mixtures containing 0 percent and 0.1 percent Na_2CO_3 using methods 1 and 5 indicated that it is possible to improve casting qualities when moulds are prepared from sand mixtures which have been

prepared using a combination of Na_2CO_3 addition and high preparation techniques.

(14) The results of these investigations generally show that improvements on the properties of foundry sands are possible by adding small amounts of Na_2CO_3 to sand mixtures. The improvements in sand properties can still be enhanced by using a better method of preparation. Among the five methods of preparation investigated, method 5 gave the highest overall improvements.

(15) Although a combination of better methods of preparation and Na_2CO_3 addition brought about general improvements in sand properties, increased preparation means higher costs. Therefore an economic analysis of the advantages derived from these methods should be done to see whether the advantages outweigh the increased cost before embarking on higher preparation methods.

CHAPTER SEVEN

GENERAL CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORKS

7.1 General Conclusions

This research work dealt wholly with synthetic sand mixtures prepared from two local clays and a local sand (Battatti and Kankara clays and Giwa river bed sand). The increase in tempering time (storage time after preparation) from 4 hours to 24 hours has been found not to bring significant changes in the properties of foundry sands. However slight changes in the properties were noticed. While some properties were slightly improved with increase in tempering time, some were impaired. The choice of tempering time would therefore depend on a combination of properties needed for a particular application and the type of clay involved.

Results obtained by previous investigators have shown that Nigerian foundry sands prepared from Battatti and Kankara clays may not be good enough for production of high quality castings unless they are improved upon by some other means. Improvements on properties of foundry sands were found possible by cation exchange treatment brought about by Na_2CO_3 addition. Further improvements on properties of foundry sands can be obtained by better methods of preparation.

It is believed that the results of this research work are also applicable to other clays and sands both Nigerian and non-Nigerian but the extent to which changes in properties occur would depend on the types of clay and sands used. A lot of work has been done on ways of improving the properties of Nigerian foundry sands which in turn will yield good

quality castings, it is hoped that Nigerian foundries will benefit from this work and help them to make use of clays and sands locally available to them which will reduce the transportation cost of these foundry sand ingredients.

7.2 Recommendation for further Work

(1) Efforts should be extended to locating more clay and sand deposits for foundry use within Nigeria.

(2) Blending of the two types of clays used for these investigations could be used to prepare the sand mixtures and see what results would be obtained.

(3) Use of binders other than clay on Nigerian sands can be investigated. The usefulness of sodium silicate - carbon dioxide binder on local sands is worth investigating.

(4) In the investigations involving tempering times, initially, a closer range of tempering time can be chosen and then increased as the tempering time increases (i.e 0 hour, 1 hour, 2 hours, 3 hours, 4 hours, 6 hours, 8 hours, 12 hours, 16 hours) to see exactly to what extent the properties of sand mixtures would be changed with increase in tempering time.

(5) The use of chemicals other than Na_2CO_3 as deflocculants should be tried. Sodium silicate ($NaSiO_3$) being another good deflocculant should be tried to see to what extent the properties of sand mixtures would be improved.

(6) An economic analysis of the advantages derived from improved methods of preparation should be done to see if the advantages outweigh the increased cost due to higher preparation before embarking on these high preparation techniques.

(7) High temperature properties of sand mixtures containing Na_2CO_3 and prepared using different preparation techniques are worth investigating as high temperature tests are particularly relevant to foundry conditions and enable moulds and cores to be assessed under conditions similar to those existing during casting and cooling processes.

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