CHAPTER -4
EXPERIMENTAL PROCEDURE

4.1 INTRODUCTION:-

The experimental investigation was carried out in two phases. In phase I, fabrication of an experimental pneumatic cell and an experimental horizontal centrifugal scrubber was carried out. Reclamation of used CO$_2$ sand was carried out using pneumatic reclamation unit, horizontal centrifugal scrubber, chemical method, wet method and combined reclamation. The properties of the sand was assessed by reusing the reclaimed sand in the CO$_2$ -Sodium Silicate system. SFSA standard test block, step cone casting, and penetration test casting moulds were produced in the CO$_2$ -Sodium Silicate system. The test moulds were used to produce test castings with molten steel and cast iron. The castings were checked and surface roughness of the castings was also measured. Economic evaluation of castings was carried out for all the trials conducted.

In phase II, the used CO$_2$ sand reclaimed by horizontal centrifugal scrubber, chemical method, wet method and combined reclamation was used as a substitute for new sand in the conventional Green sand moulding and the properties were evaluated. The standard test moulds produced by Green sand moulding with bentonite as binder and gray cast iron was poured. The castings were checked and surface roughness was also measured on the castings. Economic evaluation of castings was carried out for all the trials conducted.

The experimental plan for studies on reclamation of CO$_2$ - Sodium Silicate bonded sands are shown Figures 4.1 and 4.2 schematically.
Figure 4.1 Flow chart of the investigation on for reclamation CO₂ sand for reuse in CO₂ moulding.

STUDIES ON RECLAMATION OF CO₂-SODIUM SILICATE BONDED SAND AND REUSE IN PRODUCTION OF TEST CASTINGS BY GREEN SAND MOULDING SYSTEM

SAND RECLAMATION

- Pneumatic Method
- HCS
- Wet Method
- Chemical Method
- HCS+ Wet
- HCS+ Che
- Che + Wet

Investigations on the properties of reclaimed sand without binder to evaluate
- Na₂O, AFS No., Acid Demand Value, Base permeability
- Clay content, Loss on Ignition, Water Absorption, pH,
- Fritting index, SEM surface analysis, Sand grain shape study, EDAX and Chemical Composition of Sand.

Investigations on the properties of reclaimed sand with Sodium Silicate binder to evaluate
- Moisture, Loss on Ignition, Compactability, Permeability, As Gassed Strength, Mould Hardness, Mouldability, Bench Life, Strength at Elevated Temperature and Friability

COLLECTION OF USED SAND

PRODUCTION OF TEST CASTINGS BY CO₂ MOULDING

CASTINGS QUALITY EVALUATION

ECONOMIC EVALUATION OF SAND RECLAMATION

RECLAMATION AND REUSABILITY STUDIES ON CO₂-SODIUM SILICATE BONDED SANDS FOR FERROUS FOUNDRIES.
Figure 4.2 Flow chart of the investigation on reclamation CO₂ sand for re-use in green sand moulding.

Investigations on the properties of reclaimed sand with bentonite binder to evaluate:
- Moisture,
- Permeability,
- Loss on Ignition (LOI),
- Compactability,
- Shatter Index,
- Mouldability,
- Clay Content,
- Green Strength.

PRODUCTION OF TEST CASTINGS BY GREEN SAND MOULDLING

CASTING QUALITY EVALUATION
PHASE -I

4.2 MATERIALS USED:-

4.2.1 Sand :-

The details of new sand used in the present investigation is shown in Table 4.1 and the distribution of sand grain for cast iron is shown in Table 4.2.

Table 4.1 Properties of new sand used in the present investigation

<table>
<thead>
<tr>
<th>Chemical Composition</th>
<th>For Cast Iron Foundry Use</th>
<th>For Steel Foundry Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂ %</td>
<td>95.70%</td>
<td>96.84</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.15%</td>
<td>0.97%</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>2.01%</td>
<td>1.62%</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.75%</td>
<td>0.69%</td>
</tr>
<tr>
<td>Loss on Ignition</td>
<td>0.26%</td>
<td>0.41%</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.06%</td>
<td>0.05%</td>
</tr>
<tr>
<td>Balance</td>
<td>CaO</td>
<td>CaO</td>
</tr>
<tr>
<td>Other Properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>7.8</td>
<td>7.2</td>
</tr>
<tr>
<td>A.D.V. ml / 100g</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>AFS Clay Content</td>
<td>0.54%</td>
<td>0.46%</td>
</tr>
<tr>
<td>AFS Fineness Number</td>
<td>54</td>
<td>52</td>
</tr>
</tbody>
</table>
Table 4.2. Distribution of sand grains

<table>
<thead>
<tr>
<th>Standard U.S.Sieve No</th>
<th>Percentage retained for 100 gms</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0.1</td>
</tr>
<tr>
<td>30</td>
<td>2.56</td>
</tr>
<tr>
<td>40</td>
<td>12.68</td>
</tr>
<tr>
<td>50</td>
<td>25.96</td>
</tr>
<tr>
<td>70</td>
<td>30.39</td>
</tr>
<tr>
<td>100</td>
<td>21.84</td>
</tr>
<tr>
<td>140</td>
<td>5.64</td>
</tr>
<tr>
<td>200</td>
<td>0.64</td>
</tr>
<tr>
<td>270</td>
<td>0.1</td>
</tr>
<tr>
<td>Pan</td>
<td>0.04</td>
</tr>
</tbody>
</table>

4.2.2 Binder:-

Foundry grade sodium silicate was used as the binder in the CO₂ process. The properties of Sodium silicate used in the present investigation are given below. Commercial grade CO₂ gas was used in this investigation.

- Specific gravity = 1.55
- Na₂O content = 14.61%
- SiO₂ content = 31.0%

For green sand moulding bentonite was used as the binder and the properties of bentonite are given below.

- pH = 8.5,
- Gel Index = 29
- Swelling = 18.15.
4.2.3 Used sand for reclamation:

The used sand for reclamation was collected from two different foundries and sand preparation was carried out under controlled conditions.

4.2.3.1 Sand from Cast Iron foundry:

New silica sand was mixed with 4.5% sodium silicate, 0.5% coal oil and 0.25% Dextrin in a sand mixer and then used for the preparation of moulds. \(\text{CO}_2\) gas was passed to develop the required strength. Cores were also made with the prepared sand. The moulds and cores were used for pouring molten metal after 3 hours of mould making. Induction melted gray cast iron with a carbon equivalent of 3.9 was poured into the moulds at a temperature of 1420\(^\circ\)C. The casting was allowed to remain in the mould for sufficient length of time before it was knocked off. The knocked off sand was collected and crushed in the jaw crusher and roll crusher. The crushed sand was collected and sieved using a 20 mesh sieve. This sand was termed as the used sand (Crushed sand) which was subjected to reclamation studies in the present investigation.

4.2.3.2 Sand from steel foundry:

New silica sand was mixed with 4.5% sodium silicate, 0.25% Iron oxide and 0.25% Dextrin. The sand was mixed in a sand mixer and used in the preparation of the moulds. \(\text{CO}_2\) gas was passed to develop the required strength. Cores were also made with the same prepared sand which is used to prepare the moulds. In the prepared moulds weldable grade carbon steel with carbon 0.22%, \(\text{Si} = 0.4\%\) and \(\text{Mn} 0.9\%\) was poured at a temperature of 1560\(^\circ\)C. The casting was allowed to remain in the mould for sufficient length of time before it was knocked off. The knocked off sand was collected, crushed and sieved using a 20 mesh sieve. The sieved sand was termed as the used sand (Crushed sand) which is subjected to reclamation studies in the present investigation.
4.3 DEFINITION OF TERMS:

New Sand:

The sand purchased for use in the foundry is called "new sand" (fresh sand).

Used Sand:

The sand collected after knock off, crushed and sieved using a 20 mesh sieve is termed as "used sand" (Crushed sand).

Reclaimed Sand:

The used sand subjected to reclamation is called as "reclaimed sand".

Facing Sand

The sand touching the pattern during moulding and molten metal will be in contact with this sand.

Backing Sand

The sand used for filling the space left out in the mould cavity. Return shake-out sand mulled with 0.5-1.0 % bentonite and 4.0-4.5 % moisture.

Unit Sand

The mulled green sand used in moulding prepared with new sand, system sand, bentonite and water.

System Sand

Return shake-out sand after reconditioning is called "system sand" (magnetically separated and sieved sand). It is also called as "reconditioned sand".

Reclamation:

Reclamation may be defined as the treatment of a used refractory moulding aggregate to enable its reuse as a moulding or core making material.
Re-reclamation :-

The sand which is subjected to repeated use and reclamation (even more than once) is called as re-reclaimed sand.

Combined reclamation:

Combined reclamation is the combination of two different reclamation processes or techniques. At first the used sand is reclaimed by one technique [e.g. By horizontal centrifugal scrubber] and the same sand obtained as the output of the first is subjected to further reclamation by a different technique [e.g. by chemical method].

Recovery

Recovery of sand is the "yield" of the reclamation processes. It is the quantity of reclaimed sand available for use after reclamation and is expressed as the percentage of original sand used.

\[
\text{% recovery} = \frac{\text{Weight of sand after reclamation}}{\text{Weight of sand before reclamation}} \times 100
\]

Regeneration cycle

Regeneration cycle is the number of times a given quantity of sand is recirculated in a particular reclamation unit.
4.4 RECLAMATION OF CO₂ SODIUM SILICATE BONDED SAND :-

Reclamation of CO₂ -Sodium Silicate bonded was carried out by using pneumatic reclamation unit, horizontal centrifugal scrubber, chemical method, wet method and combined reclamation. The knocked off sand was collected and crushed in a jaw crusher and roll crusher. The crushed sand was collected and sieved using a 20 mesh sieve. This sieved sand was termed as the used sand (Crushed sand) which was subjected to reclamation studies in the present investigation.

4.4.1 Reclamation by pneumatic reclamation unit:-

A pneumatic cell was designed for a capacity of 90-100 kg per cycle i.e. about 12 Tons per day and fabricated for conducting experiments to reclaim sand from CO₂ process.

4.4.1.1 Details of pneumatic reclaimer:-

The schematic of the pneumatic reclamation unit is shown in Figure 4.3 and the photograph is shown in Figure 4.4. The equipment consists of i) regeneration tube ii) a target iii) nozzle, iv) sand carrying tube, v) a dust collector and vi) bottom cup vi) Regeneration tube.

It is a cylindrical tube of 50 mm diameter and 1 meter long. It is made of 3 mm thick mild steel sheet.

ii) Target

Although a wear resistant plate is preferable, in the present experimental work a mild steel plate of 25 mm thickness was used. It was designed to have an angular shape so that sand hits its surface uniformly.
iii) Nozzle

It is made of mild steel with its diameter chosen according to the velocity with which the air should enter the regeneration tube. The nozzle diameter used in this cell are 12 mm and 19 mm respectively.

iv) Sand Carrying Tube

It is also made of mild steel sheet of 3 mm thickness which is cylindrical in shape and is placed over the regeneration tube. Its diameter was chosen according to the capacity. The diameter chosen was 180 mm.

v) Dust Collector

It was placed on the top of the cell to collect dust and loose binder which comes out during the treatment of sand in pneumatic cell.

vi) Pressure Gauge and Valves:

It was arranged in such a way to the pipe to measure the incoming pressure. Valves were fixed in such a way that the air pressure in the pipe was measured.

4.4.1.2 Working of pneumatic reclamation cell:

The general principle of pneumatic reclamation is schematically illustrated in Figure 4.3 and a photograph is shown in Figure 4.4. The sand to be reclaimed was crushed using a jaw crusher and a roll crusher upto 2 mm size and a fixed quantity (25 kg) is fed into the pneumatic reclaimer. A high pressure turbulent air stream is allowed through the nozzle to lift the sand through a vertical pipe and the sand particles are made to impinge against a target plate. During the travel through the vertical pipe the grains rub intensively against each other and the binder film gradually gets abraded. The air escaping from the target zone carries away the finely abraded binder and dust particles which are collected in a dust collector.
The sand returning to the main mass moves downward and soon finds itself being forced to repeat the cycle. The sand is recycled as many times as necessary to obtain a desired degree of cleanliness in the reclaimed product.

The sand is recirculated several times in the cell. The reclamation efficiency in a pneumatic cell is influenced generally by the nozzle diameter, air pressure and the treatment time in the cell. Air pressure and time duration of these trials are given in Table 4.3. For all the trials, pressure of 5 Kgf/cm² and 7 minutes was used.

Table 4.3. Air pressure and time duration of pneumatic reclamation trials

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Pressure Kgf/cm²</th>
<th>Time in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>
Fig. 4-3 SCHEMATIC OF THE EXPERIMENTAL PNEUMATIC UNIT

1. REGENERATION TUBE
2. TARGET
3. NOZZLE
4. SAND CARRYING TUBE
5. DUST COLLECTOR
6. BOTTOM CUP

ALL DIMENSIONS ARE IN mm
4.4.2 Reclamation by Horizontal Centrifugal Scrubber:

A Horizontal Centrifugal Scrubber with a capacity of 500 kg per hour i.e. about 12 Tons per day was designed and fabricated for conducting experiments to reclaim sand from CO₂ process.

4.4.2.1 Details of Horizontal Centrifugal Scrubber:

The single phase motor rotating at 1440 rpm with a power rating of 0.5 HP was used to drive the impeller. Wear resistant Ni hard Cast iron was used to make the Impeller and the impingement rings. The designed and fabricated plant is capable of reclaiming 500 kg of sand / hour. Fabrication of horizontal reclamation unit was carried out based on design parameters. The schematic diagram of the horizontal centrifugal scrubber is shown in Figure 4.5 and the photograph of the same is shown in Figure 4.6.

4.4.2.2 Working of horizontal centrifugal scrubber:

The used sand was fed into the inlet pipe of the horizontal centrifugal scrubber. The sand directly enters the vanes rotating at 3200 rpm. The pulley of about 114.3 mm is fixed in the motor shaft and another pulley of about 50.8 mm is fixed in the shaft. The belt is connected to both the pulleys. The speed from the motor is transferred to the impeller by two 'V' belt drives.

When the sand falls on the impeller it is thrown against the target ring at a controlled velocity by the impeller. Some sand-on-sand attrition takes place, but the most intense part of the scrubbing occurs at the target ring. The exhaust plenum surrounds the target ring to remove dust and binder husks. Due to the centrifugal forces the Na₂CO₃ bonded to the sand grains was removed. The holes provided at the top cover allow the dust particles [Na₂CO₃] to come out of the reclaimed sand. The sand comes out through the cores and it is termed as reclaimed sand.
Fig 4.5 SCHEMATIC DIAGRAM OF HORIZONTAL CENTRIFUGAL SCRUBBER
Figure 4.4 Photograph of Pneumatic Reclamation Unit
Figure 4.6 Photograph of the Horizontal Centrifugal Scrubber
4.4.3 Reclamation by Wet Method:

Wet reclamation washes scrubs, grades and dries the sand. Reclamation by wet method was carried out in a 150 kg capacity sand mixer lined inside with AISI 304 stainless steel. 75 Kg of used sand to be reclaimed was fed in to the sand mixer, 100 litres of water was added to the sand mixer, and mixed for 10 minutes. Then the water was siphoned off, and the wet sand was charged into a rotary drier to remove the water content. The dried sand is termed as the wet reclaimed sand.

4.4.4 Reclamation by Chemical Method:

In chemical reclamation sodium silicate residues from used sand was successfully neutralised using commercial hydrochloric acid. First the amount of commercial hydrochloric acid required to neutralise the sodium carbonate was determined. Commercial HCl addition was carried out in a 150 kg capacity sand mixer lined inside with AISI 304 stainless steel, then the sand was dried in a rotary drier to remove the water content. The dried sand is termed as the chemically reclaimed sand.

4.4.4.1 Estimation of Normality of Commercial HCl:

The normality of commercial HCl was estimated by titration against known normality Na₂CO₃ solution. The molecular weight of Na₂CO₃ is 106 gm. So 53 gm in 1000 ml of distilled water gives 1 N solution. In 100 ml of water 0.53 gm of Na₂CO₃ was dissolved to prepare 0.1N Na₂CO₃ solution in a 100 ml standard flask. The steps of the process are listed below:

i) Commercial HCl [10 ml of acid in 100 ml of distilled water] was taken in the cleaned burette up to the zero mark.

ii) 20 ml of 0.1N Na₂CO₃ solution was transferred into the cleaned conical flask.
iii) Two drops of methyl orange indicator was added to the Na₂CO₃ solution in the conical flask and shaken thoroughly. The colour obtained was yellow.

iv) Then the HCl solution was added slowly from the burette to the Na₂CO₃ solution and the end point is noted by the colour change from yellow to pink. The volume of HCl added was noted down.

V) The steps ii) to iv) were repeated to get the consistent reproducible values.

Sample Calculation:

Observation

<table>
<thead>
<tr>
<th>Volume of Na₂CO₃ solution</th>
<th>= 20 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of HCl solution</td>
<td>= 2.1 ml</td>
</tr>
<tr>
<td>Normality of Na₂CO₃ solution</td>
<td>= 0.1N</td>
</tr>
</tbody>
</table>

Then Normality of HCl = \( \frac{20 \times 0.1}{2.1} \)

Normality of commercial HCl = 9.5N

4.4.4.2 Estimation of commercial HCl to be added:

i) 10 gm of sieved sand was taken in a beaker and 50 ml of distilled water was added to it and thoroughly mixed using a glass rod.

ii) The solution is heated till it boils and held for about 30 minutes and then removed from the heater.

iii) The aqueous extract of the above solution is prepared by filtering it and then taken in the 250 ml standard flask. Distilled water was added up to the mark at the top.

iv) 50 ml of this solution was transferred from the standard flask to the conical flask using a pipette.
v) Three drops of methyl orange indicator was added to it and the colour of the solution in the conical flask turns yellow.

vi) The 0.1N commercial HCl solution was prepared by adding 9.5 ml of HCl to the 100 ml distilled water and it was taken in the burette.

vii) The 0.1N HCl solution was slowly added from the burette into the conical flask.

viii) When yellow colour turned to pink the burette knob was stopped and the reading was noted.

ix) The above steps were repeated to get the consistent reproducible values.

Observation and sample Calculation:

Observation

<table>
<thead>
<tr>
<th>Volume of sand extract</th>
<th>= 50 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of HCl consumed</td>
<td>= 3.4 ml</td>
</tr>
</tbody>
</table>

10 gm of sand requires \((5 \times 3.4) = 17\) ml of 0.1N commercial HCl for neutralisation

So 1 kg of sand of sand requires = \(17 \times 100\)

\[= 1700 \text{ ml of 0.1N HCl}\]

1000 ml of 0.1N HCl is having only 9.5 ml of commercial HCl [9.5 N]

So 1700 ml of 0.1N HCl contains \[\frac{1700 \times 9.5}{1000} = 16.15 \text{ ml of HCl}\]

Therefore to neutralise 1 kg of sand 16.15 ml of commercial HCl is required.

4.4.4.3 Chemical Reclamation by commercial HCl addition.

Reclamation by chemical method was carried out in a 150 kg capacity sand mixer lined inside with AISI 304 stainless steel. The 25% HCl solution was prepared by adding 1615 ml of commercial HCl to 4845 ml of water. Then the concentration of commercial HCl changes to 2.375N. The used sand which requires reclamation was charged into the
sand mixer. Then the commercial HCl solution was added to the sand mixer. Mixing was carried out for 5 minutes. The sand mixed with commercial HCl was dried in a Rotary drier to remove the water content. The dried sand is termed as the chemically reclaimed sand.

4.4.5 Combined Reclamation of Used Sand:

Various combination of reclamation systems were attempted, in order to select the best possible reclamation combination, as well as to find out the suitability of the combined reclamation systems and to get the maximum binder removal in the sand by reclamation.

4.4.5.1 Horizontal centrifugal scrubbing and wet method:

In this combination the used sand was at first reclaimed using horizontal centrifugal scrubber (HCS). The reclaimed sand was again reclaimed by the wet method.

4.4.5.2 Horizontal centrifugal scrubbing and chemical method:

In this combination the used sand was reclaimed using horizontal centrifugal scrubber at first. The amount of HCl required to neutralise the balance Na₂CO₃ in the reclaimed sand was estimated. The reclaimed sand was again reclaimed by the chemical method using commercial HCl. For chemical reclamation previously calculated amount of commercial HCl was added. The output sand is termed as the combined reclaimed sand by HCS and chemical method.

4.4.5.3 Chemical method and wet method:

In this combination the sand was subjected to chemical reclamation at first. For chemical reclamation the quantity of HCl required to neutralise the effect of Na₂CO₃ was estimated. The sand reclaimed by chemical means is subjected to further reclamation by...
the wet method. In this combined reclamation method wet reclamation was carried out after chemical reclamation to remove the residual NaCl produced by chemical reclamation.

4.4.6 Recovery (Efficiency of Reclamation) of reclamation processes:

Recovery of sand represents the "yield" of the reclamation processes. It is the quantity of reclaimed sand available for reuse after reclamation, expressed as the percentage of original sand used.

\[
\% \text{ recovery} = \frac{\text{Weight of sand after reclamation}}{\text{Weight of sand before reclamation}} \times 100
\]

Recovery of sand was calculated for all the different reclamation processes.
4.5 STUDIES ON THE PROPERTIES OF RECLAIMED SAND, NEW SAND AND USED SAND WITH OUT BINDER:

A schematic representation of studies carried out to evaluate the properties of reclaimed sand is shown in Figure 4.7.

The used sand was subjected to various reclamation processes, the efficiency of reclamation and the suitability of reclaimed sand for moulding and core making was evaluated based on the following properties whose values were compared between the new sand and the used sand.

- $\text{Na}_2\text{O}$ content
- AFS grain fineness number
- Acid Demand Value
- Base permeability
- Clay content
- Loss on Ignition (LOI)
- Water absorption
- pH Value
- Fritting index
- SEM Surface analysis
- Sand grain shape study
- E D A X
- Chemical composition of sand
Figure 4.7 Schematic diagram for studies on properties of reclaimed sand, new sand and used sand.
4.5.1 Percentage Na₂O content Present in sand:-

This is a very important analysis to measure the extent of residual binder before and after reclamation of the sand in connection with CO₂ - Na₂SiO₃ bonded sand. Determination of the percentage of Na₂O was conveniently carried out by volumetric analysis. The alkali Na₂O was neutralised by HCl of known normality. The reaction involved is

\[ \text{Na}_2\text{O} + 2 \text{HCl} \rightarrow 2 \text{NaCl} + \text{H}_2\text{O} \]

From the above reaction it can be seen that two gram-molecular weight of HCl was required to neutralise one gram-molecular weight of Na₂O.

In the reaction

weight of two molecules of HCl = 2 [1+35.45] = 79

weight of one molecules of Na₂O = 1 [23+23+16] = 62

That is on the basis of weight

\[ 2 [1+35.45] \text{ HCl} = 1 [23+23+16] \text{ Na}_2\text{O} \]

Or, on the basis of volume

20,000 ml of 0.1 N HCl solution = 62 g Na₂O

Or 1 ml of 0.1 N HCl solution = 0.0031 g of Na₂O

\[ \frac{\text{ml of HCl} \times 0.0031}{\text{sample weight}} \]

% Na₂O = --------------------------
The procedure for finding the percentage of Na₂O content present in the sand sample is explained below. Solutions required for analysis are 0.1N HCl solution and methyl orange as indicator.

i) 10 g of sand was accurately weighed using Electronic digital balance and was taken in a beaker.

ii) 50 ml of distilled water was added to it.

iii) This solution was heated for about 30 minutes in a hot plate, and just before boiling, the beaker was removed from the hot plate and cooled.

iv) The aqueous extract of the above solution was prepared by filtering it.

v) Then this solution was taken in 250 ml standard flask and distilled water was added up to the mark.

vi) 50 ml of this solution was transferred to the conical flask with the help of pipette and four drops of methyl orange indicator was added to it and shaken thoroughly. The colour of the solution changed to yellow colour.

vii) This solution was titrated against 0.1N HCl solution in the burette. When the yellow colour turns to pink colour the readings in the burette was noted.

vii) The above steps were repeated to get consistent reproducible values.

**Model Calculation**

<table>
<thead>
<tr>
<th>Volume of Na₂O Solution (ml)</th>
<th>Volume of HCl Solution (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>4.2</td>
</tr>
<tr>
<td>50</td>
<td>4.2</td>
</tr>
<tr>
<td>50</td>
<td>4.1</td>
</tr>
</tbody>
</table>
So, for 10 g of sand the 0.1 N HCl Solution required is \(= 5 \times 4.2 = 21.0 \text{ ml}\)

\[
\frac{\text{ml of HCl} \times 0.0031}{21 \times 0.0031}
\]

That is \(\% \text{ of } \text{Na}_2\text{O} = \frac{\text{------------- x 100}}{\text{sample weight}} = \frac{\text{------------- x 100}}{10}\)

\[
\text{Percentage } \text{Na}_2\text{O} = 0.65
\]

4.5.2 AFS Grain Fineness number

It is the physical property of moulding sand mixture which allows gas to pass through it. The Grain Fineness number is approximately the number of openings or holes per linear inch (25.4 mm) of the sieve which would pass the entire sample if its grains were of uniform size i.e., the average size grain in the sample.

Procedure

i) 50 g of dried and weighed sample was placed on the top most sieve of the assembled set of sieve series. George Fischer Laboratory Sifter Type PSA with sieves arranged as per table 4.3 was used in this experiment. A pan fits on the bottom of the set of sieves to collect the materials passing through 270 mesh sieve and a cover fits on top of the series of sieves.

ii) The whole sieve series assembly was placed in position on the sieve shaker machine and vibrated for 15 minutes.

iii) The amount of sand remaining on each sieve was weighed and recorded. The weight of the grains of various sizes were expressed as percentage of the original 50 g sample.

The results obtained for each sieve was multiplied by the multiplying factor. The sum of the products was divided by the sum of the grain percentages obtained. Table 4.4
gives the method of AFS grain fineness number calculation. The result gives the AFS grain fineness number.

**Model calculation:** AFS Grain Fineness number

**Table-4.4 AFS Grain Fineness number calculation**

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>US Sieve No.</th>
<th>Sand retained in g</th>
<th>% Sand retained (A)</th>
<th>Multiplying factor (B)</th>
<th>A xB (product)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>0.04</td>
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</table>

Total: 101.2

AFS Grain Fineness number = \( \frac{5271.4}{101.2} \)

= 52.06 =52

**4.5.3 Acid Demand Value (ADV)***

Acid Demand Value of sand is indicative of the alkalinity of the sand and represents the chemical balance of the sand system.

Procedure :-

i) 50 g sample of dry sand was weighed accurately and placed in a 600 ml beaker.
ii) 50 ml of N/1 sodium hydroxide (NaOH) solution was added by pipette together with 50 ml of distilled water and the solution was stirred thoroughly.

iii) After allowing to stand for approximately 2 hours a further titration was carried out using N/1 sulphuric acid.

iv) A blank was then determined by repeating the above procedure but without the reclaimed sand.

The acid demand value expressed as the amount in ml of normal sodium hydroxide required to neutralise 100 g of sand and it was calculated as follows.

Acid demand value ml/100gm = \( \frac{\text{Blank titrate (ml) - Sample titrate (ml)}}{2} \) 

Model Calculation

\[
\begin{align*}
\text{Blank titrate value} &= 17 \text{ ml} \\
\text{(New sand) Burette value} &= 6 \text{ ml} \\
\text{Acid demand value ml/100gm} &= (17-6) \times 2 \\
&= 11 \times 2 \\
&= 22 \text{ ml } / 100 \text{ g}.
\end{align*}
\]

4.5.4 Base Permeability:

Base permeability is a measure of sand grading distribution in loose packed condition. Base Permeability was measured using type PED George Fischer Electric permeability meter.

Procedure:-

i) A base permeability screen of size 100 mesh was placed at the end of the specimen tube, so that the flange faces upwards, when the tube was seated in the pedestal cup.

ii) 150 g of accurately weighed clay free sand was put in the specimen tube to give a 50x50 mm rammed specimen.
iii) Before ramming a second screen was placed in the specimen tube on the top of the sand, with the flange facing downwards.

iv) Sand was then rammed in the type PRA George Fischer Sand Rammer for three times with drop weight.

v) The tube was removed carefully from the rammer and attached to the permeability meter and permeability was measured.

4.5.5 Total Clay

It represents the particles [mineral] in moulding sand with a grain size equal to or less than 0.02 mm. Type PWB George Fischer Agitator was used in this experiment.

Procedure

i) 50g of dried sand sample was taken in a wash bottle.

ii) 475 ml distilled water and 25 ml of caustic soda solution (25g / litre) was added to the sand sample.

iii) Solution was stirred for 10 minutes in the agitator, then diluted with water to a height of 150 mm and left alone for 10 minutes for settling.

iv) 125 mm of water i.e. muddy liquid was siphoned off, then diluted again to 150 mm height and left alone for settling.

v) Steps 3 and 4 were repeated sufficient number of times so that on standing for 5 minutes, the water be clear.

vi) The left out sand in the beaker was dried and weighed again.

vii) Total clay content = 2 x loss in weight.

4.5.6 Loss on Ignition (L O I) :-

Loss on Ignition value is an useful test for moulding sands and is indicative of the level of carbonaceous materials, residual organic material and volatile present in the sand.
Procedure

i) About 25 g of sand was dried in an oven.

ii) 10 g sand was taken in the weighed Silica crucible.

iii) The crucible was kept in the muffle furnace.

iv) Heated to 920°C for 2 hours.

v) Crucible was taken out of the furnace and cooled in a desicator.

vi) Crucible was weighed and loss in weight was calculated.

The loss in weight expressed as a percentage of original weight gives the loss on ignition.

4.5.7 Water absorption

The determination of water absorption capacity sand is important as it represents the retained water content in sand grains which are soaked with water and is expressed as percentage.

Procedure

i) 200 g of sand was taken in a beaker and stirred thoroughly.

ii) Sand with water was filtered using a filter paper.

iii) 100 g of weighed sand from the filter paper was taken and dried in an infrared rapid drier, until the weight remains constant.

Water absorption capacity was measured as the weight difference between dry sand and wet sand and is expressed as percentage of dry sand.

4.5.8 pH Measurement:

pH measures the alkalinity and acidity of the sand.
**Procedure**: -

i) 10 grams of representative sample was taken in a beaker and 50 ml of distilled water was added to it.

ii) The mixture was stirred thoroughly using a glass rod to ensure through mixing.

iii) The pH meter was immersed into the mixture.

iv) pH value was measured directly from the pH meter.

**4.5.9 Fritting Index:-**

Fritting index of the sand was carried out to assess the sintering behaviour.

**Procedure :-**

i) Sand sample to be tested for fritting index was filled in a porcelain boat

ii) The porcelain boat filled with sand sample was kept in a high temperature furnace maintained at 1400°C for five minutes.

iii) The condition of sand was determined by piercing the sand with a pin and observed with a magnifying glass.

Loose sand condition means higher sintering point while hard sand condition means lower sintering point.

**4.5.10 SEM Surface analysis:-**

The sand particles were smeared over a paste spread over an aluminium disc of 20 mm length, 15 mm width, and 5 mm thickness. The smeared sand particles were then given a gold coating for conduction using a sputter vacuum coating unit. The surface nature of the sand was studied using a scanning electron microscope at high magnification with adequate depth of focus.
4.5.11 Sand grain shape study:

The shape of the sand grains were studied using a stereo microscope.

4.5.12 EDAX analysis of sand:

EDAX analysis of the sand was carried out to find out the composition of the sand.

4.5.13 Chemical analysis of sand:

Chemical analysis of sand was carried out to estimate Silica, Iron oxide, Aluminium oxide, Titanium oxide, Calcium oxide and Loss on ignition by the analytical method.
4.6 STUDIES ON THE PROPERTIES OF RECLAIMED SAND, NEW SAND AND USED SAND WITH SODIUM SILICATE BINDER

Schematic representation of studies carried out to evaluate the properties of bonded and rebonded sand is shown Figure 4.8. The used sand was subjected to various reclamation processes, the efficiency of reclamation and the suitability of sand for moulding and core making were evaluated based on the following properties. The new sand and the used sand was mixed with 4.5% sodium silicate and tested for the following properties.

- Moisture,
- Loss on ignition (LOI),
- Compactability,
- Permeability,
- As gassed strength,
- Mould Hardness,
- Mouldability,
- Bench life,
- Strength at elevated temperature and
- Friability.
Figure 4.8 Schematic diagram for studies on properties of reclaimed sand, new sand and used sand with Sodium silicate binder.
4.6.1 Moisture :-

The moisture content is one of the routine control test for the CO₂-sodium silicate process. Infrared direct reading moisture teller was used to find out the moisture content.

4.6.2 Compactability:-

The compactability test measures the percentage decrease in height from the original constant level of loose sand, under the influence of a fixed compacting force. The compactability of prepared moulding sand depends almost exclusively on the degree of "tempering" and not on its composition. The "tempering" here refers to "temper water" as contrasted to "pour water", present in the moulding sand, in common foundry terminology. When compactability is on increasing trend, moisture will increase and casting defects such as blows, shrinks, pin-holes, oversize castings, poor surface finish, expansion defects are likely to occur and, also shake out problem will increase.

When compactability is on a downward trend, moisture will decrease and casting defects such as cuts and washes, liable broken edges, crushes, penetration and born-on defects are likely to occur. Hence the optimum level of compactability for the given operation is to be selected.

Procedure

i) The sand to be treated was loosely filled into a specimen tube of 50.8 mm diameter, through a funnel fixed with mm sieve on top. The inner height of the tube will be 100 mm.

ii) The riddled sand was rammed with three drops of the sand rammer.

iii) The percentage decrease in height from the original level gives the Compactability of the sand.
4.6.3 Permeability :-

Permeability is expressed as the volume of air (ml) that will pass in one minute under a pressure of one gram per square cm through a sand specimen of one square cm in cross sectional area and one cm in height.

If the permeability increases, it indicates a more open structure and may cause burn on and penetration, with a rough casting surface. If the permeability decreases, it indicates a tighter packing or a change in void shape. Build up of fines also, will decrease permeability and may cause blows, pin-holes. Permeability was measured using type PED George Fischer Electric permeability meter.

Procedure

i) The permeability was determined on a cylindrical standard specimen (50.8 mm diameter & 50.8 mm height)

ii) The sand compact was retained in the specimen tube and tested after hardening with CO₂ gas.

iii) Permeability was measured in the standard specimen kept in the specimen tube itself i.e., with out stripping from the tube.

iv) The tube was placed in the instrument cup and a specified volume of air was forced through the specimen under controlled conditions. The permeability number was read directly from the precision pressure gauge.

4.6.4 Compression Strength and Shear Strength :-

The test measures the stress at which failure occurs under a constant rate of loading. The test was conducted on a standard specimen (50.8 mm dia x 50.8 mm height) in type PFG George Fischer universal strength machine with high - dry compressive strength type
PHD attachment. For compression strength, compression pad was fixed and for shear strength shear pad was fixed to the universal strength machine.

Procedure:-

i) The sand was filled in a specimen tube (i.e. split tube).

ii) CO$_2$ gas was passed for until it hardens (The CO$_2$ gas is passed for 15 seconds for each specimen).

iii) The specimen was separated from the split specimen tube, after one hour the specimen was fixed on the universal strength machine for compression testing and load was applied gradually.

iv) when the failure occurs the value on the dial was noted.

This was repeated for three specimens and the average value was taken. Shear strength testing was conducted in the same way with shear pad fixed to the machine. In this process, the amount of binder, gas flow rate, and time factor affect the strength.

4.6.5 Mould Hardness:

This test was conducted for obtaining an idea about the uniformity of degree of compaction. For that, the surface hardness of a mould cavity was measured. Mould Hardness was measured using Harry W. Dietert company scratch hardness tester on the standard specimen (50.8 x 50.8 mm) for each sand after one hour.

4.6.6 Mouldability:

Mouldability is the term used for the property of a moulding sand characterising its behaviour when rammed into a mould. The mouldability index, a quantitative measure of
the qualitative behaviour in processing the sand, is measured with the aid of a sieve. Mouldability testing was carried out on the type PMT George Fischer Mouldability tester.

Procedure:-

i) 200 g of sand was filled in the sieve drum and sieved for 10 seconds.

ii) the sand passing through the sieve was then weighed

The weight divided by two was the mouldability index.

4.6.7 Benchmark :-

Bench life is a parameter which is indicative of the time available for the foundry man to store and use the sand mixture for preparation of moulds. In bench life determination the prepared standard specimens were tested up to 24 hours for compression after they have been hardened by CO₂ and have stood in air. The bench life determination was carried out with 4.5% sodium silicate binder and 4.0% sodium silicate binder.

Procedure
i) Sand mix was prepared with addition of 4.5% sodium silicate and 4.0% sodium silicate.

ii) Required number of standard specimens were (50.8 mm dia and 50.8 mm height) prepared.

iii) The standard specimen was fixed in the type PFG George Fischer universal strength machine with type PHD high-dry compressive strength attachment.

iv) The compressive load was applied gradually and when the failure occurs the value on the dial was noted.

v) The above procedure is repeated at one hour interval of time starting from 1 hour up to 24 hours and all the values were noted down.
4.6.8 Retained Strength

In the case of CO₂-Sodium silicate process sodium silicate being an inorganic material, is not decomposed by heat. In the case of organic binders, heating above a certain temperature destroys the bond. However, in sodium silicate bonded sands, the bond (which consists of fine silica gel and Na₂O) does not decompose at all, till the melting point, which is very high. Thus, sodium silicate bonded moulds have distinctly superior high temperature strength. The superior high temperature properties CO₂-Sodium silicate sand has been examined in detail by heating the sand compacts to a high temperature (1100°C), and cooling to room temperature.

Procedure:

i) A number of specimens were prepared, with addition of 4.5% sodium silicate and 4.0% sodium silicate.

ii) The specimens were heated to different temperatures and soaked for 15 minutes. (The temperatures used were 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000 and 1100°C).

iii) The specimens were then cooled to room temperature.

iv) The cooled specimens were then tested for compression and shear strength.

4.6.9 Friability

The property which determines how well a sand rams, is termed "Friability". Friability is an inverse expression of the unrammed or bulk cohesion of a sand. Friability testing was carried out in the type PMT George Fischer Mouldability tester.

Procedure

50.8 mm dia and 50.8 mm height sand specimens were prepared from the sand mixes and kept horizontally inside the sieve drum of the mouldability tester and rotated for
a minute and the sand passing out of the drum is weighed. During this period a heat lamp is provided to raise the temperature of the screen above that of the sand. This avoids moisture condensation on the screen during the screening operation. The ratio of the weight of the sand separated from the sand specimen to the original weight of the sand specimen is expressed as the percentage friability.
4.7 PRODUCTION OF TEST CASTINGS BY CO₂-SODIUM SILICATE MOULDING

To check the performance of the reclaimed sand production of various types of test castings was carried out using gray cast iron and steel.

4.7.1 Types of test castings

Schematic diagrams of the test castings are shown in Figures 4.9 to 4.11 as detailed below

i) SFSA (Steel Founders Society of America) standard test block to evaluate the relative erosion, penetration and burn on conditions of the sand used for moulding [Figure 4.9 (a) and 4.9 (b)].

ii) Step cone casting developed by M/s.Ashland Chemical Company to evaluate veining defect/finning defect [Figure 4.10(a) and 4.10(b)].

iii) Penetration test casting developed by M/s.Ashland Chemical Company to evaluate penetration defect [Figure 4.11(a) and 4.11(b)]

4.7.2 Moulding

The test castings were produced with various types of sand mixtures SFSA standard block, step cone casting and penetration test casting. Each type of sand mix as given in table 4.5 (New sand, used sand, reclaimed sand, mixed sand consisting of new sand and reclaimed sand) was mixed with 4.5% sodium silicate, 0.5% coal oil and 0.25% Dextrin for the production of moulds to pour Gray Cast Iron, similarly for the production of steel castings the sands were mixed with 4.5% sodium silicate, 0.5% Iron Oxide and 0.25% Dextrin. The sand was mixed in a sand mixer and the mixed sand was used in the preparation of moulds. CO₂ gas was passed to develop the required strength. Cores were also made with the same prepared sand used for making the moulds. The moulds and cores
were used 3 hours after the production of mould making. In the case of penetration test casting the standard AFS compressive 50 x 50 mm test core is made out of different types of sand mixtures.

Table 4.5 Different types of sand mixes used in CO₂ moulding

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<th>Sl No</th>
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<th>HCS</th>
<th>Che</th>
<th>HCS+Che</th>
<th>HCS+Wet</th>
<th>Che+Wet</th>
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</table>
4.7.3 Melting and Pouring

Melting and pouring was carried out in a cast iron foundry and steel foundry.

Induction melted gray cast iron with a carbon equivalent of 3.9 was used. It was inoculated with 0.3% proprietary inoculant and poured into the test castings at a temperature of 1420°C. The pouring temperature was measured using a Pt-Pt 13 Rh thermocouple with digital display.

Induction melted weldable grade carbon steel with 0.22% carbon, 0.4% silicon and 0.9% manganese was poured [ASTM A216 Grade WCB]. Deoxidation in the ladle was carried out with 0.2% Aluminium and 0.15% calcium silicide. Metal was poured at a temperature of 1560°C and measurement of temperature was done using a Pt-Pt 13 RH thermocouple with digital display.

After pouring the castings were allowed to cool for sufficient time then knocked off and shot blasted. The sand after knock off was collected for further reclamation studies from the SFSA casting and step cone casting.
Fig. 4.9(a) SFSA TEST BLOCK PATTERN

ALL DIMENSIONS ARE IN mm
Fig. 4.9(b) SFSA PATTERN ASSEMBLY
Fig. 4.10 (a) STEPCONE CASTING CROSS SECTION

ALL DIMENSIONS ARE IN mm
Fig. 4.10 (b) STEPicone MOULD ASSEMBLY

ALL DIMENSIONS ARE IN mm
Fig. 4.11(a) PENETRATION 50 x 50 mm TEST CASTING
Fig. 4(b) PENETRATION 50x50 MOULD ASSEMBLY

ALL DIMENSIONS ARE IN mm
4.8 STUDIES ON CASTING QUALITY

The quality of castings was measured by measuring the surface finish by two different techniques: (i) Surface Inspection by Comparison Methods. (ii) Direct Instrument Measurements.

4.8.1 Surface Inspection by Comparison Methods

In comparative methods, the surface texture is assessed by observation of the surface. But these methods are not reliable as they can be misleading if comparison is not made with surfaces produced by same techniques. The various methods available under comparison method are:

(i) Inspection with standard MSS SP 55

(ii) Normal visual Inspection.

4.8.2 Direct Instrument Measurements

RMS value and Ra values were measured directly with the instruments.

4.8.2.1 Root Mean Square Value (RMS Value)

The following instruments were used for Measuring Surface Roughness (RMS):

(i) Dial gauge showing minimum deviation of .01 mm. (ii) Slip gauges and iii) Rectangular blocks. The Procedure is described below

The experimental set-up for measuring surface roughness is shown in Figure 4.12 Casting surface whose surface finish is to be measured was kept on the rectangular block. Surface measuring gauge was used to check whether it is in the horizontal position or not. After this slip gauges were taken, say 70 mm and it was placed in between the 2 reference blocks. Then the dial gauge tip was made to touch the surface of the casting and it was set to show zero reading. Then by replacing the 70m slip gauge, 60 mm + 9 mm slip gauges

RECLAMATION AND REUSABILITY STUDIES ON CO₂ - SODIUM SILICATE BONDED SANDS FOR FERROUS FOUNDRIES. 4.50
were placed in between them. Then the reference block on which dial gauge was placed was moved in a particular direction correctly and the deviation in the gauge was noted. Then by repeatedly changing the slip gauges each by 1 mm the dial gauge deviation readings were taken without changing the particular direction. The cut off length is taken as 10 mm. For this 4 random locations were selected and the readings were noted. RMS average value was calculated from the formula $\sqrt{\frac{\sum y_i^2}{n}}$

4.8.2.2 Ra Value Measurement:

The Ra height of the roughness irregularities on a surface is defined as the average value of the departure from its centre line throughout a prescribed sampling length. The Ra value measurement was carried out using Surtronic 3P surface roughness tester manufactured and supplied by Rank Taylor Hobson Limited.

4.8.2.3 Internal Surface Quality of Castings:

The trial castings were sectioned to study the internal surface quality of castings.

4.9 ECONOMIC EVALUATION OF SAND RECLAMATION:

One of the main reasons for reclaiming sand in foundries is to achieve considerable savings in foundry operating costs. The present cost of sand and the cost of sand in the previous years was used to forecast the cost of sand in the future years. A mathematical model has been used for economic appraisal to find out the various costs and savings of the reclamation system. Programme in "C" language was developed to predict the cost of sand in the future years.
Fig. 4.12 EXPERIMENTAL SET UP FOR SURFACE ROUGHNESS MEASUREMENT
PHASE -II

4.10 INTRODUCTION

In phase II, the used CO$_2$ sand reclaimed by horizontal centrifugal scrubber, chemical method, wet method and combined reclamation was used as a substitute for new sand in the conventional Green sand moulding system and the properties were compared with the other sand mixes. The standard test moulds were produced by Green sand moulding with bentonite as the binder and cast iron was poured. The castings were checked for visual defects and surface roughness was also measured on the castings.

4.11 STUDIES ON THE PROPERTIES OF RECLAIMED SAND, USED SAND, NEW SAND FOR USE IN GREEN SAND MOULDING WITH BENTONITE

Schematic representation of studies carried out to evaluate the properties of bonded and rebonded sand is shown Figure 4.13. The used sand was subjected to various reclamation processes and the efficiency of reclamation and the suitability of sand for moulding was evaluated based on the following properties. The used sand and reclaimed sand (subjected to single reclamation and combined reclamation) was used as substitute for new sand, rebonded with bentonite and moisture. The combination of various sand mixes used in this investigation is given in Table 4.6. Testing was conducted on two types of sand mixes:

(i) Actual foundry condition involving 5-6% active clay with 2-3% bentonite addition
(ii) Standard mix test by maintaining 10% active clay with required bentonite addition

The test mixes were tested for the following properties:
- Moisture
- Permeability
- Loss on ignition (LOI)
- Compactability
- Shatter Index
- Mouldability
- Total clay
- Active clay
- Green strength
Figure 4.13 Studies on the properties of reclaimed sand, used sand and new sand for use in green sand moulding with bentonite
Table 4.6 Different types of sand mixes used in Green sand moulding

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<tr>
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<th>Che</th>
<th>HCS</th>
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4.11.1 Active Clay

Active clay that forms the bond in green sand moulds is destroyed by heat of the molten metal. The direct determination of active clay content is carried out utilising the strong absorption and base exchange properties which clays posses on certain dyes, such as methylene blue.

Procedure
i) 50 gms of the representative sample was taken for evaluation.
ii) 5 gms from above sample was placed in a clean dry conical flask.
iii) 50 ml of distilled water was added using pipette and boiled gently on a hot plate for 10 minutes.
iv) Cooled to room temperature and then 1.5 ml of 0.5N H₂SO₄ was added by a pipette and shaken thoroughly.
v) 1 ml of standard methylene blue solution was added using a burette and continuously stirred.
vi) A glass rod was used to transfer a drop of the slurry on to a filter paper.
vii) Appearance of the filter paper, was initially found to be a faint blue spot of solid surrounded by a transparent ring of colourless liquid. This indicates insufficient clay.
viii) Steps v, vi and vii were repeated to get a blue spot breaking down into a diffuse light blue halo, radiating outwards. This indicates sufficient active clay.

Calibrator graph prepared for the bentonite was used to find out the value of active clay from the volume of methylene blue solution added.

4.11.2 Dead Clay

It is the amount of burnt clay, fines etc., which are not responsible for the binding activity. Dead Clay is determined approximately as the difference between the total clay and active clay.

\[
\text{Dead Clay} = \text{Total Clay} - \text{Active Clay}
\]
4.11.3 **Green compression strength and shear strength:**

The test measures the stress at which failure occurs under a constant rate of loading.

The test was conducted on a standard specimen (50.8 mm dia x 50.8 mm height) in type PFG George Fischer universal strength machine.

4.12 **PRODUCTION OF TEST CASTINGS:**

To check the performance of the reclaimed sand production of various types of test castings was carried out using gray cast iron in the green sand system.

4.12.1 **Types of test castings**

Schematic diagrams of the test castings are shown in Figures 4.9 to 4.10 as detailed below:

i) **SFSA (Steel Founders Society of America) standard test block** to evaluate the relative erosion, penetration and burn on conditions of the sand used for moulding [Figure 4.9 (a) and (b)].

ii) **Step cone casting developed by M/s. Ashland Chemical Company** to evaluate veining defect/finning defect [Figure 4.10 (a) and (b)].

4.12.2 **Moulding**

The moulds for test castings for SFSA standard block and step cone casting was produced with various types of sand mixtures. The combination of various sand mixes used in this investigation is given in table 4.6. Production of moulds for test castings was carried out in green sand moulding. In the unit sand system 5-6% active clay was maintained with 2-3% bentonite addition. The sand mix consisting of system sand, reclaimed sand/used sand, (usual addition of new sand was substituted by reclaimed sand) bentonite, coal dust and water was mixed in a sand muller.
4.12.3 Melting and Pouring

Melting and pouring was carried out in a cast iron foundry. Induction melted gray cast iron with a carbon equivalent of 3.9 was used. It was inoculated with 0.3% proprietary inoculant and poured into the test castings at a temperature of 1420°C. The pouring temperature was measured using a Pt-Pt 13 Rh thermocouple with digital display.

After pouring the castings were allowed to cool for sufficient time then knocked off and shot blasted.

4.13 STUDIES ON CASTING QUALITY

The quality of castings was measured by measuring the surface finish by two different techniques. (i) Surface Inspection by Comparison Methods. (ii) Direct Instrument Measurements.

The trial castings were sectioned to study the internal soundness of castings.