Development of Low Bulk Density Fireclay Insulation Brick

A Thesis Submitted in Partial Fulfilment
Of the Requirements for the Degree of

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In
Ceramic Engineering

By
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National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that this thesis entitled, "**Development of Low Bulk Density Fireclay Insulation Brick"** submitted by Mr. **Rahul Kumar (Roll no. 107CR022)** in partial fulfilment of the requirements for the award of Bachelor of Technology Degree in Ceramic Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date: 7 May 2011

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6th May, 2011 Rahul kumar

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ABSTRACT

The present study deals with the development of low bulk density 0.54 to 0.88 g/cc, high cold crushing strength 8.95 to 79.97 kg/cm^2 insulation brick using low cost raw materials. In the present study river silt is used as low cost raw materials in the insulation brick formulation. Effect of plastic clay to silt ratio on the proportion of insulation brick has been studied, and attempt has also be made to study the effect of pore former, firing temperature and calcined clay on the properties of insulation brick. The study suggest that incorporation of river silt enhance the strength of brick while keeping the apparent porosity unaltered at a low firing temperature 1050^{0}C.

Chapter 1

Introduction

Low bulk density in the range of 0.5-0.6 g/cc with a CCS value of 40-60 kg/cm^2 has a tremendous requirement in lowering thermal mass of a kiln. Low thermal mass kiln are coming out as an emergent technology to lower the fuel consumption in processing industry. Low bulk density, high strength insulation brick is manufactured with different raw materials. Fire clay, semi-silica, kyanite based and vermiculite based materials. However the cost of the raw materials and subsequent processing cost could be required with the incorporation of low cost raw material like silt. This low cost insulation brick may have a potential application as backup / cold face insulation brick.

Objective

The present study focus the development of low bulk density, high CCS insulation brick with river silt as one of the raw material constituent. Impression has been given to the study the effect of plastic clay to silt ratio on the properties of insulation brick. The effect of firing temperature and pore former on the properties of the insulation refractory has also been studied. Finally the effect of calcined clay on the properties of insulation refractories has been repaired.

Chapter 2

Literature review

2.1 Refractories

Materials that can withstand very high temperature without degrading or softening are known as refractory materials. Refractory materials include certain ceramics and super alloys and are used in heat insulation of furnaces. The main function of a refractory is to withstand and maintain high temperatures and resist the abrasive and corrosive action of molten metal, slag and gases [1].

2.2 Classification of Refractories

According to the chemical properties the Refractories are classified into three different categories namely i) acidic refractories ii) basic refractories and iii) neutral refractories [1-3].

Acidic refractories consist of acidic materials like Silica (SiO_2). They are not attacked by acidic materials, but easily attacked by basic materials. Silica based refractories silica brick, super duty silica brick and semi-silica brick used in coke oven and regenerators lies in this category

Basic refractories consist of the materials of basic chemical character. They are characterized by their withstanding power under basic environment at high temperature. They are usually used in the basic environment of the metallurgical furnaces. Magnesia direct bonded or chemically bonded bricks, lime refractories etc. falls under this category. They show improved performance at the slag zone of the furnaces [4].

Neutral refractories have the chemical constituent which does not have acidic or basic in chemical character. These refractories could be used both acidic and basic environment of the furnace. Alumina, spinal, mullite, chromites refractories falls under this category.

Refractories could be classified according to their shapes namely shaped and unshaped refractories. Shaped refractories are manufactured as per the design requirement. Various shapes of refractories are available for the construction of different furnaces. Shaped refractories are made from the different raw materials followed by pressing and firing at high temperature. Mostly shaped refractories are used to construct kilns. Unshaped refractories on the other hand are marketed as a mixture of refractory aggregates, binders, plasticizers etc. This ready to use mixture is mixed with water and the desired refractory lining is construed on site with it. The development of unshaped refractories gives the endless lining concept at the user industries. Various unshaped refractories include conventional castables, Low cement castable, ultra-low cement castable, gunning mixtures, ramming mixture, mortar etc.[2]

2.3 Dense and Porous Refractories

Refractories could be classified into two categories depending on the porosity present in it namely dense and porous refractories. Dense refractories contain porosity in the range 15-20%. These refractories were used in contact with hot liquid metal and gases. On the other hand porous refractories contain porosity as high as 80%. The porous refractories are light weight and possess very good thermal insulation properties. These refractories are used at high temperature or as back up lining of the furnaces. The high temperature insulation bricks are known as hot face insulation brick. The backup insulation bricks are known as cold face insulation brick. [1]

2.4 Insulation Bricks

Insulation brick is characterized by the presence of large amount of porosity in it. The pores are mostly closed pores. The presence of porosity decreases the thermal conductivity of the refractory drastically. These porous refractories are called insulation brick. The bulk densities of these bricks are usually low due to the presence of the porosity in these bricks. The application temperature of these bricks depends on the constituents. For example, kyanite based insulation bricks can be used at a temperature greater than 1250^{o}C. Whereas fireclay based insulation refractories are usually used at low temperatures [2].

2.5 Properties of Insulation Bricks

Insulation bricks should have low bulk density, high porosity as a result the strength of the brick is low. These brick also showed very low thermal conductivity and low heat capacity. Typical property requirements of insulation bricks is provided in Table –I

Table-I Properties of insulation bricks

	Service temperature (^{o}C) Max.	Bulk density (gm/cc) Max	Apparent porosity (%) Min	CCS (Kg/cm^{2}) Min	PLC at ST/3h (5) Max	PCE (OC) Min	TC Kcal/m/h/^{o}C Max
Cold face Insulation Bricks	**1000**	**1.0-0.8**	**50-70**	**10-60**	**±1.5**	**-**	**0.2-0.24**
Hot face Insulation Bricks	**1250**	**1.0-.8**	**40-60**	**20-70**	**±1.5**	**27**	**0.2-0.24**

2.6 Raw materials for Insulation Bricks

Raw materials required for the production of insulation bricks could be categorized into thee namely aggregates, binders and combustibles/ pore formers [5].

2.6.1 Aggregates

Aggregates are porous aggregate prepare with clay and sawdust fired at a temperature around 1000-1050^{0}C. Sometimes vermiculite, mica based materials which undergo volume expansion during firing is also used as aggregate in mica based insulation brick. Row kyanite also shows volume expansion during heating is used as aggregate in hot face insulation brick. Diatometerous clay shows volume expansion property during heating is also used as raw materials in manufacturing cold face insulation brick. Vermiculite is a member of the phyllosilicate group of minerals, resembling mica in appearance. In its natural form vermiculite is a flaky but quite solid material. On heating it suddenly exfoliates. Solid flakes burst into a large number of thinner flakes separated by air space [6].

2.6.2 Combustibles

Rice husk/ sawdust straw or low cost biomaterial are used as combustibles or pore former in manufacturing of insulation brick. However naphthalene, starch are also used for pore former in high duty insulation brick. These combustibles either evaporate or burnout during initial stage of firing and creates pores in the brick. The size and shape of pore former controls the pore morphology in insulation brick. Polystyrene foam each particle, which is dissipated during firing process and leaves behind a cavity that can improve thermal insulation properties of the brick. Polystyrene foam is, therefore, used as a pore forming material in the brick body .To that correspondence should be addressed for reducing thermal conductivity. Sawdust is combustible material, which produce channel and porosity at high temperature [4].

2.6.3 Binders

Normally plastic clay based binder are used in manufacturing of insulation brick. Other binders are ethyl cellulose, starch and molasses. These binders are used in manufacturing paste insulation brick. However calcium oxide based binder lime or sometime gypsum is used during manufacturing of insulation brick via casting and setting process [5].

2.6.4 Manufacturing of insulation refractories

Insulation brick are manufactured by two different ways mainly casting and setting and pressing.

2.6.4.1 Casting and setting

In this process refractory aggregates and pore former are mixed with binder; water which plaster of Paris as a setting agent. During the mixing process plaster of Paris undergoes hydration. This hydrated product caste in mould following vibro- casting technique. After casting the mould is allowed to set. After final setting is achieved the product is remould and dried slowly. The dry article is fired slowly to maximum firing temperature above the service temperature of brick. During the firing process the incorporated in brick composition burns out and produce pores in the brick matrix. as the water requirement for this processing is quite high this brick does not able to return their shape after firing. Final shape of the brick is prepared by cutting the surface of the fire brick. This is most popular method for industrial production [7, 8]

2.6.4.2 Pressing

Aggregates, binders and pore former are mixed with 4 -5 % water and pressed either uniaxial or hand moulded to produce insulation brick. Plasticity of the mix is a important parameter in achieving a good quality test brick. The plasticity is achieved with the increase in binder content in the row mix. The bricks manufacturing in this process are very prone to lamination. However careful control over the composition and of the process parameter for pressing could improve the quality of press product. The pressed brick are dried in hot air oven and then fired at the temperature above the service temperature brick. The service temperature depends on the properties of the row material used in the formulation of batch. This process gives high productivity if the green rejection is minimized. As the water requirement for this processing is low. The brick manufacture in this process need not required any surface grinding or cutting [9].

Chapter 3

Experimental Work

3.1 Brick Formation

The row material used for the preparation of fire brick and calcined clay (0-1 mm), Fine clay, river silt and saw dust. The different batch formulation is given in table II.I

Table II.I. Composition of different bricks

Calcined Clay 40 wt%		Calcined clay 50 wt.%		Calcined Clay 60 wt%	
Plastic clay	Silt	Plastic Clay	Silt	Plastic Clay	Silt
0	60	0	50	0	40
10	50	10	40	10	30
20	40	20	30	20	20
30	30	30	20	30	10
40	20	40	10	40	0
50	10	50	0		
Saw dust over all 50%					

3.2 Mixing

Required amount of row material were properly weighted and dry mix for half hour in plastic clay. Water was gradually added and mixed properly with the dry mix. The consistency of the mixture was checked with hand filling method. The typical water requirement was 3-4wt%.

3.3 Pressing

Cubic cast iron mould of 50x50x50mm was used for hand moulding the brick. The mould surface was cleaned properly and lubricated with oil. The mould was filled with the wet mixture and moulded with a rectangular metallic punch. The material level decreases with the progress in and hand moulding. The surface of the moulded brick was scratched with a sharp knife edge and refilled with row mix and again moulded. This process was repeated until the mould cavity is filled up the row material after pressing. The pressed brick were remoulded and dried in open air for 24 hours followed by drying in air oven for another 24 hours

3.4 Firing

Dried shapes were fired in an electric furnace in the temperature range 1050-1150^{0}C 4 hours. The heating rate during firing was very slow. During the heating process in low temperature shocking at 450^{0}C for 2 hours has been provided for concrete burning of the sawdust use in the brick formulation .the sample were cooled and taken out for further characterisation [7].

3.5 Characterization

As for sample were inspected for any visual defects (crack, lamination and surface deformation). The good quality samples were selected for further characterization.

3.5.1 Apparent porosity and bulk density measurement

Apparent porosity and bulk density of the sample were measured using Archimedes method. The formula is given below

Apparent porosity = $\frac{W-D}{W-S}$

Bulk density = $\frac{D}{W-S}$

Where, W = soaked weight, S = suspended weight and D = dry weight

Small piece of the sample was used for the measurement. Dry weight of the sample was recorded. The sample were then immersed in water and boiled for 2 hours. This sample was kept for 24 hours in the water bath in ordered to insure complete weighting the entire sample. Suspended weight of sample was taken by immersing the sample in water bath. Soaked weight of the sample was noted after removing the surface water by a wet cloth. The density and apparent porosity of the sample has been calculated using the above formula.

3.5.2 Cold crushing strength

Cold crushing strength of the cubic sample has been measured with universal testing machine. Curve of the sample below in Fig.3.1.

The maximum load has been recorded from the load deflection curve for each sample.

CCS value of the brick has been calculated from the formula CCS = load/ cross-sectional area

Load is the maximum recorded from the load deflection curve

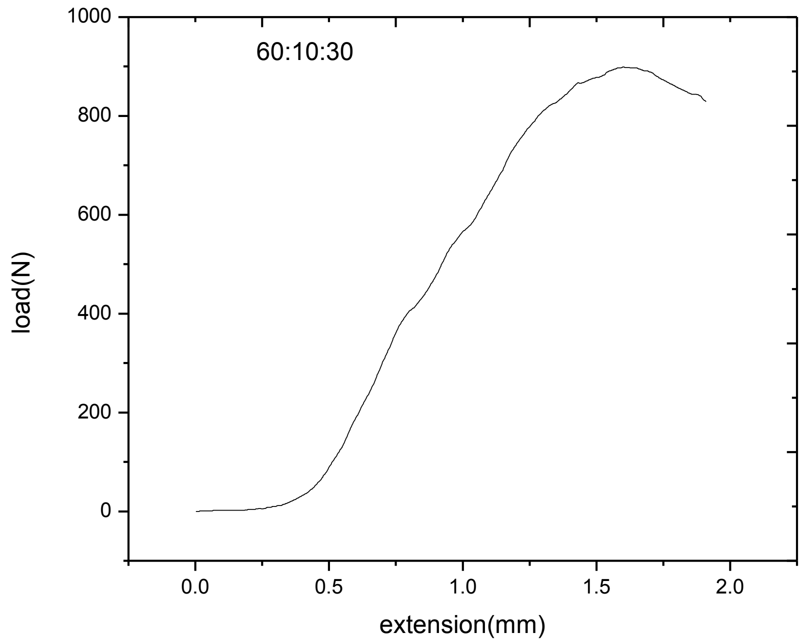

Fig 3.1 Load deflection curve

Chapter 4

Results and Discussions

The prepared bricks have been studied for apparent porosity, bulk density and strength. The following sections discuss the effect of raw materials on the different properties of the brick.

4.1 Effect of Plastic Clay to Silt Ratio

4.1.1 Apparent porosity

The variation of apparent porosity of the samples containing different plastic clay to silt ratio as a function of calcined clay content is shown in Fig. 4.1 (a, b and c). All the samples presented here have been fabricated with 50 % overall sawdust.

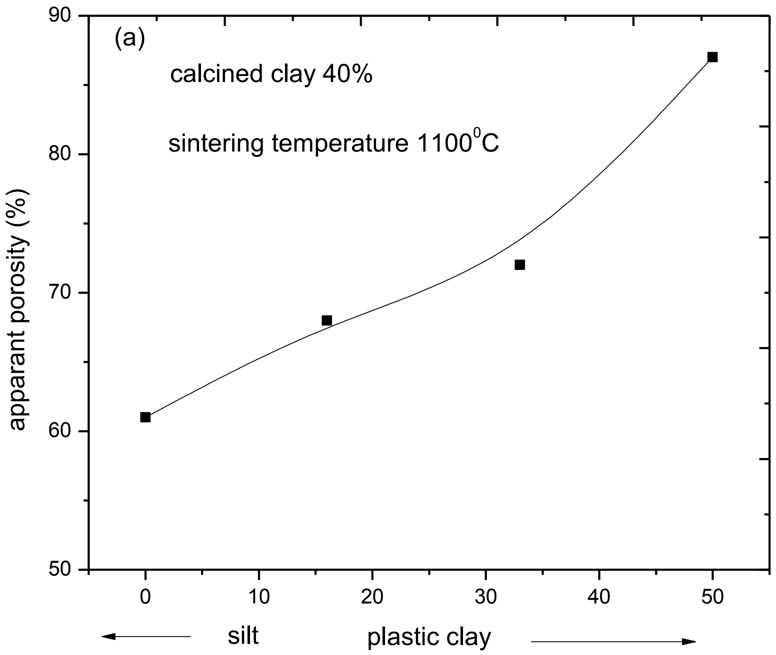

Fig 4.1(a) Effect of plastic clay to silt ratio on apparent porosity of brick containing 40% calcined clay

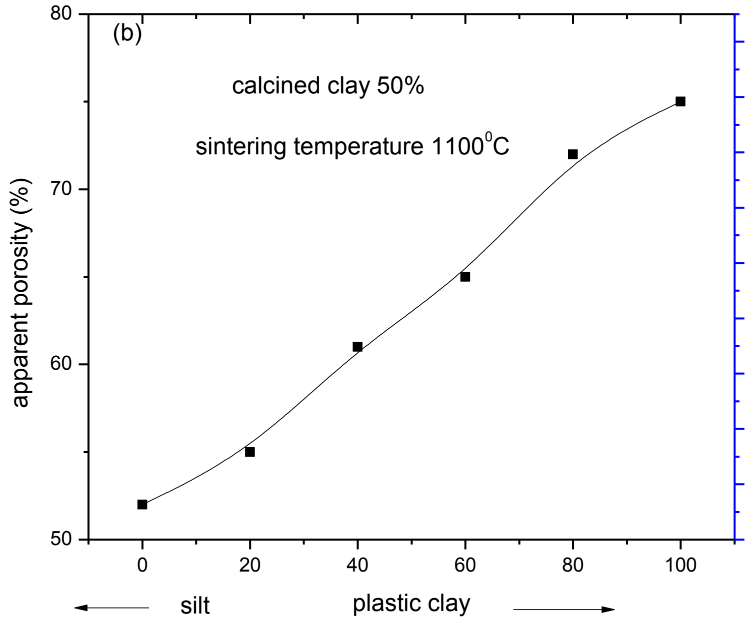

Fig 4.1(b) Effect of plastic clay to silt ratio on apparent porosity of brick containing 50% calcined clay

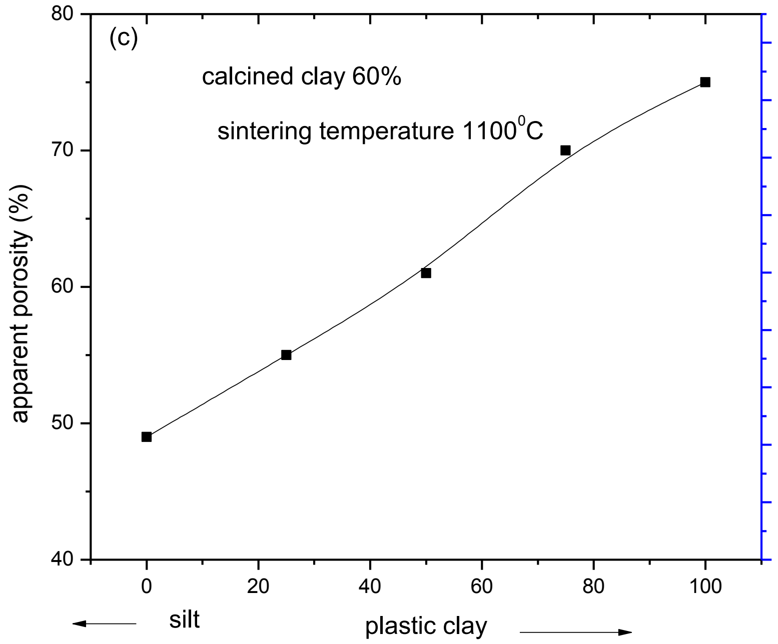

Fig 4.1(c) Effect of plastic clay to silt ratio on apparent porosity of brick containing 60% calcined clay

It could be seen from the figure that apparent porosity of the sample increases with increasing plastic clay to silt ratio in the composition. It is well known that silt has a lower melting temperature as compared to plastic clay. Thus increase in silt amount in the composition leads to higher densification in the sample resulting low apparent porosity in the sample. Similar trend was observed all the brick to prepare with different amount of calcined clay.

4.1.2Bulk density

The variation of bulk density of the sample containing different plastic clay to silt ratio as a function of calcined clay has been shown in Fig. 4.2(a, b and c)all the samples has been prepared with 50 % overall sawdust.

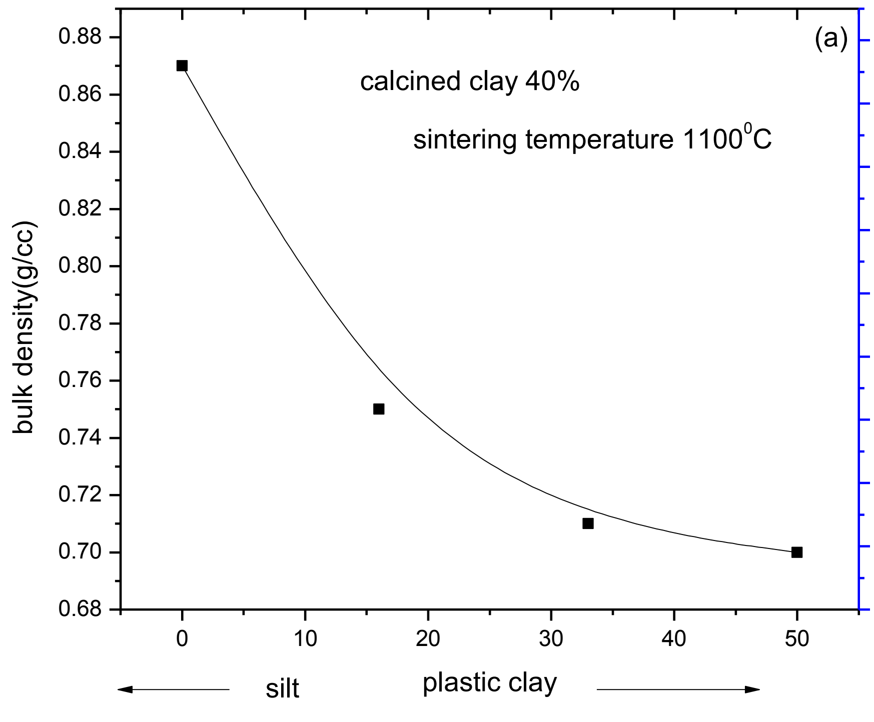

Fig 4.2(a) Effect of plastic clay to silt ratio on bulk density of brick containing 40% calcined clay

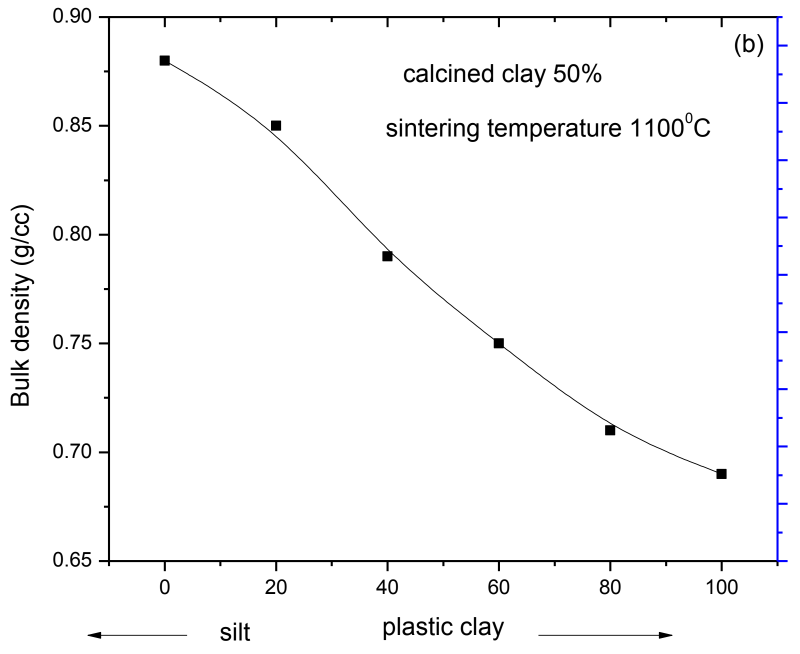

Fig 4.2(b) Effect of plastic clay to silt ratio on bulk density of brick containing 50% calcined clay

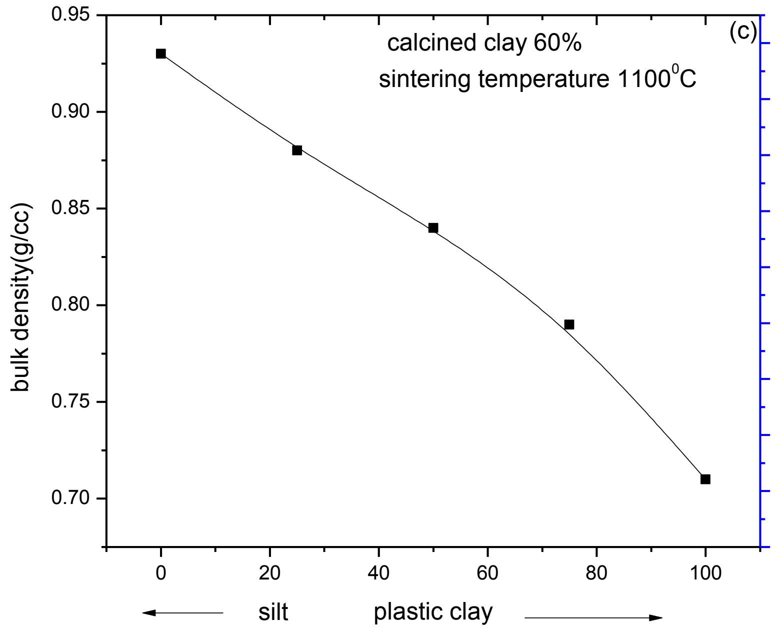

Fig 4.2(c) Effect of plastic clay to silt ratio on bulk density of brick containing 60% calcined clay

It could be seen from the figure that bulk density of the sample decreases with increase in plastic clay to silt ratio. The decrease in bulk density is correlated with the increase in porosity as observed in Fig. 4. Plastic clay has higher melting temperature than that of silt as a result the densification of the sample reduces with increase in plastic clay. The lower densification results lower bulk density in the sample. All the samples prepared with different amount of calcined clay showed the similar behaviour.

4.1.3 Cold crushing strength

The variation of CCS of the sample containing different plastic clay to silt ratio as a function of calcined clay has been shown in Fig. 4.3(a, b and c)all the samples were prepared with 50% overall sawdust.

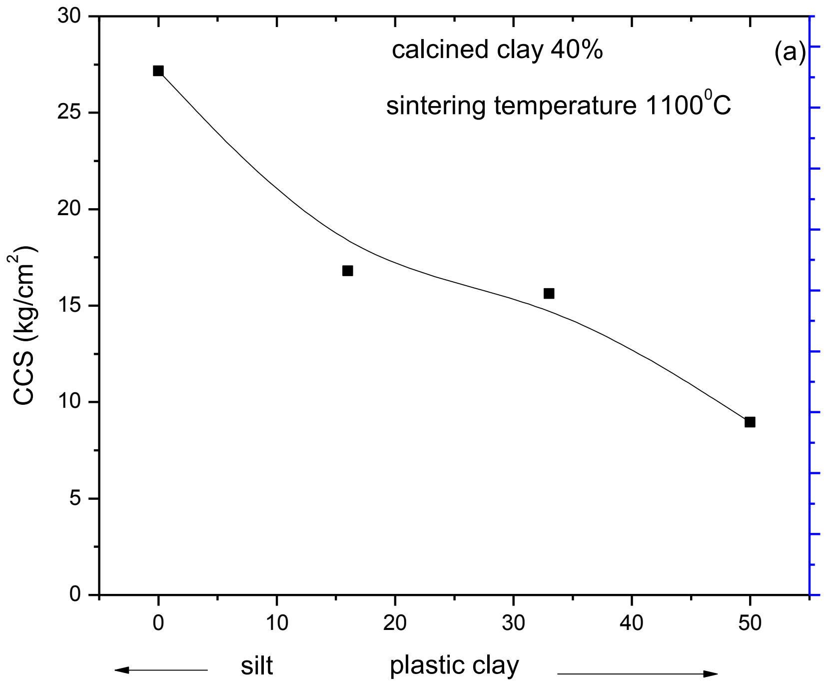

Fig 4.3(a) Effect of plastic clay to silt ratio on CCS of brick containing 40% calcined clay

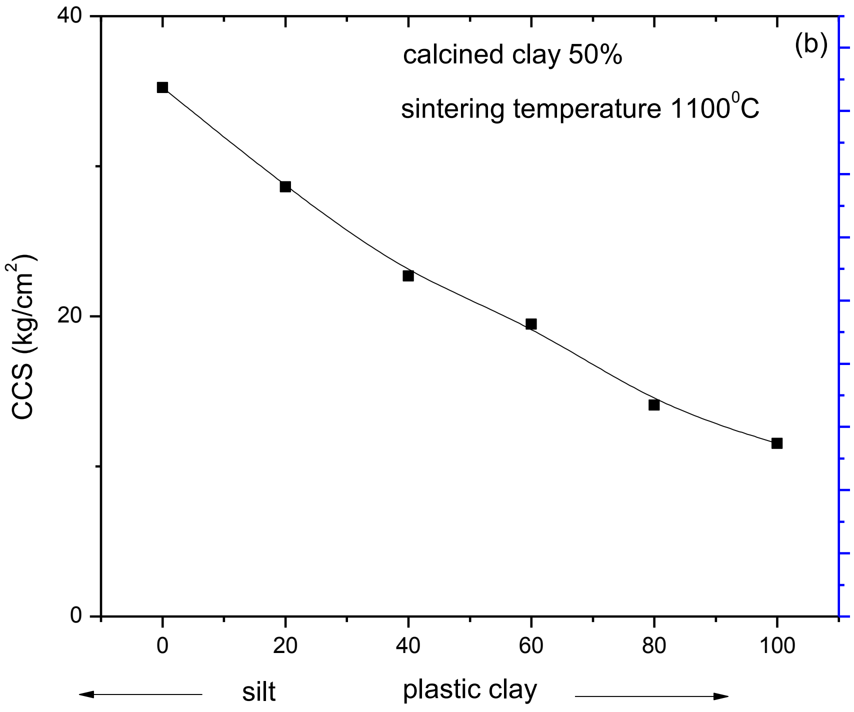

Fig 4.3(b) Effect of plastic clay to silt ratio on CCS of brick containing 50% calcined clay

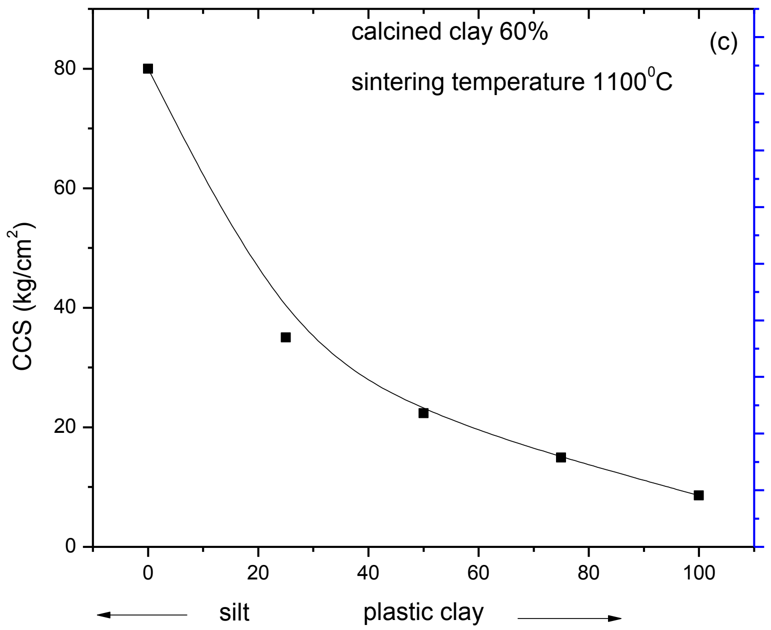

Fig 4.3(c) Effect of plastic clay to silt ratio on CCS of brick containing 60% calcined clay

It could be seen from the figure that the CCS of the ample increase with decrease in plastic clay to silt ratio. Similar observation was observed for all the bricks prepared with different amount of calcined clay. The increase in CCS value is correlated with the decrease in apparent porosity with the decrease in plastic clay to silt ratio as observed in Fig. 4.1. It has been well studied that the strength of the sample strongly dependent on porosity. Increase in porosity drastically decreases the strength of the sample. Thus the increase in porosity with increase in plastic clay to silt ratio leads to the decrease in CCS value of the brick.

4.2Effect of temperature

4.2.1 Apparent porosity

The variation of apparent porosity of the sample containing 40% calcined clay 10% plastic clay and 50%silt as a function of firing temperature has been shown in Fig.4.4.The sample has been prepared with 40% sawdust.

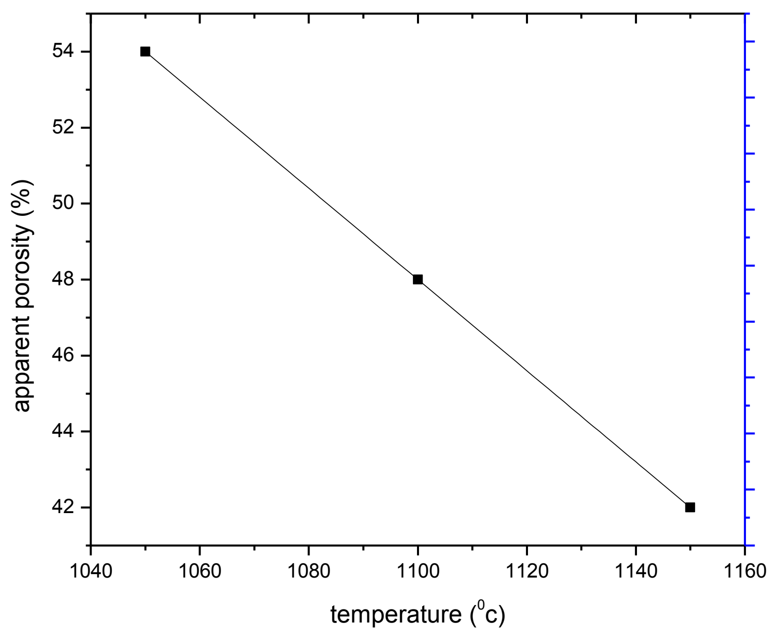

Fig 4.4 Effect of temperature on the apparent porosity of the brick

It could be seen from the figure that the apparent porosity of the sample decreases with increase in firing temperature. Apparent porosity decreases around 14 %with an increase in 100^{o}C firing temperature. The decrease in apparent porosity is related with the increase in vitrification of the sample caused by the incorporation of low melting silt in the composition.

4.2.2 Bulk density

The variation of bulk density of the sample containing 40% calcined clay 10% plastic clay and 50%silt as a function of firing temperature has been shown in figure 4.5.The sample has been prepared with 40% sawdust.

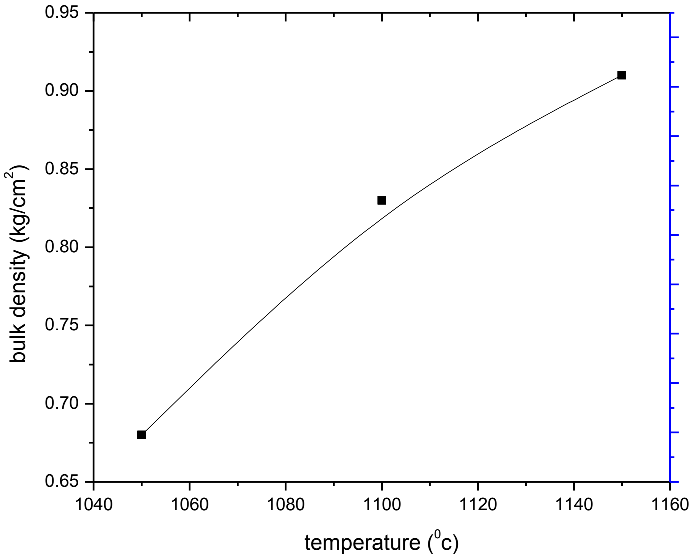

Fig 4.5 Effect of temperature on the bulk density of the brick

It could be seen from the figure that the bulk density of the sample increases with increase in firing temperature. Bulk density varies in the range of 0.682to 0.91gm/cc was observed with increase in temperature from 1050 to 1150^{o}C. The increase in bulk density is correlated to the enhance sintering of the sample with increase in firing temperature. The bricks prepared in the study are likely to undergo liquid phase sintering as it contains low melting silt as one of its component. Increase in sintering temperature may lead to enhance liquid formation at high temperature which causes an increase in bulk density of the sample.

4.2.3 Cold crushing strength

The variation of bulk density of the sample containing 40% calcined clay 10% plastic clay and 50%silt as a function of firing temperature has been shown in Fig. 4.6.The sample has been prepared with 40% sawdust.

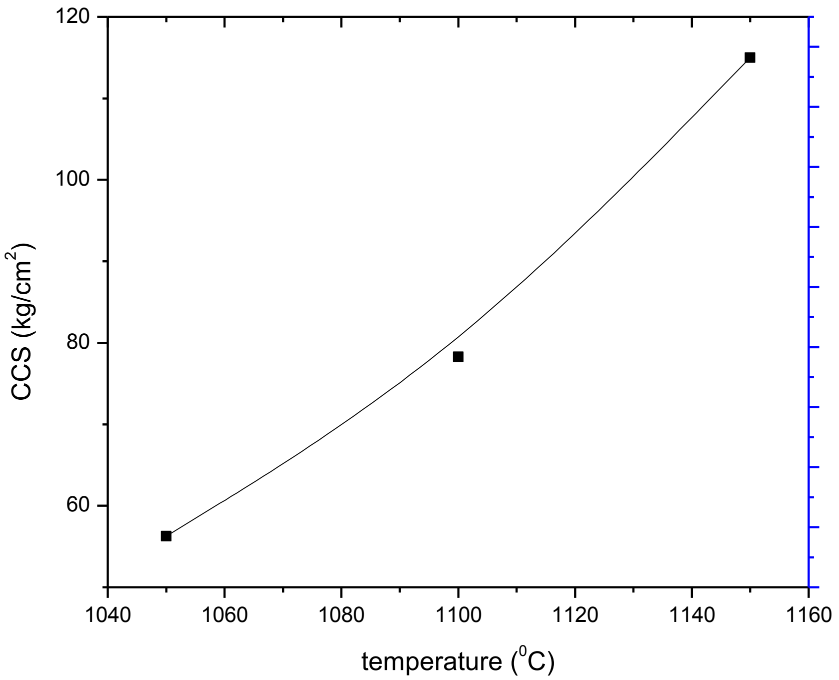

Fig 4.6 Effect of temperature on the CCS of the brick

It could be seen from the figure that CCS of the brick increases with increase in firing temperature. It has been found that the CCS increases drastically with increase in firing temperature. The sample fired at 1150^{o}C shows almost double CCC value as that sintered at 1050^{o}C.The increase in CCS value is correlated to the increase in BD of the sample with increase in firing temperature.

4.3 Effect of sawdust

4.3.1 Apparent porosity

The variation of apparent porosity of the sample containing 40% calcined clay 10% plastic clay and 50%silt as a function of sawdust has been shown in Fig. 4.7.The sample has been fired at the 1050^{o}C.

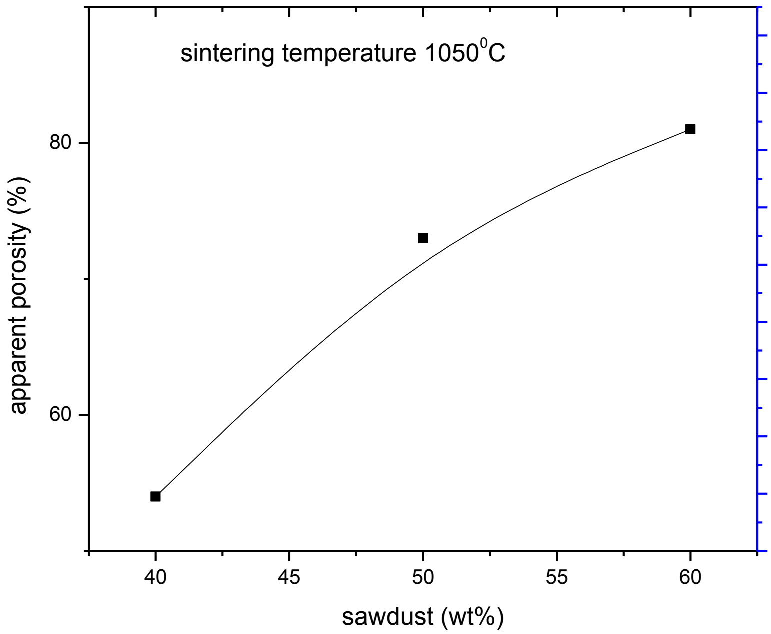

Fig 4.7 Effect of sawdust on the apparent porosity of the brick

It could be seen from the figure that apparent porosity of the sample increases with increase in sawdust content. The apparent porosity was found to increase in the range of 54 to 81 % with an increase in saw dust content from40 to 60%. The saw dust has been incorporated into the composition as a pore former. Saw dust during firing burns at low temperature region below 300^{o}C and imparts porosity in the brick. It is most obvious that increase in sawdust content in the brick composition will yield a higher porosity in the sample.

4.3.2 Bulk density

The variation of bulk density of the sample containing 40% calcined clay 10% plastic clay and 50% silt as a function of sawdust has been shown in Fig. 4.8.The sample has been fired at the 1050^{o}C.It could be seen from the figure that the bulk density of the sample decreases with increase in sawdust content. It has been observed that bulk density decreases from 0.68 to 0.54 gm/cc with increase in sawdust content from 40 to 60 %. The decrease in bulk density is correlated with the increase in porosity with increase in sawdust content in the brick composition.

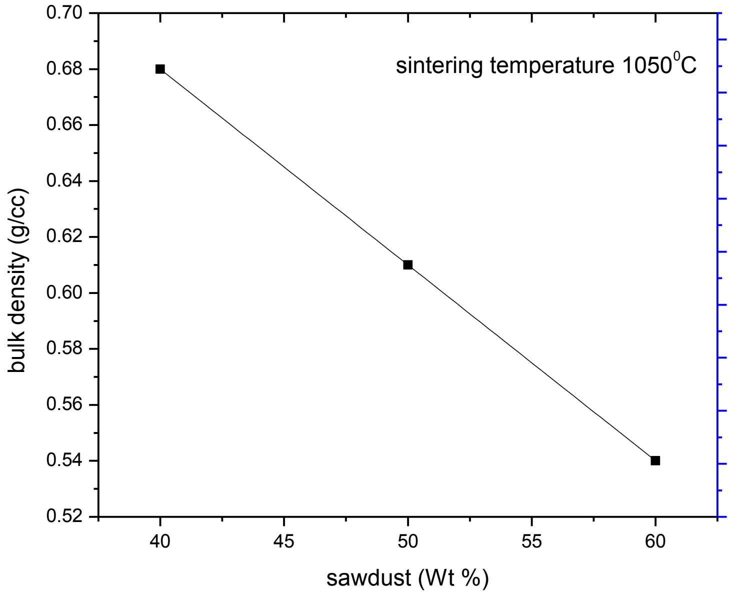

Fig 4.8 Effect of sawdust on the bulk density of the brick

4.3.3Cold crushing strength

The variation of CCS of the sample containing 40% calcined clay 10% plastic clay and 50%silt as a function of sawdust has been shown in Fig 4.9.The sample has been fired at the 1050^{o}C.

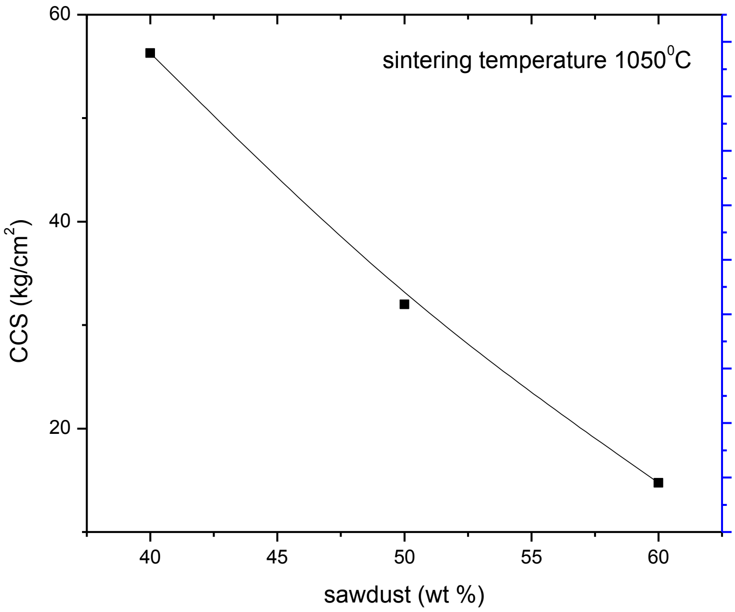

Fig 4.9 Effect of sawdust on the CCS of the brick

CCS depends on porosity of the sample. Porosity drastically reduces the strength of the sample. Thus the reduction of the strength with increase sawdust content is correlated to the adverse effect of porosity on strength.

4.4 Effect of plastic clay to silt ratio is constant

4.4.1 Apparent porosity

The variation of apparent porosity of the sample containing constant plastic clay to silt ratio as a function of calcined clay has been shown in Fig 4.10. The sample has been fired at the temperature 1100^{0}C.

It could be seen from the figure that apparent porosity of the sample decreases with increasing calcined clay to in the composition. It has been found that for a 50:50 plastic clay to silt ratio the AP decreases from 87-61% with increase in calcined clay from 40 -60%.

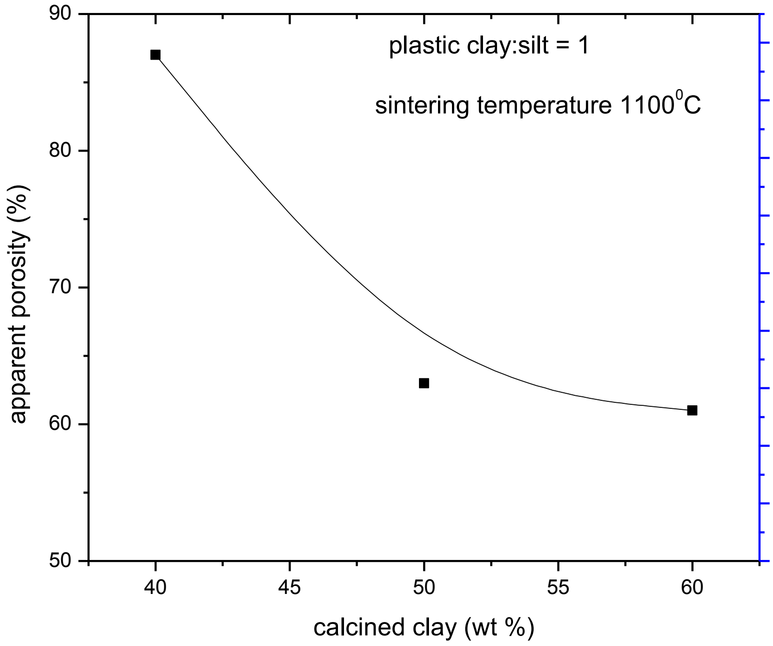

Fig 4.10 Effect of calcined clay on the apparent porosity of the brick containing plastic clay to silt ratio constant

4.4.2 Bulk density

The variation of bulk density of the sample containing constant plastic clay to silt ratio as a function of calcined clay has been shown in Fig 4.11. The sample has been fired at the temperature 1100^{0}C.

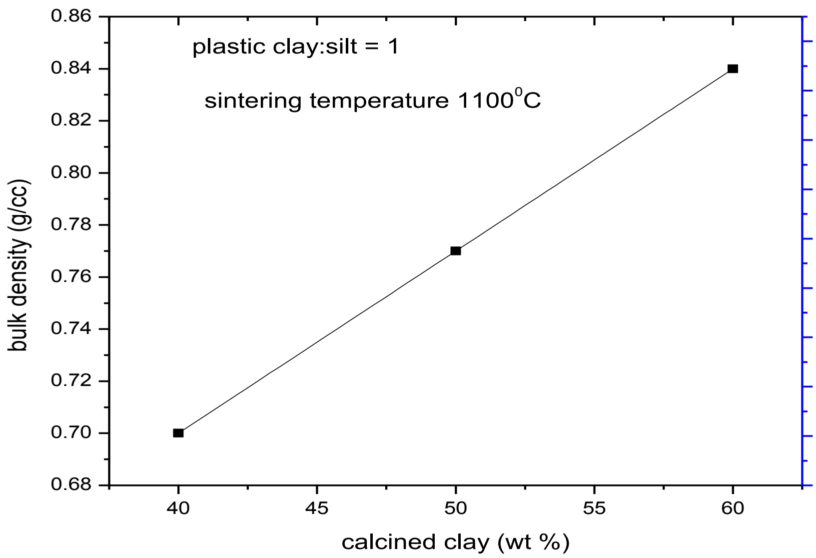

Fig 4.11Effect of calcined clay on the bulk density of the brick containing plastic clay to silt ratio constant

It could be seen from the figure that bulk density of the sample increases with increase in calcined clay in the composition. It has been found that for a 50:50 plastic clay to silt ratio the BD decreases from 0.70-0.84 gm/cc with increase in calcined clay from 40 -60%. The increase in bulk density is correlated with the decrease in porosity as observed in Fig 4.10.calcined clay has higher BD as compared to that of silt and plastic clay as a result the BD of the sample increases with increase in calcined clay.

4.4.3Cold crushing strength

The variation of CCS of the sample containing constant plastic clay to silt ratio as a function of calcined clay has been shown in Fig 4.12. The sample has been fired at the temperature 1100^0C.

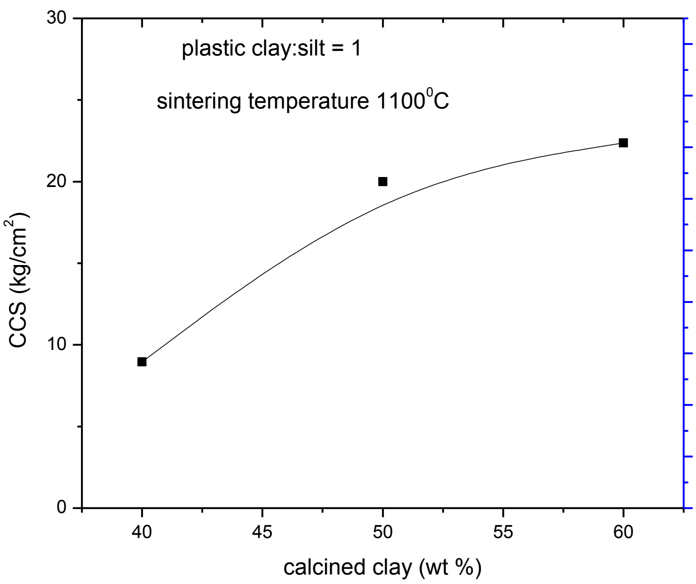

Fig 4.12Effect of calcined clay on the CCS of the brick containing plastic clay to silt ratio constant

It could be seen from the figure that the CCS of the sample increases with increase in calcined clay. It has been found that for a 50:50 plastic clay to silt ratio the CCS decreases from 8.95-22.37 $Kg/cm^2$with increase in calcined clay from 40 -60%. The increase in CCS value is correlated with the decrease in apparent porosity as observed in Fig. 4.10. It has been well studied that the strength of the sample strongly dependent on porosity. The increase in porosity drastically decreases the strength of the sample.

Chapter 5

Conclusions

The following conclusion could be obtained from the present study.

1. CCS and bulk density of the sample decreases with increase in plastic clay to silt ratio, while apparent porosity increases with increase in plastic clay to silt ratio.
2. With increase in firing temperature the CCS and bulk density of the brick increases while the apparent porosity decreases.
3. With increase in sawdust content apparent porosity in the sample increases, while the bulk density and CCS value decreases.
4. Bricks prepared with 50:50 plastic clay to silt ratio, apparent porosity decreases with increase in calcined clay content, while bulk density and CCS increases.
5. Brick prepared with 40% calcined clay, 10% plastic clay and 50% silt composition fired at 1050^0C shows CCS 56.28 kg/cm^2, bulk density 0.68 g/cc and apparent porosity 54% and may have potential application for cold face insulation brick.

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