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Solid Waste Management

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Abstract : Solid waste management has become crucial for many industries like thermal power plants, ferrous and non-ferrous metal industries. Among these non ferrous industries are facing a huge problem in managing their solid waste. These industries generate large quantities of solid waste containing heavy metals like Cr, Ni, Zn, CO etc. Though these elements are present in small quantities they cause havoc to the environment due to their gradual accumulation. This problem has to be properly addressed by disposing their solid waste in an environmentally friendly way. But technologies available are specific to the industry as well as their wastes. The bottle necking technologies are to be developed on the need based system. In the present study a simple chemical engineering principle is used and an innovative technique is developed to take hazardous solid waste in to the environment safely. Fly ash based low density bricks with zinc sludge were made. Fly ash, binder and sludge based wastes are taken in the proportions 80:15:5, 75:15:10, 70:15:15, 65:15:20. It is felt light weight bricks will help in the weight reduction of structures. Hence porosity was created by the addition of CMC (Carboxy Methyl Cellulose) in variable quantities. The quality of brick was assessed by measuring porosity, water absorption, linear and volume shrinkage, green body strength. To improve properties further the green bodies are fired at temperatures 700,800,900 and 1000 ^{0}C. Thus prepared bodies were tested for the above said properties. The bodies obtained from the study are light in weight and have sufficient strength to meet the construction brick standards. When the technologies incorporated into practice, sufficient quantities of hazardous waste would be taken into them with no damage to the environment.
Keywords: Zinc Sludge, Fly ash, Sodium Silicate, Carboxy Methyl Cellulose, Bricks.

1. Introduction

In the present day scenario industries like thermal power plants and non-ferrous metal industries are generating large quantities of solid waste. Most of these industries still lack a viable solution for their waste disposal. The gradually accumulating waste is causing havoc when it takes the route of air and ground water. Zinc industry is one among them. It generates solid waste of different forms and nature (Slag, dross and sludge forms). The current routes for disposal of solid waste of these industries are ground filling and water disposal. Such waste contains iron in large quantities while lead, zinc in moderate quantities, cobalt and antimony in ppm levels. Despite of their presence in minute quantities, they pose serious health hazards when they take the path of the ground water because of their permissible exposure limits. These limits are very low for lead, cobalt, antimony. This problem has to be addressed with utmost priority before it causes an irreparable damage to the society and environment. Management of such solid waste reduces or eliminates adverse impacts on the environment and human health and supports economic development as well as improved quality of life. Many possible techniques like ground disposal, water disposal and mine filling etc have been considered for the disposal of solid waste. Among many other techniques, disposal by the way of brick manufacture is considered a promising one. It is seen that Fly ash has been in use since a decade for the production of FALGY bricks and it became a viable solution to thermal power plants.

In the present paper fly ash based bricks along with zinc sludge of different composition were prepared. Zinc sludge obtained from industry was incinerated at high temperatures (>800 ^{0}C) leading to the production of waste powder which is used in production of fly ash based bricks. The other raw materials used were fly ash, sodium silicate, calcium oxide and carboxy methyl cellulose. The bricks made were then tested for various properties. The experimental procedure along with results is discussed in detail in the subsequent sections.

2. Literature Review

An investigation into the stabilization of soft clay with a very high lime fly ash was studied by Sezer et al (1). In his study it was found the inclusion of fly ash improved the properties of the soil. A study by Manz et al (2) showed that the replacement of coarse and fine natural aggregates by recycled aggregates at the levels of 25% and 50% had little effect on the compressive strength of the bricks and block specimens, but higher levels of replacement reduced the compressive strength The process for the manufacture of bricks from fly ash in a furnace having inlet temperature of 100^{0}c and outlet temperature of 1200^{0}C was studied by Takegawa et al (3).and Zakaria et al (4) conducted a laboratory study on the use of demolition bricks and artificial aggregates made from fly ash-clay. The results showed clearly that concretes of good performance and durability can be produced using aggregates from demolition rubble or using artificial aggregates made with wastes such as fly ash. Poon et al (5) developed a technique for producing concrete bricks and paving blocks using recycled aggregates obtained from construction and demolition waste. Fly ash-lime phosphogypsum (FALGY) hollow blocks are one of the best substitutes for conventional burnt clay hollow bricks or concrete hollow blocks in construction industry. FALGY hollow blocks are light in weight and being hollow, impart thermal insulation to the building. Kumar et al (6) through his study proposed that Falgy hollow blocks have sufficient strength for their use in general building construction. A feasibility study was undertaken on the production of fly ash-lime-gypsum (Falgy) bricks and hollow blocks by kumar et al (7) to solve problems of housing shortage and at the same time to build houses economically by utilizing industrial wastes. The compressive strength, water absorption, density and durability of these bricks and hollow blocks are investigated. He observed that these bricks and hollow blocks sufficient strength for their use in low cost housing development. Lingling et al (8) in his work replaced clay with fly ash to make fired bricks. The effect of fly ash with high replacing ratio of clay on firing parameters and properties of bricks were studied by him. The results indicated that the plasticity index of mixture of fly ash and clay decrease dramatically with increasing of replacing ratio of fly ash. The sintering temperature of bricks with high replacing ratio of fly ash was about 1000 ^{0} C, which is 50-100^0 C higher than that of clay bricks. The fired bricks with high volume ratio of fly ash were of high compressive strength, low water absorption, no cracking due to lime, any frost and high resistance to frost-melting. Hence, fly ash based bricks have been proven to be a good constructional material. The present study was aimed at developing bricks out of Fly ash with Zinc Sludge as an additive.

3. Materials and Methods

The materials used in the present study were

1. Fly ash
2. Incinerated Zinc Sludge
3. Sodium silicate
4. Calcium oxide
5. Carboxy Methyl cellulose

Fly ash is the finely divided mineral residue resulting from the combustion of ground or powdered coal in a thermal power plant. It consists of inorganic matter present in the coal that has been fused during coal combustion. Coal combustion fly ash contains primarily of silicon, aluminum, iron, and calcium oxides. The fly ash used in the present study is obtained from NTPC Visakhapatnam and its composition is as shown in the table1. It is a class C fly ash and has following properties.

Physical properties

Particle size: 100-0.5μm, specific gravity 0.6-3.0, specific surface: 3000-6000 cm^2/gm. The surface areas of India's fly ashes range between 3627 and 6091 cm^2/gm.

Crystallinity: 20% crystalline and 80% amorphous, and melting point >1400^{0}C.

Solubility: essentially insoluble. Some class C fly ashes may contain soluble sodium sulfate (1-8%). Respirable fraction: approximately 20%-40% of particles are below 7 micron in diameter.

Mineralogy: quartz, mullite, feldspar, magnetite, hematite, corundum, and hercynite.

Chemical properties

The coal burnt and the techniques used for handling and storage greatly influence the chemical properties of fly ash. Fly ash particles generally have a low thermal conductivity and are mostly chemically inert.

Table.1.Composition of fly ash

Compound	Composition (%)
SiO_2	59.96
Al_2O_3	26.15
Fe_2O_3	5.85

The zinc sludge used in the present study is obtained from Hindustan Zinc limited (HZL) of Vedanta group Visakhapatnam. Zinc sludge was calcined at 900^0C. The resulting ash was subsequently used in the preparation of bricks. The composition of the Zinc sludge was as shown in the table 2.

Table.2.Composition of Zinc ash

Compound	Composition (%)
Fe_2O_3	60
Zn based oxides	8
Pb based oxides	7
AIS (acid in soluble material)	25

The insoluble matter consists of those nonmetallic substances that do not dissolve in the mineral acid which is used to dissolve the metal. The acid-insoluble matter mostly includes silica, insoluble silicates, alumina, clays, some carbides and other refractory materials that may be introduced either as impurities in the raw material or from the furnace lining, fuel. Commercial grade of sodium silicate is used in the present study. It acts as a binding material. Na_2SiO_3 when reacts with excess $Ca(OH)_2$ permanently binds the silicates with the surface and also induces water and fire resistant properties.Calcium oxide (CaO), commonly known as quicklime is another ingredient used in the present study. It's one of the key ingredients in cement industry. It acts as a strengthening agent. Analytical grade of CaO is used in the present study.

$$CaO(s) + H_2O(l) \leftrightarrow Ca(OH)_2$$

$$\Delta H = -63.7\ kJ/mole$$

Carboxy methyl cellulose (CMC) is an organic material consisting of cellulose derivatives. One of the innovative things in the present study is CMC is used as a porosity generating material. It burns around the temperature of 300°C leaving a void in the total mass, there by generating porous objects.

4. Experimental Procedure

4.1. Preparation of the samples

Fly ash obtained from industry was sieved to obtain -150 +200 (mesh size) sample. Known quantities of materials were mixed with sufficient quantity of water. The charge was thoroughly mixed in an edge runner mill and was heated for 30 min. Different samples are prepared by varying the composition of the materials used as shown in the Fig.1.

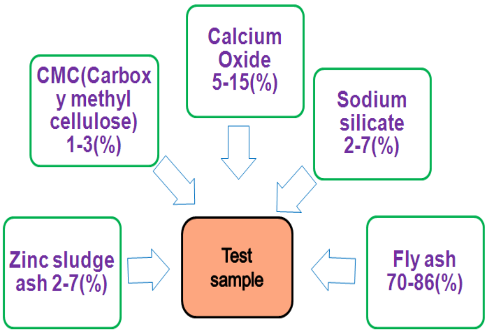


Figure.1. Composition of materials used in the present study

The mix was placed in to a mould of dimensions 8x5x5 cm and allowed for 12 hr and then released. The mould along with the brick sample is shown in the Fig.2.The bricks were dried in the open atmosphere for five days. These are called green bodies and have gained sufficient strength. These bodies were allowed to dry at 110^0C for four hours in an oven. The samples were kept in laboratory for four days. Number of samples prepared and their composition are listed in table.3.

Figure.2.Mould of dimensions 8x5x5 cm along with the brick sample.

4.2. Firing of the samples

The samples were fired in an electrically heated muffle furnace. There is no direct contact with the fuel or its products of combustion. The muffle furnace has temperature range from 0 to 1200^0 C. The samples were heated from room temperature to 100^0 C at a heating rate of 10^0 C/min from thereafter the temperature was then raised to 250^0 C at a rate of 20^0 C/min. From 250^0 C onwards, the temperature was raised to 350^0C at the rate of 10^0C/min. At the final temperature the furnace was kept for two hours. The furnace is switched off and allowed to cool over night. The samples were withdrawn from the furnace are kept ready for further study. The samples obtained are called as fired bodies and are shown in the Fig.3.

Table-3.Composition of the brick samples prepared in the present study

Brick No	Zinc (%)	CaO (%)	Na_2SiO_3 (%)	Fly Ash (%)
1.	5	5	7	83
2.	5	7	7	81
3.	5	10	7	78
4.	5	15	7	73
5.	5	5	5	85
6.	5	7	5	83
7.	5	10	5	80
8.	5	15	5	70
9.	5	7	2	86
10.	2	7	5	86
11.	7	7	7	79

Figure.3. Fired brick samples of various compositions

4.3. Characterization of bricks samples

4.3.1.Determination of Linear Shrinkage

The percentage shrinkage was calculated from the difference between measured dimensions of the green body and fired body namely length, width and height using a vernier calipers with accuracy of 0.01 mm. Percentage shrinkage in height of sample=(height of the green body-height of fired body sample)/height of the green body. Similarly shrinkage in length and breadth of the sample were computed.

4.3.2.Determination of water absorption, apparent porosity, and bulk density

These properties of the brick samples were determined using boiling water method, which is based on Archimedes principle. The step-by-step procedure involves the following steps. Weights of all dry samples were noted down with a balance of accuracy 10 mg. Samples were then taken in a vessel filled with water. It is heated and brought to boiling condition and allowed to boil for one hour and finally allowed to cool to room temperature. Weights of all samples saturated with water were measured. Using the following formulae, the properties of samples were evaluated.

Determination of Water absorption

Water absorption is defined as the ratio of weight of sample saturated with water to the weight of dry sample. The percentage of water absorption is given by eqn (1).

$$WA = \{(W-D)/D\}*100(\%) \qquad (1)$$

Determination of Bulk density

Bulk density is defined as the ratio of the mass of the material to this bulk volume and is given by eqn (2).

$$BD = D/ (W-S) \text{ g/cc} \qquad (2)$$

Determination of Apparent porosity

Apparent porosity is defined as a ratio of volume of open pores to the bulk volume of material and it is given by eqn (3).

$$AP= \{(W-D)/ (W-S)\}*100(\%) \qquad (3)$$

4.3.3.Determination of Crushing strength

The samples are tested for their strength using compression test machine (CTM) as shown in the Fig.4. The maximum load in Kg_f/cm^3 taken by the sample is indicated on the dial located on the CTM.

Figure.4.Compression testing machine

5. Results and Discussion

The bricks obtained were pale pink in color. These samples were tested for their properties as mentioned above and the effect of various parameters on bricks properties is discussed below.

5.1. Effect on Linear Shrinkage

Fig.5 presents variation linear shrinkage with percentage composition of zinc sludge at different temperatures. It can be observed that linear shrinkage decreased with increasing zinc sludge composition. The presence of zinc sludge ash has considerably affected the shrinkage resistance of the bricks. The shrinkage is less at higher temperatures. The shrinkage is minimal for the bricks fired at 900^0C. The variation of linear shrinkage is similar for calcium oxide and sodium silicate; hence the graphs are not presented. The bricks with 5% zinc sludge, 7% sodium silicate and, 7% calcium oxide when fired at 900 ^{0}C have shown good resistance to shrinkage.

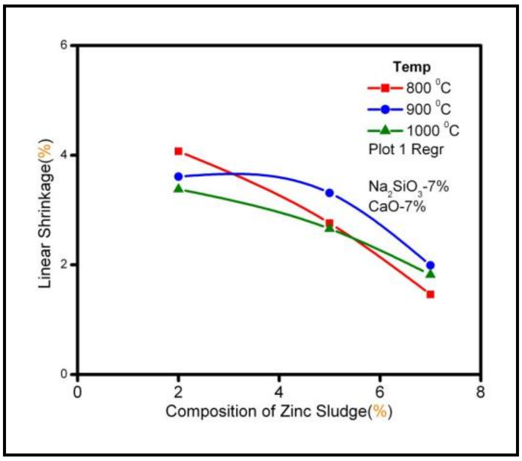


Figure.5.Variation of linear shrinkage with Zinc sludge composition at different temperatures

5.2. Effect on Water Absorption

The variation of water absorption with increasing composition of calcium oxide is as shown in the Fig.6. Water absorption is due to the pores present in the body. It can be observed that water absorption increased with increase in composition of CaO. The increase is even higher at higher temperatures. The increase is rapid up to 7% CaO beyond which addition of CaO has no influence. It suggests that 7% of CaO is sufficient for the body preparation. However, further increase in CaO offered higher strengths to the bricks. Fig.7 shows the variation of water absorption with increasing composition zinc sludge. It can be noted that water absorption increases up to 5% of zinc sludge beyond which there is slight decrease. The trend is similar at higher temperatures but of higher degree. The variation of water absorption is similar for sodium silicate.

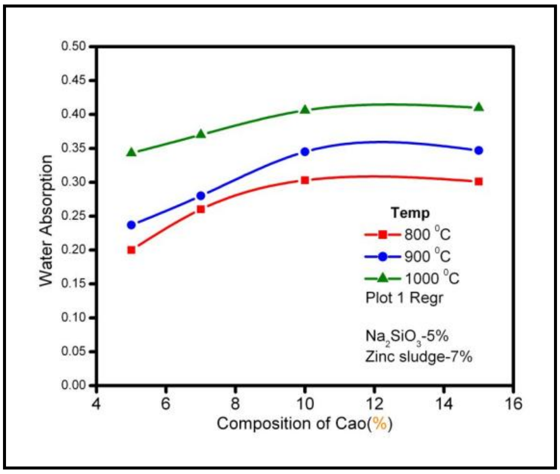


Figure.6.Variation of water absorption with calcium oxide composition at different temperatures

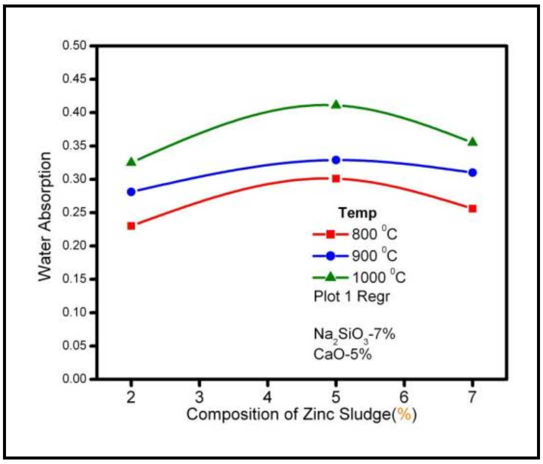


Figure.7.Variation of water absorption with zinc sludge composition at different temperatures

5.3. Effect of on Bulk Density

Variation of bulk density with compositions of CaO is presented in Fig.8. Bulk density decreases continuously with increase in CaO at 800 °C and 1000 °C. But at 900 °C it decreases to some extent then increases and then decreases. However the final value remained the same at all the temperatures. From Fig.9, it can be seen that composition of silicate did not affect the bulk density much, except at 800 0C it decreased to a minimum value. The minimum bulk density in case of zinc sludge is observed at 5% and at 800 ^{0}C can be witnessed in Fig.10.The decrease in bulk density in all the above cases may be due to the increased reactivity or maturity of the body.

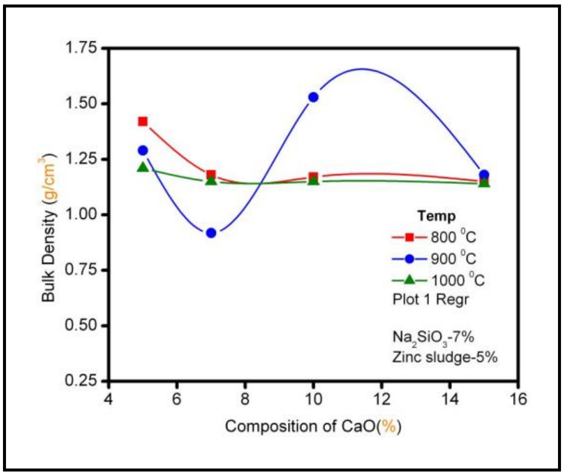


Figure.8.Variation of bulk density with composition calcium oxide at different temperatures

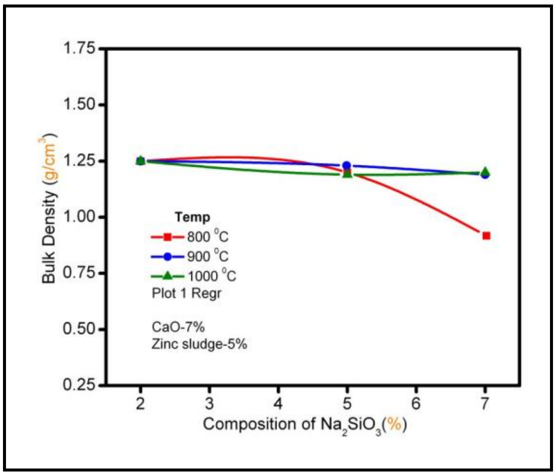
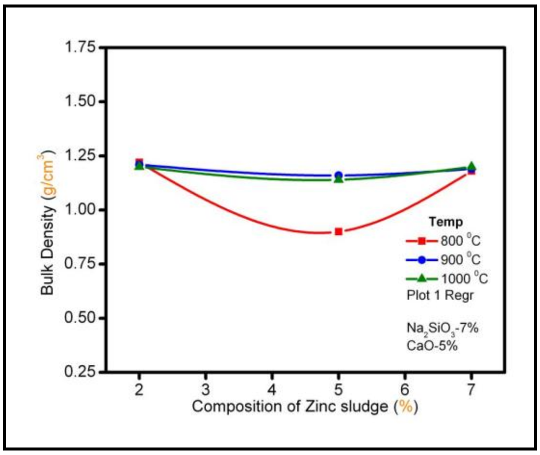


Figure.9.Variation of bulk density with sodium of silicate composition at different temperatures



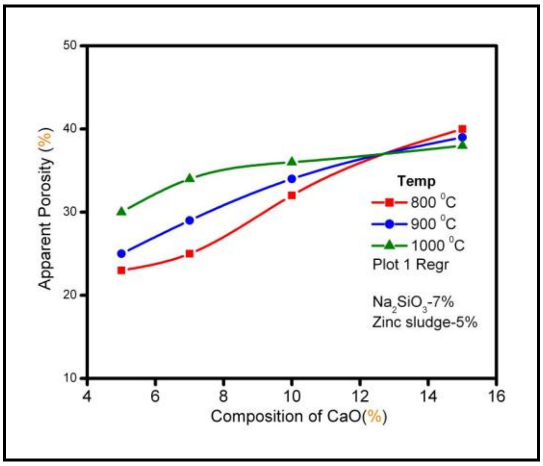
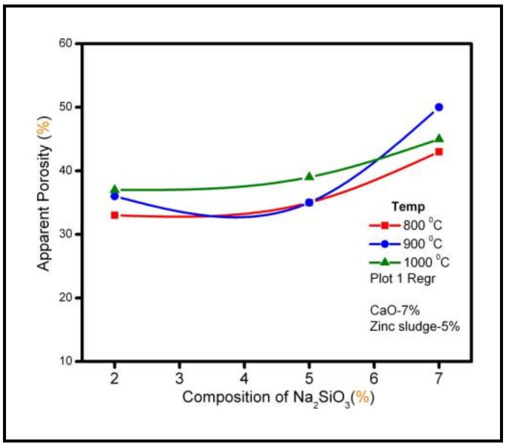


Figure.10.Variation of bulk density with Zinc sludge composition at different temperatures

Figure.11.Variation of apparent porosity with calcium oxide composition at different temperatures

5.4. Effect on Apparent Porosity

Fig.11, Fig12 and Fig13 are the graphs for apparent porosity versus CaO, Na_2SiO_3 and Zinc ash respectively. Fig.11 reveals apparent porosity increases with increase in CaO. The increase is rapid until 900 ^{0}C above which gradual increase in apparent porosity is observed. It may be due to the formation of a micro fluid consisting of $CaSiO_3$, $ZnSiO_3$, $FeSiO_3$, etc. These silicates will bring the fly ash particles together. This action results in lower values of mixed silicates resulting in higher porosity. The presence of CMC also increased porosity. Fig.12 depicts that apparent porosity increases with increase in composition of Na_2SiO_3. It may be also due to the formation of the micro fluid consisting of the silicates. Maximum porosity is obtained in case of 7% silicate and at 900 ^{0}C. Fig.13 reveals that apparent porosity increases up to 5% of zinc ash beyond which there is a decrease in apparent porosity.



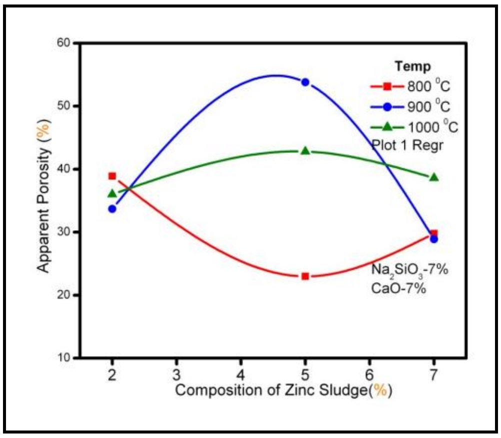


Figure.12.Variation of apparent porosity with sodium silicate composition at different temperatures

Figure.13.Variation of apparent porosity with Zinc sludge composition at different temperatures

5.5. Effect on Crushing Strength

Variation of crushing strengths with compositions of CaO, Na_2SiO_3, and zinc sludge are shown in the Fig.14, Fig.15 and Fig.16 respectively. Fig.14 reveals that crushing strength increases with increase in CaO. The increase is more rapid at higher temperatures. It can be observed that there is an considerable increase in crushing strength for the bricks fired at 900 ^{0}C. From Fig.15 it can be noted that crushing strength increases up to 5% and then decreases in case of sodium silicate. It implies that 5% of sodium silicate is enough for the body preparation. The variation of crushing strength is similar to sodium silicate in case of zinc ash as seen in Fig.16. Crushing strength increases up to 5% zinc sludge and above 5% there is a decrease in crushing strength.

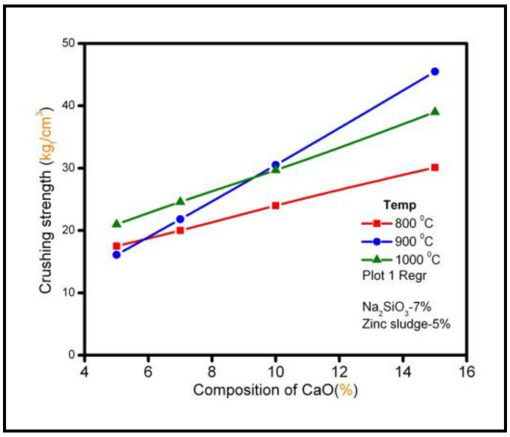


Figure.14.Variation of crushing strength with calcium oxide composition at different temperatures

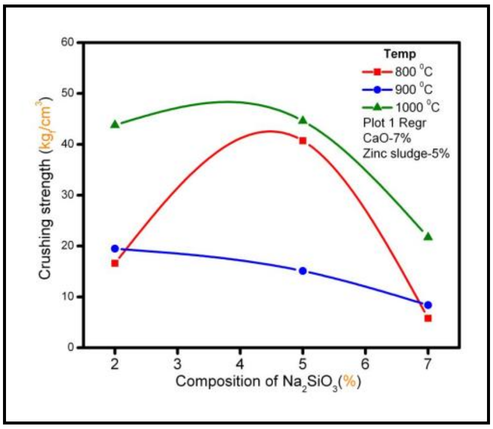


Figure.15.Variation of crushing strength with sodium silicate composition at different temperatures

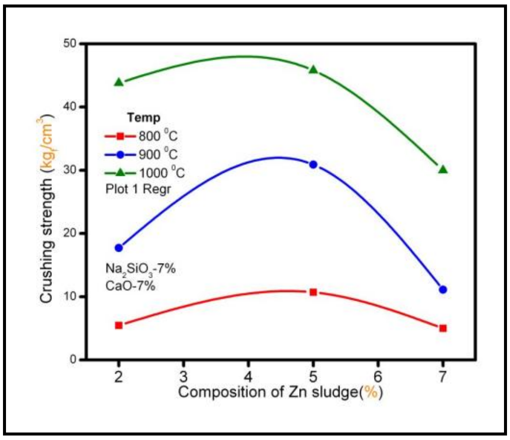
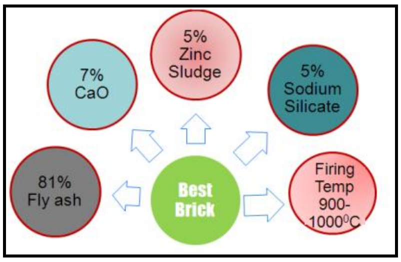


Figure.16.Variation of crushing strength with Zinc sludge composition at different temperatures

6. Recommendations

From the present study, it can recommended that the samples with the following composition yielded better properties



7. Conclusions

Zinc sludge ash could be effectively disposed by the manufacture of fly ash sodium silicate, CaO and zinc sludge bricks. The following conclusions have been derived from the present study.

1. Fly ash bricks can take up ash of zinc sludge up to 5%.
2. Bricks with 5% ash of zinc sludge yielded higher crushing strengths.
3. Sodium silicate of 5% composition yielded higher crushing strengths.
4. Greater the firing temperature greater is the crushing strength. But at 900 ^{0}C the bodies yielded sufficient strength.
5. The bodies obtained from the study are light in weight and have sufficient strength to meet the construction brick standards.

When the technologies incorporated into practice, sufficient quantities of hazardous waste would be taken into them with no damage to the environment.

Nomenclature

English	
AP	Apparent porosity(dimensionless)
BD	Bulk density(g/cm^3)
D	Dry sample(g) weight
S	Soaked weight of the sample(g)
WA	Water absorption (%)
CTM	Compression test machine

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