Use of colour adsorbed fly ash in brick manufacture

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Received 26 November 2010; accepted 27 March 2012

The fly ash, generated as a waste material at thermal power plant, has been used as an adsorbent for treating the dye effluent. The characteristics of the dye effluent before and after the treatment are studied and compared. The sludge (color adsorbed fly ash) from the sedimentation tank has been used to replace the fly ash in the manufacture of the fly ash bricks. The strength and durability properties of color adsorbed fly ash bricks are studied and compared with conventional fly ash bricks. It is found that the fly ash effectively removes the color, TDS, hardness and other toxic elements from the dye effluent and also provides a remedy to the disposal problem of fly ash. The strength of the color adsorbed fly ash brick is found to be good. One waste material is effectively used to treat the other material and the sludge is used in brick manufacturing, thus preserving the nature.

Keywords: Adsorption, Color adsorbed fly ash, Fly ash, Packed column

Dyeing is a combined process of bleaching and coloring in textile industry which generates a large quantity of effluent containing high total dissolved solids, chloride content, sulphate content, hardness and carcinogenic dye ingredients. The effluent is capable of polluting the groundwater and the soil nearby textile industries. The existing treatment methods are costlier1. Hence, it is necessary to find out an economical method for the treatment of this type of effluent. In the effluent treatment, the adsorption data follows Freundlich model2. The coal bottom ash has a good adsorption capacity. It reduces the copper, chemical oxygen demand and concentrations of various pollutants in the leachate3. In concrete the fly ash reacts like a pozzolanic material initially and later changes as a cementitious material after activation with calcium hydroxide4. The fly ash can also be used as cold bonded aggregate. With constant water content, the workability of the concrete increases with the increase in volume of cold bonded aggregate. The silica present in fly ash reacts with lime and forms calcium silicate hydrate which induces the bonding properties5. The column technique method has been found to be better to treat the dye effluent and the sludge (color adsorbed fly ash) was then used in the concrete replacing the cement in different proportions6. The properties of activated carbons are influenced by the materials used and the way of activation7. It is already proved that the fly ash can be efficiently used to remove the color from the textile dyeing and printing effluents8-9.

In this work, the colour adsorbed fly ash has been used in making bricks and the strength properties of the bricks are studied. The results are also compared with strength of the normal fly ash bricks.

Experimental Procedure

Materials

Fly ash used was finely divided fuel dust obtained from the combustion of pulverized coal in thermal power station at Mettur. Fly ash has the average composition of CaO (calcium oxide) 4.2%; SiO2 (silica) 61.3%; Al2O3 (alumina) 21.7%; Fe2O3 (ferrous oxide) 5.3%; and MgO (magnesium oxide) 0.8% by weight. Loss of ignition is 6.7%. Almost 99% of the fly ash passes through 200micron sieve. The dye effluent (not a composite) was collected from textile dyeing industries and used for the experimental study. For this experiment, naturally available river sand was used in the proportion of 3:1 (fly ash:sand) during treatment to avoid the leachate of fly ash, as it is a fine material. The fineness modulus of sand used is 2.6 and specific gravity is 2.65. The color adsorbed fly ash (CAF) was taken out from packed column and sedimentation tank in the form of sludge, dried in sunlight and then used to replace the fly ash in normal fly ash bricks. The normal fly ash brick consists of 60% of fly ash and 40% of other

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Composites. The composition of normal (conventional) fly ash brick is given in the Table 1. In this CAF brick, fly ash was replaced by colour adsorbed fly ash in the total proportions of 10, 20, 30 and 40% of ingredients. The replacement of fly ash is kept limited to 40% as minimum 20% of normal fly ash is required for the activation of lime with silica. The proportion of materials used for casting the CAF bricks is shown in Table 1.

Casting of bricks
The required quantities of constituent materials were mixed thoroughly before adding water. Water quantity (10% of the total weight of the materials) was added and clearly mixed. The wet mix was then filled in the mould and then compressed to form brick specimens of 230 × 110 × 75 mm with a pressure of 160kg/cm$^2$ as done for red clay bricks. The compressed brick was carefully removed from mould and placed under roof for 3 days. After three days the brick was kept open to sunlight and cured by using sprinkler method for minimum of 15 days.

Methods
Sedimentation Tank
Sedimentation tank was designed for the capacity of 50 L/h with a detention period of 3h. The dimension of the tank was 0.95m × 0.45m × 0.45m. Before mixing of fly ash with the dye effluent, optimum dosage of ingredients in the mix was obtained as per following procedure.

Optimization method
In the spectrophotometer test, the rate of absorbance of passing light waves is directly proportional to the reduction in the optical density of solution. This test was conducted to obtain the optimum value of parameters like pH of dye effluent, amount of dye in synthetic sample, dosage of fly ash and settlement time (retention time), as at these values the absorbance is maximum. The reduction in the optical density (absorbance) is not proportional and non-linear as it depends on these four parameters instead of single parameter. Synthetic sample was used as used in textile industries. Different combinations of these parameters were analyzed. The effective combination of parameters was attained by following optimization technique in four steps. In first step, amount of dye effluent, amount of fly ash and retention time were kept constant and then pH value was changed continuously to obtain optimal value at which the reduction of optical density was maximum. In the second step, the first parameter (pH value), third parameter (amount of fly ash) and fourth parameter (retention time) were kept constant and the second parameter (the amount of dye) was kept varying to obtain optimal value. This procedure was continued for fixing third and fourth parameters. It was found that the maximum reduction in optical density of the color water was obtained at the pH value of 8. This value may be taken as the optimum pH for better adsorption. It required 20g of fly ash for 1000mL of color water containing 10g of dye dissolved in it. The duration required for settlement was found as 180min. More percentage of reduction in optical density indicates more absorbance. These values can be proportioned accordingly for the required quantity of dye effluent and its concentration. For treating 50L of dye effluent containing 500g of dye, it required 1kg of fly ash. This volume of dye effluent was taken and the fly ash was added in it, stirred well and then allowed to settle down for a period of 3h. After the settlement, the reacted water was taken out for the tests for the standards.

The color adsorbed fly ash in the form of sludge settled in the tank was removed using slurry pump and then dried for direct use in brick.

Tests on dye effluent and bricks
The chemical characteristics tests such as, pH, total dissolved solids, suspended solids, chlorides, sulphate, COD and bio-chemical oxygen demand (BOD) tests were conducted on both raw dye effluent and treated

<table>
<thead>
<tr>
<th>Composition of bricks</th>
<th>Conventional (normal) fly ash brick, %</th>
<th>Brick A (10% CAF)</th>
<th>Brick B (20% CAF)</th>
<th>Brick D (30% CAF)</th>
<th>Brick F (40% CAF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>CAF</td>
<td>Nil</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Lime</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Sand</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Quarry dust</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Gypsum</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
dye effluent. The optical density of raw and treated dye effluent samples was measured on a spectrophotometer to find out the extent of colour removal.

Water adsorption, compressive strength and durability tests on normal fly ash bricks and 10, 20, 30 & 40% color adsorbed fly ash bricks specimens were carried out. In durability tests, for acid attack, 3% dilute sulphuric acid of 1N (H₂SO₄) with pH of about 2 was used. For chloride attack, 3.5% sodium chloride of 1N (NaCl) with pH value of about 2 was used. For alkaline test, 3% (w/w) sodium hydroxide (NaOH) solution was used.

In durability tests, brick specimens were immersed in above solutions for a period of 90 days. The concentration of the solution as above was maintained throughout this period. After 90 days, the specimens were taken out, surfaces were cleaned and weights of the specimens were taken. The compressive strength and weight loss or weight gain of these specimens were obtained.

The rapid chloride penetration test (RCPT) was performed to study electrical conductance of bricks using the ASTM C 1202 standard. The test was performed on the conventional fly ash brick and 40% of CAF brick at the age of 28 days curing and to provide a rapid indication of its resistance to the penetration of chloride ions as a quality control measure. The test method consists of monitoring the amount of electrical current passed through 51mm thick slices of 102 mm nominal diameter of cylindrical specimens for duration of 6h. Direct current across the specimen was recorded at 30min interval for the duration of 6h.

The total charge passed during this period was calculated in terms of coulombs using the trapezoidal rule given in the ASTM C 1202, as shown below:

\[
Q = 900(I_0 + 2I_{30} + 2I_{60} + ... + 2I_t + .... + 2I_{330} + I_{360})
\]

where \(Q\) is the charge passed (coulumb); \(I_0\), the current (ampere) immediately after voltage is applied; and \(I_t\), the current (ampere) at ‘t’ min after voltage is applied.

The brick quality (degree of chloride ion penetrability) can be assessed based on the limits as given in ASTM C 1202. As per this standard, chloride ion penetrability results based on the current passed are given in Table 2.

### Results and Discussion

#### Test results on dye effluent

The chemical characteristics comparison of untreated and treated samples are given in Table 3. It is observed that \(\text{pH}\) reduces by 8 - 7.2. The dissolved solid content is reduced by 16%, suspended solids by 50%, chlorides level by 20%, COD by 13.3% and sulphate by about 50%. In spectrophotometer test at the wavelength of 620nm, in untreated effluent, color absorbance was maximum. In treated effluent, there is no colour absorbance as there is no colour for the removal. The reduction in optical density i.e. the absorbance of colour, is shown in the Fig. 1. Hence, by using the fly ash as adsorbent colour is totally removed and also the work load is reduced to half for further treatment of dye effluent by suitable method for the removal of salts up to the standard level.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Untreated sample</th>
<th>Treated sample</th>
<th>WHO standards for disposal into fresh water sources</th>
<th>Disposal into inland surface waters (IS:2490;1974)</th>
<th>% Reduction after treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD, ppm</td>
<td>74</td>
<td>25</td>
<td>30</td>
<td>30</td>
<td>66.21</td>
</tr>
<tr>
<td>COD, ppm</td>
<td>1200</td>
<td>160</td>
<td>250</td>
<td>250</td>
<td>65</td>
</tr>
<tr>
<td>Chlorides, ppm</td>
<td>3125</td>
<td>2500</td>
<td>1000</td>
<td>1000</td>
<td>20</td>
</tr>
<tr>
<td>Colour, ppm</td>
<td>Dark blue</td>
<td>Colourless</td>
<td>Colourless</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dissolved solids, ppm</td>
<td>6000</td>
<td>5000</td>
<td>2100</td>
<td>2100</td>
<td>16.67</td>
</tr>
<tr>
<td>Hardness, ppm</td>
<td>5625</td>
<td>4875</td>
<td>200</td>
<td>-</td>
<td>13.33</td>
</tr>
<tr>
<td>(\text{pH}), ppm</td>
<td>8</td>
<td>7.2</td>
<td>5.5 – 8.5</td>
<td>5.5-9.0</td>
<td>–</td>
</tr>
<tr>
<td>Suspended solids, ppm</td>
<td>2000</td>
<td>1000</td>
<td>100</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Sulphate, ppm</td>
<td>165</td>
<td>82</td>
<td>1000</td>
<td>1000</td>
<td>50.30</td>
</tr>
<tr>
<td>Total solid</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>25</td>
</tr>
</tbody>
</table>

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Table 3—Chemical characteristics comparison of untreated and treated samples

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Hence one waste material i.e. fly ash can be used to reduce the pollution load of dye effluent and this waste can further be used in brick making.

Test results on brick

Water absorption test results

The findings reveal that the mean percentage of water absorption for conventional fly ash brick is 3.64, for 10% CAF brick it is 3.38, for 20% CAF brick it is 2.96, for 30% CAF brick it is 2.79 and for 40% CAF brick it is 3.10. It is observed that in the brick with CAF ash, the water absorption is reduced by more than 50% comparing with that of the conventional fly ash bricks. This may be due to the reduction in porosity of bricks.

Compressive strength test results

The compressive strengths of normal fly ash bricks, 10% CAF bricks, 20% CAF bricks, 30% CAF bricks and 40% CAF bricks are 7.25, 6.93, 6.81, 6.62 and 6.35N/mm² respectively. It is found that the compressive strength of CAF ash bricks decreases with the increase in CAF content. However, the compressive strength of CAF ash bricks is found to be well above the standard strength level of normal clay bricks (3.5-5.0N/mm²). Hence, the fly ash can be used for treating the effluent and then the sludge waste (CAF ash) obtained can be used for brick manufacturing.

Durability test results

After 90 days immersion in acid, chloride and alkaline, the compressive strength is found to be not much affected as compared to that of the normal fly ash bricks. The compressive strengths of normal fly ash bricks, 10% CAF bricks, 20% CAF bricks, 30% CAF bricks and 40% CAF bricks are 6.2, 6.12, 5.95, 5.70 and 5.67 N/mm² and their percentage of weight loss is 20.95, 18.75, 17.98, 17.15 and 16.98 respectively. The compressive strengths of these bricks after immersion in chloride solution are 6.57, 6.32, 6.13, 6.02 and 5.97N/mm² and their percentage of weight gain is 17.33, 17.98, 18.90, 20.84 and 21.61 respectively. The compressive strengths of these bricks after immersion in alkaline solution are 7.03, 6.64, 6.52, 6.32 and 6.12N/mm² and their percentage of weight gain is 18.82, 19.21, 19.96, 20.84 and 22.64 respectively. The compressive strength of all bricks, after immersion in these solutions, is more than the standard value of 5N/mm². There is more loss of weight in normal fly ash bricks than that in CAF bricks for acid immersion, while the gain in weight of CAF bricks in chloride and alkaline is almost same as in normal fly ash bricks.

RCPT and chloride ions penetrability characteristics

RCPT test was carried out for normal fly ash bricks and 40% CAF bricks. The quality of brick can be assessed on the basis of chloride penetrability. If the average chloride penetrability is moderate i.e. from 2000 to 4000 coloumb, then quality of specimen is taken as well.

The current penetrability values in coloumb for 40% CAF bricks and normal fly ash bricks are given in Table 4.
For 40% CAF bricks
Q₁ = 3620.7 coloumb
Chloride ion penetrability = Moderate

For normal fly ash bricks
Q₂ = 6799.5 coloumb
Chloride ion penetrability = High

In RCPT test, the percentage of gain in weight for conventional fly ash brick is 2.60 and for 40% CAF brick it is 1.65. Chloride ion penetrability and gain in weight show that the chloride penetration for conventional fly ash brick was more than that of the 40% CAF brick due to loss of porosity in the CAF bricks. The value of current in amperes is increased with time due to the penetration of chloride ion in normal fly ash bricks. The chloride ion reduces the resistance of brick. For 40% of CAF bricks the chloride ion penetrability is less, as compared to normal fly ash bricks. This is due to the increase in impermeability resulting from incoming extraneous species.

Conclusion
For treating 50L of dye effluent containing 500g of dye in it, 1kg of fly ash is required. This experimental study reveals efficacy of fly ash in the removal of color, TDS, hardness and other toxic elements from the dye effluent and also providing a remedy to the disposal problem of fly ash after the dye treatment. In this methodology, even though the dye effluents are not treated fully, the dye effluent’s pollutant concentration is found to decrease. The strength of the color adsorbed fly ash brick also is found to be good. Here, one waste material is effectively used to treat the other material and disposing of sludge after effective treatment is solved by utilizing adsorbed fly ash in brick in an effective way. As a net result, environment and energy can be preserved.

References