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Glazed Sludge Tile

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ABSTRACT
In this article, glaze with different colorants was applied to tile specimens manufactured by incinerated sewage sludge ash (ISSA) and Clay. Improvements using different amounts of colorants, and glaze components and concentrations on tile bodies were investigated. Three different proportions of clay (by weight ratio) were replaced by ISSA. Tiles of size 10cm *10cm*1 cm were made and left in an electric furnace to make biscuit tiles at 800°C. Afterwards, four colorants, Fe_2O_3 (red), V_2O_5 (yellow), and $CoCO_3$ (blue) and three different glaze concentrations were applied on biscuit tile specimens. These specimens were later sintered into glazed tiles at 1050°C. The study shows that replacement of clay by sludge ash had adverse effects on properties of tiles. Water absorption increased and bending strength reduced with increased amounts of sludge ash. However, both water absorption and bending strength improved for glazed ash tiles. Abrasion of grazed tiles reduced noticeably from 0.001 to 0.002 g. This implies glaze can enhance abrasion resistance of tiles.

I. INTRODUCTION

Since Chennai city is extending its zones for the growth of heavy population, the government in Tamil Nadu has been very positive in the construction of sanitary sewer and wastewater treatment plants. With this increases in house connections, the amounts of wastewater and sewage sludge will likely increase as well. It is becoming harder to find land to be used as sanitary landfill for dry sludge cakes in Chennai city. As a result, how to efficiently reclaim from sewage sludge is important, the sewage is incinerated which reduces its volume building bricks are also manufactured by mixing dry sewage sludge with clay comprising 30-40% of dry sludge seen as the optimum amount. The properties such as bending strength and abrasion of ash bricks met the standards and properties of sludge bricks were found to be way below average [1]. Using sewage sludge as construction materials are commonly seen in research. However, high-priced tiles manufactured by sewage sludge and clay were studied less. Bio-solid ash was used to make tiles which showed water absorption and bending strength met the requirements of standard specifications. But when different amounts of ISSA (incinerated sewage sludge ash) were added to clay to manufacture biscuit tiles, shortcomings such as higher water absorption, abrasion, and excessive pores were noticed [2]. In order to solve such shortcomings, we mix ISSA with clay to make glazed tiles. Results indicated that application of glaze to biscuit tiles could improve drawbacks such as water absorption and abrasion. It also slightly increased the bending strength of tiles. In addition, bending strengths of tiles with various amounts of ash added when sintered at same temperature also proved good. When glazes were applied on the surface of ash tiles, a hard dense impermeable layer formed after being fired in a kiln at high temperature. This layer provided glazed ash tiles with better resistance in physical and chemical erosions. Moreover glaze with application of different colorants potentially make ash tile more colorful and meet specific requirements for tile usages. Hence, glaze not only improves beauty and increases the economic value of ash tiles, but also improves the extent and uses for reclamation of sewage sludge. In this study, improvements on the appearances and properties of biscuit ash tiles through applications of different colorants are investigated.

II. METHODS AND MATERIALS

2.1 Materials:

2.1.1 ISSA, Clay with sludge ash:

Dewatered sewage sludge samples were obtained from a local municipal wastewater treatment plant. These samples are dried at room temperature and incinerated at kiln at 800°C.Incinerated sludge ash passing 200mm sieve was collected and properties such as unit weight (2.71 g/cm3), specific weight (2.67), specific surface area (4860 cm2/g), and pH values (5.97–6.02) were obtained. The specific weight (2.52) and specific surface area (5398 cm2/g) of clay were also determined. The plasticity index of clay, which is decided by the Atterberg

Fig.1 Wet Sludge collected from STP (sewage treatment plant)

Limits test, was 19.11 and reduced to 16.94 when 30% of ash was mixed with clay. This indicated that ash can lower the plasticity of mixture. Further, both chemical components of clay and ISSA are shown in Table.1.

Table.1 Colorant components result in tile materials

Colorants Components	Clay	Sludge ash	Clay with 30%sludge ash added
Al	17.54	21.3	21.81
Si	38.64	14.35	28.56
O	38.64	30.1	24.47
Fe	8.16	22.26	13.48
Na	0.67	6.45	2.75
Ca	0.76	1.01	1.49
Mg	1.53	3.29	4.76
K	4.41	--	2.69

As seen in the table, thequantities of each component in ISSA were more than those in clay, with the exceptions of Si.

2.2 Methodology

In this study, three different proportions of ash, 0%, 30% and 45% were prepared for mixing with clay. The optimum amount of water for air in the mixture was expelled using a De-airing vacuum pug mill to knead the mixture for about 16 min and then pressed by a pressing machine with an averaged vertical pressure of 300 kg/cm^2 to make strips with a thickness of 1 cm. Tiles of size 10 cm x 10 cm x 1 cm were made then, tile specimens were left in an electric furnace to make biscuit tiles at 800°C. Temperatures in the furnace were raised at a rate of 2 °C/min before reaching 800°C and at 1°C/min thereafter. A sintering temperature of 1050°C is to be obtained. When temperature is higher than 1000°C, pure clay tile body has a better bending strength; and when temperature is more than 1100°C, melting phenomenon was observed for tiles with 30% ash added and large strains in tiles were noticed when 45% ash was added. The wet glaze can easily, uniformly, and effectively sinter into the surface of ash tiles at 1050°C. Besides temperature, the choice of glaze is another controlled experimental variable. In this study, glaze was formulated by mixing base glaze together with different glaze colorants. Four different glaze concentrations of 0, 0.03, 0.06, and 0.1 g/cm2 were applied on biscuit ash tiles. In order to investigate the influences of different glaze colorants on properties of ash tiles, four glaze colorants with different amounts (in percentage) were applied: 2% of iron oxide Fe_2O_3 (red colorant), 6% of vanadium oxide V_2O_5 (yellow colorant) and 0.5% of cobalt carbonate $CoCO_3$ (blue colorant). A series of tests and inspections such as appearance and dimensions, shrinkage measurement, water absorption test, weight loss on ignition test, bending resistance, abrasion resistance, and acid–alkali resistance tests were performed to determine properties of glazed ash tiles.

III. RESULTS AND DISCUSSION

3.1 Penetration test

To help investigate the effects of ash replacement on water when used in making a mixture of ash clay paste, penetration tests were performed on specimens of mixture (150 mm in height) with 0% and 30% ash added. If the amount of water applied was higher than 45%, liquefied phenomena were noticed in the mixtures and 150 mm of penetration depth was easily reached. The depth of penetration for the mixture with 30% ash added was less when the same amount of water was used. This implies that the replacement of ash could reduce the plasticity of mixture and lead specimens to a semi-solid state.

3.2 Tile water absorption

Water absorption is used to estimate the pore ratio of tile specimens. High water absorption in tile is characterized by a high pore ratio. The water absorption of tile earthenware should be less than 16%. Water absorption of tiles increased by about 3–4% with the addition of ash, However, glaze formed a thin film, which helped protect the surface and reduce water absorption of ash tiles. The water absorption for 30% ash tile specimens was 13% before glaze was applied, and became less than 10% with the application of glaze. It also indicates that water absorption decreased with the increase of glaze concentration application. Furthermore, all glaze colors tested helped reduce more than 2–3% of water absorption. Performances of different colors were closely related to components of glaze as well as degrees of crystallization during the firing process.

3.3 Warp measurement

Since, shrinking force increased with glaze thickness in per unit area, the increment of warpage of specimens became larger with higher glaze concentration. The red glazed tile had the least increment. The addition of ash also increased the warpage of tiles and the amounts increased ranged from 0.3 to 1.0 mm. Therefore, ash can improve the melting property of tile bodies. This melting crystallization can even make tiles denser. These phenomena of warpage became more noticeable as greater amounts of ash were added.

3.4 Abrasion of tile surface

The durability and hardness of tiles are determined by abrasion, which is influenced by daily human activities. Abrasion types such as drag motion, friction, and impact are commonly seen in daily life. Hence, requirements for tile abrasion are decided by locations and frequencies of different activities. The abrasion of tile earthenware should be less than 0.1 g. The abrasion of tile with 30% ash added was twice that of the controlled group (clay tile with no glaze).This indicates that simply replacing part of the clay with ash in tiles was insufficient for resisting abrasion and weathering process. After application of different glazes on ash tiles, abrasion resistance of tiles improved about 10–20 times more than ash tiles without glaze applied. This result matched closely to tiles with glaze applied in the controlled group. It can be seen that application of glazes to ash tiles was important in abrasion resistance. Further, different glaze colors had similar effects on abrasion resistance, even though the red color was slightly better.

3.5 Tile weight loss on ignition

Weight loss on ignition is to measure the weight differences in tile specimens before and after firing. As stated before, sewage sludge was incinerated at about 800°C before applying it to manufacture tiles. In this manner, organic materials in sludge samples were burnt away. The only source of organic materials came from the clay used in making ash tiles. Hence, weight loss on ignition reduced with an increase in amount of ash added, and the amount reduced was about 2–3%. Further, glaze concentrations had a slight influence on weight loss on ignition. This was due to glaze composed of high-temperature oxides such as SiO_2 and Al_2O_3. Most oxides in glaze can be burnt, but not incinerated at 1050°C. The reduction in weight loss on ignition caused by glaze is about 0.3–0.5%, and rose with the increase of glaze concentrations. In addition, differences in the reduction of weight loss on ignition among various glaze colors are little, about 0.05–0.1%. This indicates that different colorants have a very small effect on weight loss on ignition.

3.6 Bending strength of tile

Bending strength is affected by the pore distributions and the vitrification level of the tile body. Different bending strengths of tiles are listed in regulations according to the location and frequency of application. For example, bending strengths of wall tile earthenware ranges from 60 to 100 kgf/cm^2 and 100 kgf/cm^2 for floor tile earthenware. Theoretically, if glazes were applied to tiles, bending strength would reduce with increased thickness. However, bending strengths of glazed tiles improved to about 5–10 (kgf/cm^2). Glazes melted tightly into tile bodies in the sintering process at high temperatures. After crystallizations were rearranged, melted glazes formed a hard layer on the surfaces of tile, which could improve the bending strength of tiles. By comparing the effects of different glaze colors on bending strength, red glaze gives a better performance. Since, red colorant contains iron oxide, which could lower sintering temperature, interface adhesion between red glaze and tile bodies improved most. Hence, its bending strength increased. Therefore, the bending strengths of tiles with ash added were less than tiles without ash added.

3.7 Acid–alkali resistance of tiles

Tiles are easily eroded by activated chemical solutions such as grease and detergent. The object of acid–alkali resistance test is to examine any discoloring or other abnormal reactions that occurred to the surface of glazed tile. Na, one of the glaze components, dissolves in acid easily, possibly leading to discoloring of the glazed surface. Applying concentration equivalent to or less than 0.03 g/cm^2 causes the glazed surface of tiles to fail in acid–alkali resistance tests. This was due to the effect of Na. A higher concentration of glaze was needed for tiles to show better performance in acid–alkali resistance tests. At 0.06 g/cm^2, all yellow glazed tile specimens performed well in acid–alkali resistance tests, implying that vanadium oxide in the yellow colorant was better in resisting acid–alkali.

3.8 Break Strength:

Tiles used on floors and walls must be able to withstand the expected load bearing capacity of various installations. In order to determine the strength and durability of the tile, a standard test method is used to evaluate individual pieces. A force is applied to an unsupported portion of the tile specimen until the breakage occurs. The ultimate breaking strength is then recorded in pounds per square inch. Final selection of the tile should be based upon the breaking strength and the appropriate installation method.

3.9 Coefficient of Friction:

Tiles used on commercial and residential floors should provide a safe walking surface in wet and dry conditions. By measuring the coefficient of friction, a quantitative number can be determined. To determine this, a 50 pound weight is placed on a neolith heel and is pulled across the surface both wet and dry. The maximum amount of force (pounds) needed to initiate the weight is then recorded. This measurement is divided by the amount of weight (50lbs.) and referred to as the static coefficient of friction value.

3.10Tile durability:

P.E.I. Wear Rating System – To help select suitable tiles for specific applications tiles are rated theP.E.I. (Porcelain Enamel Institute) scale. The tiles are evaluated for wear resistance on a scale from 1 (lowest) to 5 (highest).

- **P.E.I. 1** - Tiles suitable only for residential bathrooms where softer footwear is worn.
- **P.E.I. 2-** Tiles suited general residential traffic, except kitchens, entrance halls, and other areassubjected to continuous heavy use.
- **P.E.I. 3 -** Tiles suited for all residential and light commercial interiors such as offices, receptionareas and boutiques.
- **P.E.I. 4 -** Suited for all residential interiors and moderate traffic commercial applications.
- **P.E.I. 5 -**Group V Recommended for all interior residential and commercial uses.Our**glazed sludge tile** comes under the category of **P.E.I. 3.**

IV. CONCLUSIONS

In this study, results obtained on the basis of experimental data are directed towards comparing various amount of ISSA added to the tile body, as well as different colorants and quantities of glaze concentration applied to the surface of biscuit tile bodies. The results are summarized as follows:

1. Test results indicate that glaze formed a thin film that could protect the surface and reduce water absorption in ash tiles. They also show that water absorption decreased with an increase in glaze concentration applied. However, different colorants had very small effects on weight loss on ignition.
2. Comparison of the effects of different glaze colors on bending strength showed that red glaze gave a better performance. Since red colorant contains iron oxide thereby lowering the sintering temperature, interface adhesion between red glaze and tile bodies improved most. As a result, bending strength also increased.
3. In this study, red glazed ash tiles were most stable in ageing resistance tests, followed by blue, yellow. With the help of iron oxide, red glaze makes glaze crystallization better. A more excellent light fastness of ash tiles surfaces was produced.
4. Applying a concentration of less than or equal to 0.03 g/cm2 caused the glazed surface of ash tiles to fail in the acid–alkali resistance tests due to the effect of Na. A higher glaze concentration was needed for ash tiles to show better performance in acid–alkali resistance tests. At 0.06 g/cm2, all yellow glazed ash tiles specimens performed well in acid–alkali resistance tests, which imply that vanadium oxide in yellow colorant was better in resisting acid–alkali.

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