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Investigation on Mechanical properties of Geopolymer Concrete Floor Tiles

E.Prabakaran[1]*, J. ShriIndhu[2], Dr. A. Vijayakumar[3], D. Gokila[4]

[1, 2&4]Department of Civil Engineering, KPR Institute of Engineering & Technology, Coimbatore, India
[3]Department of Civil Engineering, GMR Institute of Technology, Razam (A.P) , India

Abstract : The concrete world needs to be update day by day to control the emission provided by cement industries. In addition, the building material sector needs different kind of material for both interior and exterior with good durability and ease of availability. Geopolymer concrete which an alternative for the concrete for both structural and nonstructural applications which is having a better character of durability and strength parameters. In this paper, the geopolymer tiles with partial replacement of fly ash for a floor tiles with 300mm x 300mm has been discussed for the mechanical and physical properties as per Indian standards. Adding of alkaline solution strength of the geopolymer concrete tiles in Modulus of rupture (MOR) has been improved with the curing temperature. It also shows 1.69 times more strength when compared to the normal concrete tiles. Water absorption and compression strength shows better results as per IS code requirements.
Keywords : Building materials, Geopolymer, Tiles, Alkaline, Durability.

Introduction:

Infrastructure developments become an essential one for the growing country like India. In this scenario, the development of building materials like bricks, blocks and other materials like tile and partition panels were also play role in construction industries. To produce new building material with low cost and maximum durability is a challenge now days. To ensure the sustainability in the society, need of utilization of industrial by products in large manner being an important one. Many researchers using SCM (Supplementary cementitious material to produce the building materials and concrete as a partial replacement for concrete. This may concern with reduce the cement usage by means of ensuring the sustainability values. Geopolymer concrete is a new version of material which is used for replacement for conventional concrete. It's the polymer bonded material which is a product from non-carbon and aluminosilicate reaction with alkali hydroxide or silicate solutions [(7) (28)]. Mean time it ensures the durability and also sustainability by reducing the greenhouse gas emission [(11)]. The material selection and preparation of specimens may vary the properties of strength, setting time, curing temperature and period, acid resistance and varies characters of the specimen [(9)].

Building material like tile has advantage in aesthetic view and performance based utilization. These can be made from clay in early days and it improved in a way of different material like glass & fiber added materials. In this, the use of floor tiles becomes similar in all cases of materials and they have to satisfy the common conditions. In manufacturing process, the cost plays a major role. When using the floor tile in normal condition and for an economically weaker section group society, the cost and local available material utilization improves the sustainability among the society.

Geopolymer made with partial replacement or complete replacement level of cement may control the cost of the production. It may also improve the durability properties [(28)]. The building material like flooring tile has been taken in this study, which give a way to new market for the building material sector and producers of waste from energy.

Fig . 1 Casting of the specimen

Fig 2 Specimen after curing

Fig 3 Specimen after Flexural strength

Experimental method:

Materials Used: OPC 33 grade were used to make conventional concrete tile to compare with geopolymer tile. Fly ash, which is used to produce the geopolymer drawn from Mettur thermal power plant, Tamilnadu, India, has been taken and the chemical properties of the fly ash tabulated in Table 1. The fine aggregate from river sand and coarse aggregate with 10mm were to be taken for specimen casing. Solutions of Sodium silicate and sodium hydroxide with 12M were used as alkali activators.

Table 1 Chemical Analysis of Mettur Thermal Power Plant Flyash Sample

Sl.No	Constiutent	Concentration%
1.	Silicon di oxide (SiO2)	56.01
2.	Aluminum oxide(Al2O3)	11.1
3.	Ferric Oxide (R2O3)	3.58
4.	Calcium oxide (CaO)	2.36
5.	Titanium oxide(TiO2)	1.75
6.	Potassium oxide(K2O)	0.73
7.	Sodium oxide(Na2O3)	0.61
8.	Phosphorous oxide(P2O5)	0.44
9.	Magnesium oxide (MgO)	0.30
10.	Loss on ignescent	0.40

Preparation of solution: Sodium hydroxide and sodium silicate solution which is used as alkaline solution to make the specimens. Sodium hydroxide and sodium silicate solution prepared for 12M value with normal tap water which is available in laboratory. The solutions were prepared a day before of casting.

Mix proportion of concrete: From the conditions provided by anuradha et.al, the mix proportions for geopolymer were calculated and the proportion of geopolymer presented in table 2. The ratio between Sodium hydroxide to sodium silicate is 1:2.5. The normal concrete mix proportion was calculated for M20 as per the guidelines of IS10262-2009 and the proportions were presented in table 2.

Table 2 Mix Design:

Type of Concrete	Sodium Hydroxide kg/m^3	Sodium Silicate kg/m^3	Water kg/m^3	Cement kg/m^3	Fly ash kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3
Normal	-	-	191.61	383	-	546	1187
Geopolymer	95.86	239.64	16.5	191	225	600	838.3

Casting of specimens: The tiles with 300*300*10mm were casted with normal concrete and geopolymer concrete. Generally, the tile having minimum thickness does not need compaction and the surface has been smoothened by travel only. For normal concrete, the specimen was casted before setting and in geopolymer concrete; the specimen was casted immediately to avoid the porosity formation.

Curing: Normal concrete cube and tile were allowed to cure in water tank for 28 days and for geopolymer concrete tile, the curing taken place after a day of placing concrete with hot air oven at 60^oC for 24 hours which provides more strength compare to other methods [(5)].

Experimental results and discussion:

The tile specimens were casted for the size of 300mm*300mm and they were tested as per IS1237:2012. In the experimentation the ISO10545 & IS1237:2012 were considered. A good tile should possess the water absorption, modulus of rupture, flatness, perpendicularity, abrasion, acid resistance and straightness. In this paper all the test results were given except acid resistance and abrasion character.

Water absorption: In water absorption, the geopolymer concrete tile produces maximum absorption compare to conventional concrete tiles (From Table 3) due to the presence of porosity in the geopolymer was by the length of time increased, the mixture was left in slurry form before being placed in an oven to harden. As per ISO10545 – 3 the water absorption of floor tile should be within 3%-6% which has been satisfy the both concrete and geopolymer tile. Water absorption of normal concrete tile is 1.520 % while water absorption for geopolymer concrete tile is 2.88 % which may able to change with the % of replacement taken in place.

Table 3 Water Absorption test

Sample	Saturated Weight (g) (W_1)	Dry Weight (g) (W_2)	Water absorption (%) $\{(W_1-W_2)/W_2\} \times 100$
Normal concrete tile	220.30	217.00	1.520
Geopolymer Concrete Tile	140	136.63	2.88

Perpendicularity: As per IS1237-2012 annexure C the right angle between two lines made from the two adjacent tiles were ensured and there was no gap between arm of the square frame and the edge to the tiles were observed which ensures the codal provisions.

Flatness: A metal ruler with length greater than the diagonal of tile used to check the flatness of tile. In the specimen, there is no concavity or convexity found above 1mm and ensures the flatness as per IS1237:2012 annexure B.

Straightness: The straightness test been carried out based on the procedure which is given in Annexure D (IS 1237: 2012). A fine thread, which is used to find the straightness of the tile. The two corners of tiles connected with a fine thread along the one of the tile edges and the largest gap between the thread and the plane value recorded. The test repeated alongside each of the other edges also. The gap between the thread and the plane of the tile does not exceed 1 percent of the length of the edge of the tile.

Compressive strength: The strength character of concrete can be attaining through its curing period and the hydration process takes in place. In geopolymer concrete, the polymer bond has been created through the Si and O molecules, when the hydroxide has been deboned. This may be taken with the early age only and it increased with little manner about 2-5% in later ages. In this investigation, the strength has been attaining with 1.36times higher than the geopolymer concrete tile (From Table 4). However, it is the minimum value of cement (50%) produces the nearer strength value of concrete tile. The polymer bonding taken place in early age with minimum water content in hot air oven influence the strength parameter.

Table 4 Compressive Strength

Sample	Load (kN)	Stress (N/mm^2)
Normal concrete tile	1642.00	41.05
Geopolymer concrete tile	1200	120

Table 5: Flexural Strength

S. No	Specimen	Type of fracture	Ultimate load(kN)	Transverse strength (N/mm2)
1	Normal mix	Brittle	3.0	132
2	Geopolymer Concrete tile	Brittle	6.4	224

Flexural Strength: Generally, the tiles need maximum flexural behavior when it lay in flooring. In geopolymer concrete, it provides maximum flexure (1.69 times) to maintain its stability against the load application. As per ISO10545-4 the flexural strength should be >22MPa, has been attain in both concrete and geopolymer tile. Flexural strength of normal concrete tile is 132 N/mm^2 at 3.1 kN load but the Flexural strength of geopolymer concrete tile is 224 N/mm^2 at 6.4 kN load, which shows the improved quality in stiffness and the strength can be auxiliary improved by changing the alkali activator molarity and replacement level of cement (Table 5).

Conclusions:

The type curing is important one to improve the mechanical behavior of geopolymer concrete. The hot air oven method of curing provides better strength parameters.

Water absorption of normal concrete tile is 1.520 % while water absorption for geopolymer concrete tile is 2.88 % which may able to change with the % of replacement taken in place.

Free moisture content of normal concrete tile is 3.938 % while free moisture content of geopolymer concrete tile is 4.752 %, which improves the indoor environment by ensuring the maintenance.

Flexural strength of normal concrete tile is 132 N/mm2 at 3.1 kN load but the Flexural strength of geopolymer concrete tile is 224 N/mm2 at 6.4 kN load, which shows the improved quality in stiffness and the strength can be further improved by changing the alkali activator molarity and replacement level of cement.

Compressive strength of normal concrete tile is 41.05 N/mm2 while compressive strength of geopolymer concrete tile is 30 N/mm2. This may be due to the cement replacement and type of curing and curing period. The polymer bonding taken place in early age with minimum water content in hot air oven influence the strength parameter.

Thus the tested property of geopolymer concrete tile with 50% of cement added has more values than normal concrete tile when the depth is 10 mm. when compared with normal concrete tiles; geopolymer concrete tile has high strength. Moreover, geopolymer tiles were very easy to manufacture and easy to install & replace in industries for flooring.

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