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Experimental investigations on fibre reinforced geopolymer concrete as repair material for pavements.

Investigaciones experimentales sobre hormigón geopolimérico reforzado con fibras como material de reparación de pavimentos

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ABSTRACT

Geopolymer is a relatively new construction material which could be produced by the chemical action between alumino-silicate material such as fly ash and alkaline solutions like sodium silicate or sodium hydroxide. Geopolymer concrete (GPC) reduces the CO_2 emission by 9 % compared to the concrete made with ordinary portland cement. Fibre reinforced geopolymer concrete (FRGPC) has already been used as a repair material for different construction purposes such as for tunnel linings and sewage pipes repairs due to its improved tensile characteristics and crack control properties. This study involves the experimental investigations on FRGPC as a repair material for rigid pavements. A mixture of sodium silicate and 8M sodium hydroxide solution is used as the alkaline activator to prepare the fly ash based geopolymer concrete. To increase the mechanical properties at ambient temperature calcium additives in the forms of calcium hydroxide and calcium oxide are added separately by replacing fly ash in the proportion 3%, 5% and 7% by weight of fly ash. Further to increase the low tensile strength of GPC, addition of polypropylene fibre in 0.2%, 0.4% and 0.6% by volume of concrete were also incorporated. The aspect ratio of the polypropylene fibres used is 300. The optimum values were determined based on the fresh concrete properties and mechanical properties. The results showed that the 7 day compressive and tensile strengths of FRGPC were increased by 36% and 14% respectively from fly ash GPC. The bond strength between the pavement substrate and the geopolymer repair material is also studied. The bond strength of the fibre reinforced repair material is found to be more than the permissible values as per relevant codes of practice. Abrasion resistance of the repair material is also tested as a measure of durability aspects to check the suitability for usage on rigid pavements.

Keywords—Geopolymer Concrete, Alumino-Silicate, Rigid pavements, Substrate, Alkaline solution, Repair material.

RESUMEN

El geopolímero es un material de construcción relativamente nuevo que podría producirse por la acción química entre el material de aluminosilicato, como las cenizas volantes, y soluciones alcalinas como el silicato de sodio o el hidróxido de sodio. El hormigón geopolímero (GPC) reduce la emisión de CO2 en un 9% en comparación con el hormigón elaborado con cemento Portland ordinario. El hormigón geopolímero reforzado con fibra (FRGPC) ya se ha utilizado como material de reparación para diferentes propósitos de construcción, como para revestimientos de túneles y reparaciones de tuberías de alcantarillado debido a sus características mejoradas de tracción y propiedades de control de grietas. Este estudio comprende las investigaciones experimentales sobre FRGPC como material de reparación de pavimentos rígidos. Se utiliza una mezcla de silicato de sodio y una solución de hidróxido de sodio 8M como activador alcalino para preparar el concreto geopolimérico a base de cenizas volantes. Para aumentar las propiedades mecánicas a temperatura ambiente, se añaden aditivos de calcio en forma de hidróxido de calcio y óxido de calcio por separado reemplazando las cenizas volantes en la proporción de 3%, 5% y 7% en peso de cenizas volantes. Además de aumentar la baja resistencia a la tracción del GPC, también se incorporó la adición de fibra de polipropileno en 0,2%, 0,4% y 0,6% en volumen de hormigón. La relación de aspecto de las fibras de polipropileno utilizadas es 300. Los valores óptimos se determinaron en función de las propiedades del hormigón fresco y las propiedades mecánicas. Los resultados mostraron que las resistencias a la compresión y a la tracción de 7 días de FRGPC aumentaron en un 36% y 14%, respectivamente, a partir de las cenizas volantes GPC. También se estudia la fuerza de unión entre el sustrato del pavimento y el material de reparación de geopolimero. Se encuentra que la fuerza de unión del material de reparación reforzado con fibra es mayor que los valores permitidos según los códigos de práctica relevantes. La resistencia a la abrasión del material de reparación también se prueba como una medida de los aspectos de durabilidad para verificar la idoneidad para su uso en pavimentos rígidos.

Palabras clave: concreto geopolímero, alumino-silicato, pavimentos rígidos, sustrato, solución alcalina, material de reparación.

INTRODUCTION

Geopolymer Concrete (GPC) is a new class of concrete based on an inorganic alumina silicate binder system compared to the hydrated calcium silicate binder system of concrete, which is activated by alkaline liquids to produce the binder. The basic material used for the activation of the geopolimerization process is Fly ash, which is also used to replace the conventional portland cement. To activate alumino silicate compounds in fly ash, sodium hydroxide solution and sodium silicate solution is used in combination [1]. The geopolymer possesses the advantages of rapid strength gain, elimination of water curing, good mechanical and durability properties and are eco-friendly and sustainable alternative to Ordinary Portland Cement (OPC) based concrete. In the construction industry the production of portland cement is the major cause of emission of air pollutants. Use of geopolymer cement reduces CO_2 emissions by 70-80% in comparison with OPC [2].

Concrete pavements undergo various types of distresses and damages during its life time such as -spalling of joint, shrinkage cracking, corner breaks, punch out, linear cracking, durability cracking etc. The main techniques used for rigid pavement repairs are full depth repair, partial depth repair, diamond grinding and retrofitting dowels. The repair materials used are either normal setting plain cement concrete (PCC) , high early strength PCC, rapid strength developing materials such as epoxy resin mortar or epoxy concrete. A "green" alternative for the rigid pavement repair could be fibre reinforced geopolymer concrete (FRGPC). Fly ash based GPC has been used as a construction material for both building and infrastructure projects worldwide. One of the biggest applications is the heavy duty GPC pavements for Australia's first Greenfield public airport - Brisbane West Wellcamp airport (BWWA). 40,000m^3 of geopolymer concrete was used for the construction of this airport [3].

Geopolymer cement has been widely used for the construction of rigid pavements in North America for the last three decades under the brand name Pyrament© [4]. The incorporation of polypropylene fiber in to geopolymer concrete resulted in improved tensile characteristics, crack control, and increased durability properties particularly with outdoor heat exposure (OHE) cured composites [5]. Fibre reinforced concrete has been used as a repair material for various construction activities due to its enhanced mechanical properties such as for tunnel linings and for sewer pipe lines [6]. Thus fibre reinforced geopolymer concrete could be used as a sustainable and economical solution to pothole repair for both flexible and rigid pavements [7]. The enhanced bonding between the concrete substrate and better durability properties of fibre reinforced geopolymer concrete are ideal properties to be considered as a repairing material for rigid pavement.

MATERIAL AND METHODS

EXPERIMENTAL STUDY: The objective of this study to evaluate the feasibility of fly ash based fibre reinforced geopolymer concrete as a repair material for rigid pavements. The parameters for a material to be considered as a repair material are workability, rapid setting, high tensile and compressive strength, bond strength to the substrate and high abrasion resistance to the traffic flow. In this experimental investigation a GPC equivalent to M30 concrete as per mix design from literature is established. The fly ash in the established GPC is partially replaced with calcium oxide (CaO) and calcium hydroxide ($Ca(OH)_2$) by weight in 3%, 5% and 7%. The workability and setting time of calcium added fly ash based polypropylene fibre added geopolymer concrete is evaluated. The fresh concrete properties are investigated in accordance with the Indian codes of standards. (IS 1199-1959-Reaffirmed 2013 & IS 8142 - 1976-Reaffirmed 2002). The GPC specimens are then investigated for its compressive strength and split tensile strength in accordance with IS 516-1959-Reaffirmed 2004 & IS 5816- 1999-Reaffirmed 2004. Based on the strength parameters and fresh concrete properties an optimum percentage of CaO or $Ca(OH)_2$ is finalized. Polypropylene fibres are further added to increase in 0.2%, 0.4% and 0.6% by volume of GPC and the optimum % of fibre content is selected based on the strength parameters.

The bond strength of the repair material is evaluated by slant shear strength test (ASTM C 496-1996) and split tensile strength (ASTM C 882-1999). In slant shear strength test the test angle was geopolymer repair material is kept at 45^0 to the concrete substrate. In the other method for evaluating the bond strength, concrete substrate is bonded with FRGPC repair material and the split tensile strength is calculated to assess the bonding.

Abrasion resistance is one of the measures of durability of concrete pavement materials. The durability aspect of the repair material is evaluated as per the abrasion loss test in IS 9284-1979-Reafiirmed 2002. This method approximately stimulates abrasion under physical effects suffered by concrete pavements.

MATERIALS: The materials used for the study are Class F fly ash, Sodium hydroxide pellets and sodium silicate solutions as alkaline activators. Calcium hydroxide and calcium oxide were used as calcium additives to enhance the fresh concrete properties. M sand and 12mm to 4.75 mm downgraded coarse aggregates were used for the aggregate part of geopolymer concrete. Polypropylene fibres of 12mm length are added for developing crack control properties and lignosulphate based Conflo LN is used as a workability aid. All the materials used in the experimental study were purchased locally. Table 3.1 to Table 3.6 lists physical and /or chemical properties of the materials used for the study.

Table 3.1: Chemical Properties of Fly Ash

Parameters	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	SO_3	LOI
% Content	46.80	23.70	10.20	7.90	1.00	0.77	1.20	6.90

Table 3.2: Physical Properties of Sodium hydroxide

Physical state	Colour	pH	Melting point	Boiling point	Solubility in water
Solid	White pallets	13-14	318 °C	1390 °C	111g/100g of water

Table 3.3: Physical Properties of Sodium silicate

Physical state	Colour	pH	Melting point	Boiling point	Solubility in water
Liquid	Opaque viscus	11.2	0.6 °C	100 °C	Soluble in water

Table 3.4: Physical Properties of PP fibre

Length	Tensile strength	Elasticity modulus	Specific gravity	Elongation (%)
Hybrid, 3-12 mm	33 MPa	1.8×10^3 MPa	0.92 g/cc	12.-15

Table 3.5: Physical Properties of Calcium hydroxide

Physical state	Colour	pH	Melting point	Boiling point	Densilty
Solid	White pallets	13-14	318 °C	1390 °C	2.13 g/cc

Table 3.6: Physical Properties of Calcium hydroxide

Physical state	Colour	pH	Melting point	Boiling point	Density
Solid	White powder	12.5	2.614 °C	2.850 °C	3.3 g/cc

Table 3.7: Physical Properties of Calcium hydroxide

Aspect	Relative density	Consistency	Chloride ion content
Brown liquid	1.19-1.20	Low viscosity	Nil

TESTING

Property testing of materials

The materials using for the preparation of concrete are tested to determine their quality and physical properties and the tests were done according to relevant Indian Standard Codes. The results of the material testing done in the laboratory are also given below.

Table 4.1: Physical properties of fly ash and aggregates

Materials	Specific gravity	Water absorption (%)	Fineness Modulus	Relevant IS Code
Fly Ash	2.54			IS 3812: 2013 part I (Third revision)
Fine Aggregate	2.63	1.23	2.901	IS 2386:1963 part I & part III (Reaffirmed 2011)
Coarse aggregate	2.66	0.73	2.49	IS 2386:1963 part I & part III (Reaffirmed 2011)

Mix proportions

M30 equivalent GPC is considered for the experimental investigations of the material in study. There are no codal provisions available for the mix design of geopolymer concrete, and so the density of geopolymer concrete was assumed as 2400 kg/m^3 and other calculations were based on the density of concrete as per the design given by Lloyd and Rangan [8]. The combined total volume occupied by the coarse and fine aggregate was 76% [9]. The alkaline liquid to binder ratio was taken as 0.4. Target strength of 30MPa was fixed considering GPC as a regular strength concrete. Fibre proportion is calculated by multiplying fibre density and dosage of fibre.

Table 4.2: Quantity of materials for 1m^3 of GPC equivalent to M30 concrete

Fly Ash	Fine aggregate	Coarse aggregate	Sodium hydroxide (8M)	Sodium silicate
412 Kg	607 Kg	1217 Kg	47 Kg	117 Kg

Fly ash: fine aggregate: coarse aggregate is 1:1.47:2.95.

Fly ash: NaOH: Na_2SiO_3 is 1:0.11:0.28

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Table 4.3 shows mix designations adopted for this experimental study.

Table 4.3: Mix designations

Mix Designation	Description
GPC	Geopolymer concrete
GPC+3CH	Geopolymer concrete with 3% Calcium Hydroxide
GPC+5CH	Geopolymer concrete with 5% Calcium Hydroxide
GPC+7CH	Geopolymer concrete with 7% Calcium Hydroxide
GPC+3CO	Geopolymer concrete with 3% Calcium Oxide
GPC+5CO	Geopolymer concrete with 5% Calcium Oxide
GPC+7CO	Geopolymer concrete with 7% Calcium Oxide
0.2FGC+5CH	0.2% PP fibre with 5% Calcium Hydroxide
0.4FGC+5CH	0.4% PP fibre with 5% Calcium Hydroxide
0.6FGC+5CH	0.6% PP fibre with 5% Calcium Hydroxide
0.2FGC+5CO	0.2% PP fibre with 5% Calcium Oxide
0.4FGC+5CO	0.4% PP fibre with 5% Calcium Oxide
0.6FGC+5CO	0.6% PP fibre with 5% Calcium Oxide

Specimen preparation: To prepare 8 M concentration of sodium hydroxide solution, 320gm of sodium hydroxide pellets were dissolved in water and made up to one litre. The sodium hydroxide solution was prepared 24 hours prior to use, since dissolving NaOH pellets in water is an exothermic reaction and the temperature of solution goes up. Hence it is necessary to cool it at room temperature. The sodium hydroxide solution thus prepared was mixed together with sodium silicate solution to get desired alkaline solution. Then the other ingredients used for preparing geopolymer concrete include fly ash, fine and coarse aggregate and were dry mixed for about 2 minutes. For calcium compound replaced geopolymer concrete, calcium hydroxide and calcium oxide were added in relevant proportion separately to the dry geopolymer mix. For obtaining fibre reinforced geopolymer concrete, Polypropylene fibres were added in relevant proportion and mixing was continued for 2 more minutes. After this the alkaline solution and superplasticizer were added to the dry materials and mixed for 4 to 5 minutes.

Workability and setting time: After mixing slump of fresh concrete were determined for GPC in the beginning and later for FRGPC as well. Representative samples were taken from the fresh mix for the evaluation of initial and final setting time of GPC and FRGPC. After that the concrete was placed in steel mould by giving proper compaction.

Compressive strength test: Compressive strength testing is conducted on cube shaped specimens. Cubes were casted in150 mm x 150 mm x 150 mm cast iron moulds. The specimens are removed from the moulds after 24 hours and then allowed to cure in the room temperature till the required day of testing. The specimens were tested at 7 and 28 days from the day of casting.

Split Tensile strength: Cylindrical specimens were used to test the split tensile strength of GPC and FRGPC specimens. Cylinders of 300 mm high and 150 mm φ are casted and tested at 7 days and 28 days of curing. The tests were conducted for both GPC and FRGPC specimens. The split tensile strength is given by the equation:

$$\text{Split Tensile Strength} = \frac{2P}{\pi LD}\ \text{N/mm}^2$$

where, P= Compressive Load in N

L=Length in mm and D=Diameter in mm

Bond strength: The bond strength of FRGPC material is evaluated by split tensile strength as per ASTM C 496-1996 and slant shear test as per ASTM C 882-1999.

4.3.4.1. Split tensile strength test

For the split tensile strength, the substrate is made with pozzolanic cement concrete. The half cylinders of 300mm height and 75 mm φ radii are casted with PCC concrete and cured for 28 days. After the curing period the face of the substrate is roughened with wire brush and sand paper. The other half of the cylinder is cast with repair material and the cylinders are tested for 7 days and 28 days. The bond strength as per split tensile strength testing is:

$$\text{Split Tensile Strength} = \frac{2P}{\pi LD}\ \text{N/mm}^2$$

where P= Compressive Load in N

L=Length in mm

D=Diameter in mm

Slant shear strength test: For the slant shear test, the substrate half cylinders of 150 mm φ are casted at angle 45^0 to the horizontal. The half cylinders are cured for 28 days. After the curing period, the surface of the substrate is roughened using wire brush and sand paper. The FRGPC repair material is cast over the substrate and tested after 7 days and 28 days curing to evaluate the bond strength. The bond strength is given by the equation:

S = P / A, where S is the bond strength (in MPa)

P = The maximum force recorded (in N)

A= The area of the slant surface (in mm^2)

Abrasion loss test: The abrasion loss test is conducted as per IS 9284-1979. The test is a measure of durability of concrete pavements against physical forces. Cubical specimens with 150mm sides of FRGPC repair material are casted. The specimens are cured for 28 days and the test is conducted. The size of abrasion loss test specimen is of 100mm x 100mm x 100mm a side.

The abrasion loss of concrete shall be calculated as:

% mass loss = (m1-m2) / 100

ml = mass of the specimen before each test in gram,

m2= mass of the specimen after each test in gram

The permissible value of abrasion resistance for pavement material with pneumatic tyred traffic as per IS 9284-1979 is 24%

RESULTS AND DISCUSSIONS

Workability and setting time: The workability of the specimens is determined by the slump test as per IS 1199: 1959 (Reaffirmed 2013). The workability of GPC mixes are found to be decreasing as the percentage of fly ash replacement increases. The mixes became medium workable when the percentage of replacement of both $Ca(OH)_2$ and CaO are 7% by fly ash. The setting time also showed the same trend, beyond 5% of calcium additives, the initial setting time reduces below 10 minutes. The 5% addition showed the favorable results with workability slumps 114 mm and 104 mm for $Ca(OH)_2$ and CaO. The initial setting times are 19 minutes and 15 minutes.

The tests were further continued with specimens with 5% replacement of fly ash by both $Ca(OH)_2$ and CaO by adding different percentages of polypropylene fibres. The added percentages are 0.2, 0.4 and 0.6 by volume of GPC. GPC with 0.6% addition of PP fibres (0.6FGC+5CH) has workability of 104 mm for $Ca(OH)_2$ replacement. The initial and final setting times for 0.6FGC+5CH are 12 minutes and 27 minutes.

Compressive strength: Increase in % of Ca compounds increases the compressive strength of GPC specimens. The maximum value was shown by 7% $Ca(OH)_2$ replaced GPC specimen with a value of 34.81 N/mm^2 for 7 days and 38.51

N/mm^2 for 28 days. Addition of Ca compounds increases the compressive strength of the specimens and the maximum 7 days and 28 days compressive strengths were shown by GPC+7CH. The increase in strength development in $Ca(OH)_2$ added GPC could be due to the reaction of the readily available free calcium ions in $Ca(OH)_2$ with silica and alumina in fly ash forming additional calcium silicate hydrate (C-S-H) and calcium aluminosilicate hydrate (C-A-S-H) within the matrix. The existence of both forms of the gels increases the strength development and leads to rapid hardening. The reaction between calcium and water is exothermic and that too accelerates the geopolymerization. In the case of CaO, the reduction strength beyond 5% addition is due to the speedy setting of the paste, which results in an incomplete geopolymerization. The 28 day compressive strength of 7% CaO added GPC is 36.5 MPa which is around 2% less than that of 5% addition of CaO. Although the workability of the specimens decreased the specimens showed better strength characteristics. The maximum strength was shown by 0.6FGC+5CH for both 7 days and 28 days. The maximum value for 7 days was 36.90MPa and 40.02MPa for 28 days. Although the strength are increased with addition of calcium compounds the specimens shows a tendency of flash setting and become medium

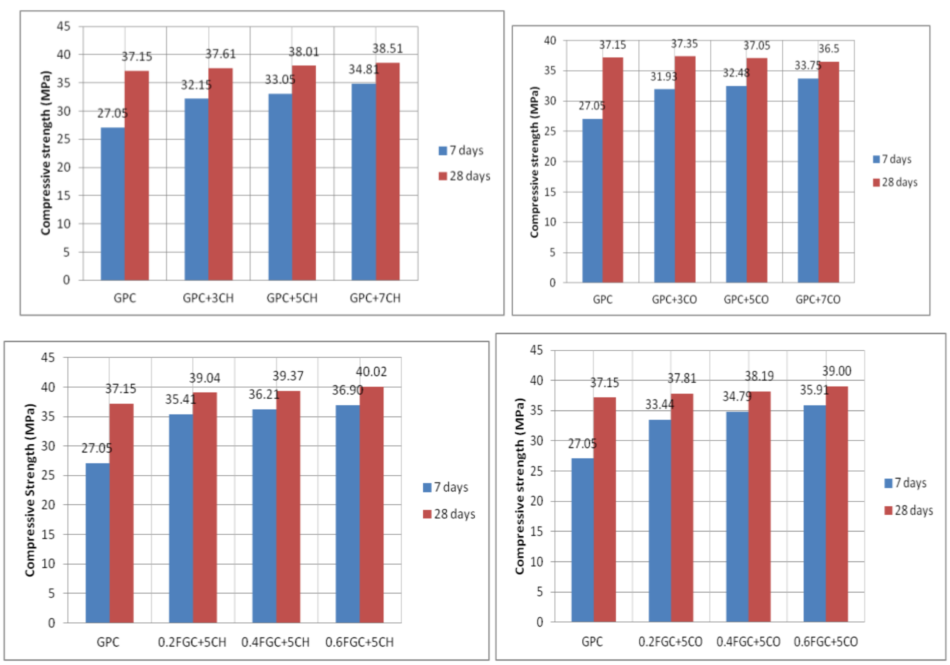
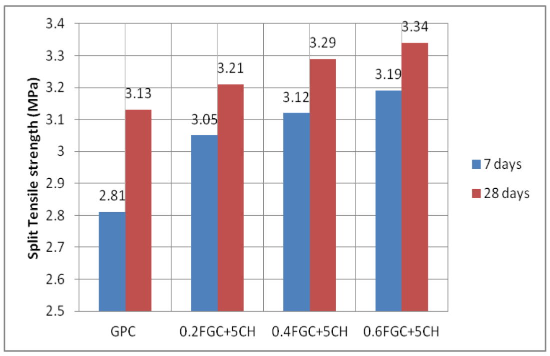


Figure 5.1: Compressive strength a) GPC with varying % of $Ca(OH)_2$ b) GPC with varying % of CaO c) FRGPC with varying % of PP fibre with 5% $Ca(OH)_2$ d) FRGPC with varying % of PP fibre with 5% CaO

workable beyond 5% addition of $Ca(OH)_2$ and CaO. Further studies with PP fibres are conducted on GPC with 5% calcium additives. Addition of PP fibres in to GPC specimens increases the compressive strength of the specimens. PP fibres were added to specimens in 0.2%, 0.4% and 0.6%. Although the workability of the specimens decreased the specimens showed better strength characteristics. The maximum strength was shown by 0.6FGC+5CH for both 7 days and 28 days. The maximum value for 7 days was 36.90MPa and 40.02MPa for 28 days

Split tensile strength



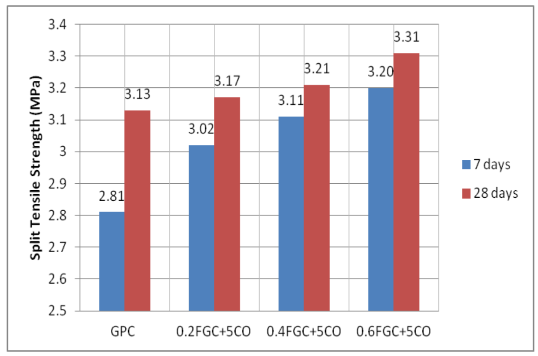


Figure 5.1: Split tensile strength a) FRGPC with varying % of PP fibre with 5% $Ca(OH)_2$ b) FRGPC with varying % of PP fibre with 5% CaO

The split tensile strength also showed the same pattern as compressive strength testing. As the quantity of calcium additives increases the split tensile strength also increases. The maximum 28 days strength was shown by GPC+7CH with 3.34 MPa. Considering the fresh concrete properties 5% calcium additives specimens were selected for further testing with PP fibre. The addition of fibres to calcium rich geopolymer concrete increases the tensile strength significantly. The maximum tensile strength was shown by the specimens with 0.6% addition of fibres. The 28 days maximum tensile strength of 3.34MPa was shown by 0.6FGC+5CH and maximum 7 day tensile strength of 3.20 was shown by 0.6FGC+5CO. The values of tensile strength are shown in Figure 5.11 and 5.12 shows the split tensile strength variation with optimum percentage of calcium hydroxide and calcium oxide with varying percentage of PP fibre.

BOND STRENGTH

Split tensile strength for evaluation of bond strength: The split tensile test of the manufactured cylindrical composite material shows the bond strength between FRGPC and PPC concrete substrate. The concrete substrate was made with M30 equivalent PPC concrete. The repair material used was 0.6FGC+5CH and testing was done for 7 days and 28 days and compared results with concrete repair overlay. The surface of the substrate was roughened with wire brush and sand paper before the repair material was cast on top of it. The results are tabulated in Table 5.1. The FRGPC repair material showed superior bond strength with concrete substrate, and the obtained bond strength in terms of split tensile strength was found to be in accordance with specified test methods.

Table 5.1: Split tensile strength for composite specimens for PPC and FRGPC

Sl.No.	Substrate	Repair Material	Split Tensile strength(MPa)		28 days minimum Bond strength (MPa) as per ACI Repair guide ACI 546R-96 (Reapproved 2001)
			7 days	28 days	
1	PPC		2.1	3.18	2.1
2	0.6FGC+5CH		3.19	3.34	
3	PPC	PPC	1.23	1.91	
4	PPC	0.6FGC+5CH	1.56	2.42	

Slant shear strength test for evaluation of bond strength

Slant shear strength was used to determine the bond strength between substrate and the repair material. This test is as per specification of ASTM C882 (ASTM-C882 1999). FRGPC repair material is casted and bonded to the concrete substrate at an angle of 45^0 to the vertical. The substrate surface was roughened with wire brush and sand paper. The slant shear strength test was carried out for 7days and 28 days and compared the strength value with PPC substrate and PPC overlay.

The ACI Concrete Repair Guide specifies the acceptable bond strength for repair work shall within the ranges of 6.9 to 12MPa and 13.8 to 20.7MPa for slant shear strength at test ages 7 and 28 days, respectively [11].

Table 5.2: Slant shear strength test for composite specimens of PPC and FRGPC

Sl.No.	Substrate	Repair Material	Slant shear strength (MPa)		Acceptable bond strength(MPa) as per ACI repair guide ACI 546R-96 (Reapproved 2001)	
			7 days	28 days	7 days	28 days
1	PPC	PPC	4.71	8.64		
2	PPC	0.6FGC+5CH	7.02	14.48	6.9-12	13.8-20.7

Test for Abrasion loss: Abrasion loss is evaluated for both concrete specimen and FRGPC repair specimen. The abrasion resistance test is conducted as per IS 9284-1979 (Reaffirmed 2002). Cubical specimens 10 cm sides are prepared with PPC concrete and 0.6FGC+5CH and abrasion loss experiment is evaluated. The abrasion loss is calculated by;

% mass loss = (m1-m2) / 100

ml = mass of the specimen before each test in g,

m2= mass of the specimen after each test

Table 5.11: Abrasion loss for PPC concrete specimen and FRGPC repair material

Specimen	m1(g)	m2(g)	$\frac{\mathrm{m1} - \mathrm{m2}}{\mathrm{m1}} \mathrm{X}\ 100$	Remarks
PPC	2320	1981	14.66	Very good
FRGPC	2270	1680	25.99	Satisfactory

As per IS 9284-1978 (Reaffirmed 2002), the maximum percent loss of abrasion is 24%. The obtained value for FRGPC is higher than permissible value so the result found to be satisfactory only.

As conclusion, based on the experimental investigations the following conclusions are reached:- The addition of CaO leads to faster setting of GPC than addition of $Ca(OH)_2$ due to the higher potential of heat generation. Calcium additives increase the mechanical properties GPC such as compressive strength and split tensile strength. Addition of CaO beyond 5% showed slight decrease in the compressive strength formation for GPC due to the speedy setting results poor geopolymer matrix formation. The addition of calcium compounds decreases the workability of the mixes and addition beyond 5% by weigh of fly ash turns the mixes in to medium workable. Addition of PP fibre in to GPC with calcium additives further increased the mechanical properties. The 28 day compressive strength of 0.6% PP fibre added GPC increased by 5.3% and split tensile strength was increased by 1.5%. The bond strength of FRGPC repair material by split tensile strength is found to be excellent as per ACI concrete repair guide. 28 day bond strength is 2.42 MPa. As per slant shear strength, the 28 day bond strength was found to be 14.48 MPa which is also higher than ACI concrete repair guide requirements for a repair material. The value of abrasion loss is found satisfactory for FRGPC repair material for concrete pavements as per IS 9284-1979 (Reaffirmed 2002). Heat curing of FRGPC can be avoided by the addition of calcium compounds like CaO and Ca $(OH)_2$. The heat curing is not practicable for a cast in situ repair material. The essential parameters of cast in situ concrete repair material are rapid setting, high tensile and compressive strength, and bond strength to the substrate, low abrasion loss and high workability. These properties have been met with FRGPC with 0.6 % addition of PP fibre by volume of GPC and 5% replacement by weight of fly ash with Ca $(OH)_2$.

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