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Development of Sustainable Green Repair Material using Fibre Reinforced Geopolymer Composites

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Abstract

The most wanted and resourceful binder material in the building sector is cement. In manufacturing process of 1 ton of cement, it is known that it emits nearly one ton of CO_2. Also one of the major problems we are facing today is the water scarcity. Due to decrease in carbon emission, Geopolymers are accepted to be the up-coming replacement for OPC and on the other hand it eliminates the use of water for curing. As a remedy to the concrete deteriorations, an environmental friendly and cost-effective repair material is required. Repair of damaged concrete is essential not exclusively to guarantee its planned service life yet additionally gives a good stability to the structure. At the same time, development of eco-friendly repair material is the need of the hour. As fibre reinforced geopolymer composite (FRGC) can elevate the impact and tensile strength behaviour, they may be employed as a patching material or an overlay mending material for the deteriorated R.C. structures or that will deteriorate due to corrosion of steel. This project work deals with the study of FRGC to be utilized as a sustainable repair material. Polypropylene fibre reinforced fly-ash based geopolymer (both Class C and Class F Fly-ash) is to be employed for repair. FRGC not only prove to be a

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suitable repair material but also facilitates ambient curing thereby saving water to be used for curing. This adds up to be an eco-friendly approach by lessening the usage of water. The geopolymer mortar cubes were tested for its compressive strength and impact strength with inclusion of 0.5%, 1% and 1.5% of polypropylene fibres. Further, inclined shear test (slant shear tests) are carried out to determine the substrate concrete-FRGC repair substance bonding strength. From these results, FRGC can be suggested as a repair material for the repair of pavement and furthermore as overlay or fix materials.

Keywords: Class F Fly-ash, Class C Fly-ash, Polypropylene fibres, FRGC, Geopolymer Mortar Cubes

1 Introduction

Davidovits initially developed geopolymer in 1978 which was found to be an innovative material [1]. When any source of material of natural or geological origin or an industrial by-product having silicon (Si), aluminium (Al) content was allowed to react with an alkaline liquid, it produced a binder forming an amorphous three-dimensional structure called the geopolymer [1,21]. The materials having higher amounts of SiO_2, Al_2O_3 are fly ash, GGBS and so on, are stimulated by strong alkali chemicals like sodium hydroxide and sodium silicate. Since geopolymer technology does not require cement, it reduced the carbon dioxide emission to the atmosphere [2]. Geopolymers produce hard, economical, sustainable and resilient infrastructures which are even strong at elevated temperature. This proved to be a new binder that could replace Ordinary Portland Cement (OPC). Since there is a gradual deterioration occurring in infrastructure worldwide, they require major repairs [3, 28]. It was obvious that the life span and serviceability of concrete structure get affected due to steel corrosion. Due to such defects, a huge volume of restoration, repair & rehabilitation works was needed. Consequently, a high volume of repair works consumed a huge amount of non-renewable resources. In order to fulfil this need, concrete construction consumed gigantic quantum of non-renewable resources. As a result, a huge sum of wealth has been spent on repairs and rehabilitation of concrete structures [4, 27]. Meanwhile, the concrete industry was in the intention of lessening its CO_2 release. As part of this research project towards the development of low- carbon-footprint repair material, strength and bond compatibility of fibre reinforced geopolymer was investigated. Here, Table 1 summarizes the various categories of repair materials available in market [5].

Table 1 Categories of repair substances

Organic based	Inorganic-based	
Resinous mortar	**Polymer based materials**	**Cement materials**
Epoxy mortar	SB modified mortar (Styrene Butadiene)	OPC mortar
Acrylic mortar	Vinyl acetate modified mortar	Flowing concrete

Due to huge load applications, thermal stress, shrinkage, unequal settlement of supports, inadequate cover between rebar and concrete surface, exposure to chloride rich environment, concrete structures undergo deteriorations such as cracking and spalling [5]. Patch repair is being done in concrete pavements when they are subjected to problems like deflection of weak areas, popping up of pieces, cracks and formation of potholes. Epoxy is not a cost-effective repair material especially in repairing large volumes. Furthermore, ordinary Portland cement (OPC) based binders are not environmentally friendly [6] and when structures are deteriorated due to chloride, polymer modified cementitious materials will not be a suitablerepair because it does not possess substantial and electrochemical affinity between repair composites and the existing damaged concrete [7,8]. Recently developed mortars based on alkali-activated binders (AABs) which is nothing but the geopolymers, could be categorized under cementitious material revealed the ability to be employed as a patch repair material.

Geopolymerization [9, 20] is the process of dissolution of SiO_2 and Al_2O_3, activated by alkaline activators. Mechanism of geopolymer produces Si-O-Al bond [9].

$$M_n\ [-\ (Si - O_2)_z - Al - O]_n\ .\ H_2O$$

where M denotes the alkaline element, z is 1, 2, or 3 and n represents the degree of polycondensation. Activation of silicon and aluminium was being done by the alkali activators which allowed it to transform totally into a compacted hard material. The mechanism of geopolymerization and the reaction taking place in it helped to achieve a better binding between repair material and underlying concrete which paved the way to use geopolymer mortar for repair purpose [10]. When fly-ash rich in CaO content are used along with Portland cement in the form of precursors for making geopolymer binder, the reaction got enhanced due to CaO composition in the geopolymer matrix. Enhanced strength was attained because of calcium-silicate-hydrate gel (C-S-H) that coexisted with alumino-silicate hydrate gel [11]. Utilization of fly-ash in concrete results in decreased strength at room temperature and so heat curing is required to improve its strength [12]. The use of Granulated Blast Furnace Slag (GBFS) content [13] and alkaline activator binder (AAB) resulted in an exothermal process that released enough heat and also formed an additional calcium-silicate-hydrate gel, calcium-alumino-silicate-hydrate. This yielded sufficient heat for room temperature curing. There are 2 types of fly-ash as per ASTM C618 [14] which are being generated as a waste when coal is burnt in the thermal power plant for power generation. They are Class F fly ash and Class C fly ash. Calcium oxide content present in the ash varies in both the types [15]. Class C fly-ash having higher calcium oxide [16, 17] content (>10%) produced the necessary heat of hydration for the geopolymer which facilitated room temperature curing. But at the same time, geopolymer mortar exhibited a brittle behaviour due to its low tensile strength. The change of brittle to ductile behaviour happened by the usage of fibers either in continuous or in the discrete form [18]. One identifying component is Polypropylene fibers which are short, discontinuous, high-performance fiber, used to achieve high tensile strength, toughness and structural integrity that is vital to pavement overlays [19].

2 Research Significance

The investigation on engineering parameters of geopolymer mortar is carried out to assess its suitability as repair material. Also to,Investigate the compressive strength, slant shear bond strength and impact strength of fibre reinforced Class C & Class F Fly ash based Geopolymer composite.

3 Materials Used

3.1 Class F Fly-ash

On flaming old, rocky anthracite and bituminous coal, purely pozzolanic natured fly-ash of Class F Type is obtained. As per code ASTM C618, the total content of SiO_2 + Al_2O_3 + Fe_2O_3 should not be less than 70% for this type of fly-ash [12]. By adding strong alkaline chemicals such as Na_2SO_3 and NaOH to Class F fly-ash, it hardens to form a geopolymer [20].

Fig 1. Photograph of Class F Fly-ash

Fly-ash of Class F Type has been procured from Tuticorin Thermal Power plant. Fig 1 shows Photograph of Class F Fly-ash

3.2 Class C Fly-ash

Fly-ash of Class C Type is discharged as a derivative material when developing lignite or sub-bituminous coal is burnt. This type of fly-ash possess self-cementing properties in addition to its pozzolanic properties and containing CaO more than 20% and higher amounts of alkali and SO_3.

Fig 2. Photograph of Class C Fly-ash

Fly ash of Class C Type has been collected from Neyveli Lignite Corporation Ltd. owned Thermal Power plant, Neyveli. Fig 2 shows Photograph of Class C Fly-ash

3.3 Alkaline Activators

Sodium Hydroxide (NaOH) – Called as caustic soda is used in the flaked inorganic form consisting of Na^+ cations and OH^- ions. Sodium silicate – The % of chemical content in Na_2SO_3 solution are Na_2O=15.7%, SiO_2=31.4%, and H_2O=53.57% by mass.

3.4 Fine Aggregate

Sand is nothing but the finely divided rock particles, its size being smaller than gravel particles and larger than silt. Sand, when mixed with OPC and lime, could be used in masonry construction. Here river sand is used.

3.5 Coarse Aggregate (For substrate concrete)

Coarse aggregates or simply the aggregates are the strength-inducing parameter in the concrete and the size of the aggregates used is 20 mm. It is used for conventional substrate concrete specimen for slant shear bond strength.

3.6 Polypropylene Fibers

Polypropylene fibers collected were of cut length – 12 mm and diameter range – 22 -35 microns. They increase impact/ shatter resistance, reduce water percolation and concrete permeability and also improve the durability of concrete.

3.7 Superplasticizers

Naphthalene based superplasticizers were used for improving the workability, up to 2% of fly ash content.

4 Experimental Result

4.1 Mix Proportions, Casting and Curing Procedure

The major objective is to utilize fly ash to its fullest to achieve 100% cement replacement. As a result, trial mixes having 96% Class F Fly-ash and 4% Class C Fly-ash, 97% F-3% C and 98% F-2% C was used as a major resource. NaOH (Sodium Hydroxide) and Na_2SiO_3 (Sodium Silicate) used as alkaline activating binder solution. It was prepared to have Na_2SiO_3/NaOH ratio to be 2.5. For further calculation of mix design, the consequent presumptions were done,

- AAS/Fly-ash = 0.35
- Water/Fly-ash = 0.23

The only variable parameter in the mix design was the molarity of NaOH solution. Based on various research results, it is viewed that the geopolymer yielded good results in the molarity range of 8 to 16. So, 10M NaOH molarity was adopted. The alkaline activating binder solution (AAS) was obtained by stirring both sodium hydroxide and sodium silicate together with distilled water. This solution should be made 1 day prior. In the pan, the fine aggregates and both the fly-ash types were blended without the addition of water for about 3 minutes. After this dry mix, the appropriate proportion of polypropylene fibers was added. And then the activator solution as well as superplasticizer (water-if needed) was added and mixed together. This blending was carried out for nearly three-five minutes. The FRGC mix had a stiff consistency and glazed appearance. During casting, both grease and oil were applied in the mould so that the specimen would not stick to the mould. The specimens were demoulded and kept at ambient temperature for curing. For the mix proportion of mortar, the mass of coarse aggregate has to be removed and uniformly distributed among other constituents of mortar such that mix proportion remains the same. Table 2 and Table 3 shows the mix proportion and mix ratio of geopolymer respectively.

Table 2 Mix Proportion

Materials	Mix Proportion in kg /m^3
Fly ash	932.37
Sodium hydroxide	93.34
Sodium silicate	233.09
Fine aggregate	1130.93
Super plasticizer	18.66

Table 3 Mix Ratio

Fly ash :	NaOH :	Na_2SiO_3 :	Fine agg. :	SP
1 :	0.1 :	0.25 :	1.21 :	0.02

4.2 Strength Test- Compressive Strength

Specimens having 70.6 x 70.6 x 70.6 mm as dimensions, which is shown in Fig. 3 were cast with different trial mixes with 10 M molarity having polypropylene fibers in the proportions of 0.5%, 1%, 1.5%. As shown in Fig. 4, the mortar samples are kept in room temperature for curing after it is demoulded. The conventional OPC mortar cubes were also cast in order to co-relate both the strength results. For each system, triplicate specimens were cast. Specimens were tested employing universal testing machine (UTM–1000 kN) after ambient curing of 7 and 28 days. The load was gradually increased at a rate of 1.1kN/sec. The load at which the failure of the mortar samples occurred was noted.

Fig 3. Casting of mortars

Fig 4. Ambient curing

4.3 Impact strength test (ACI Committee 544 2R)

This test yields the number of blows necessary to cause the 1^{st} split in the form of crack and the total collapse of test specimens [21]. This number serves as a qualitative measure of the energy that the specimen can withstand at certain distress levels. The size of the sample is a cylinder of 150 mm diameter and 65 mm thickness. Specimens were cast as shown in Fig 5.

4.3.1 Apparatus

The major components of the drop-weight test apparatus were: (1) a hand operated compaction hammer weighing 4.54 kg with a free fall from a height of 18-in. (457-mm), (2) a 63.5 mm diameter ball made of steel and (3) a base plate where the specimens were placed and provided with a bracket.

During testing, the number of blows (N_1) that caused the first break was noted as the initial crack strength. The number of blows (N_2) that led to the complete collapse of the sample was noted as the fracture strength. The energy absorption capacity due to impact loading of each specimen can be determined from the following equation,

Impact Energy in kN-mm[22],

$$(E_{imp}) = \frac{1}{2}(n \times m \times V_i^2) \quad (1)$$

where, m = weight of the hammer,

n= number of blows and

V_i = Impact velocity.

The impact velocity can be calculated as follows

$$H_f = (gx^2)/2 \quad (2)$$

$$V_i = g * x \quad (3)$$

$$m = W/g \quad (4)$$

where, g is acceleration due to gravity, x is the time taken for the free fall of hammer, H_f is the hammer height of fall, Substituting the known values in equation (2) we get,

$$457 = (9810\ x^2)/2$$

$$x = 0.305 \text{ seconds}$$

$$V_i = 9810 \times 0.305$$

$$= 2992.05 \text{ mm/s}$$

Fig 5. Specimens for drop weight impact test

4.4 Slant Shear Test (Bond strength Test for Repair Material- ASTM C882)

Fig 6. Casting of substrate with wooden block out

Fig 7. Casting of Repair material after 28 days

For the casting of specimens, top portion was cast with a concrete substrate and the rest is filled with geopolymer mortar in the specimens of size 100 ×100 × 500 mm which are shown in Fig. 6 and Fig. 7. This was achieved by a wooden block out. Concrete of M20 grade was cast as the substrate and allowed for 28 days curing. Then, the substrate concrete surface was roughened by wire brushing and fibre reinforced geopolymer mortar was placed in (100 ×100 × 500) mm^3 prism mould having an interface angle of 30^o to the vertical as per ASTM C882 code[23,26]. Curing was done for the next 28 days and tested under axial compression in a UTM machine.

5 Results and Discussion

5.1 XRF Results for Fly-ash

Based on these results, it was inferred that CaO composition in Class F type was found to be 5.09%, which is less than 10%, confirming as Fly-ash of Class F, as per ASTM C618 code. Also Class C had 49.16% CaO, which was greater than 10%, confirming it as Class C Fly-ash [16] which made the possibility for ambient temperature curing in geopolymer.

Table 3 XRF Results from CECRI, KARAIKUDI

	Al_2O_3	SiO_2	SO_3	CaO	TiO_2	Fe_2O_3
Class F	6.78	38.30	-	5.09	10.80	42.39
Class C	9.26	5.38	2.021	49.16	11.22	10.51

5.2 7th day and 28th day Compressive Strength results

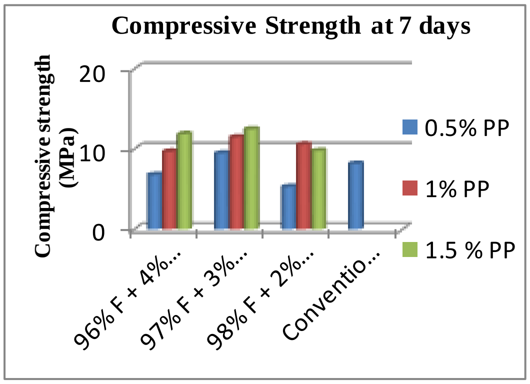

Fig 8. 7 Day Compressive Strength in MPa

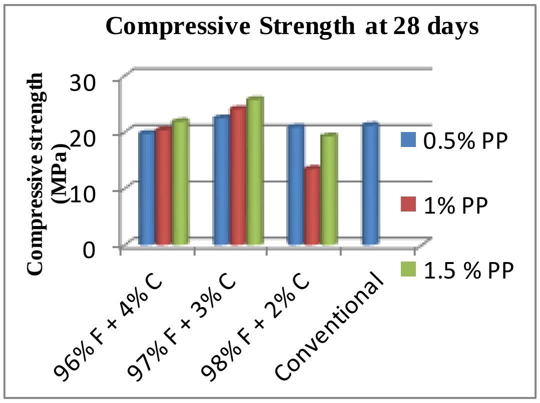

Fig 9. 28 Day Compressive Strength in MPa
Here F – Class F Fly ash, C- Class C Fly ash

From Fig. 8 and 9 it could be said that the increase in molar concentration of NaOH increased its strength but at the same time, it reduced the workability. Addition of polypropylene fibres prevented brittle failure since the failure had a bulging effect. These fibers acted as a bridging force between the particles thereby eliminating sudden failure. Also, fiber usage prevented the propagation of microcracks.

5.3 *Impact Strength Results*

The drop weight impact strength results are shown in Table 4. When the fiber content was increased gradually, the number of drops or free fall for the development of initial crack and also the number of blows that caused the total split got raised respectively. Also, it was found that the conventional geopolymer mortar had a brittle failure having a single larger crack. But with the addition of fibers, there was a change in the crack pattern into several narrow cracks showing that the fibers could retain the fragments together after full damage due to impact load.

Fig 7. Crack pattern in the impact discs

Table 4 Results from Drop Weight Test (Blows)

Trials	Number of blows that caused 1st crack	Impact energy (kN-mm)	Number of blows to failure	Impact energy (kN-mm)
Conventional GPC	10	204.23	29	592.67
4%C + 0.5% PP	5	102.12	20	408.46
4%C +1 % PP	25	510.58	32	653.54
4%C +1.5 % PP	16	326.77	47	959.88
3%C +0.5 % PP	31	633.11	76	1552.15
3%C +1 % PP	39	796.49	79	1613.42
3%C +1.5 % PP	***36***	***735.23***	***84***	***1715.53***
2%C +0.5% PP	18	367.61	31	633.11
2%C +1 % PP	15	306.35	46	939.46
2%C +1.5 % PP	24	490.15	58	1184.53

Here C-Class C Fly ash and PP-Polypropylene fibers

5.4 Slant Shear Bond Strength Results

Springkel in 2000 [24, 25], gave a brief summary on the bond strength at the interface and the test results were described as in Table 5.

Table 5 Interfacial Bond Strength quality

Bond Quality	Interfacial Bond strength(MPa)
Excellent	>2.1
Very Good	1.7- 2.1
Good	1.4- 1.7
Fair	0.7 -1.4
Poor	0-0.7

The slant shear strength for different trial mixes were listed in the Table 6.

Table 6 Slant shear Bond strength (MPa)

TRIAL	Bond strength(MPa)	Failure mode
4%C+ 0.5% PP	6.2	A
4%C +1 % PP	6.7	A
4%C+1.5 % PP	6.3	A
3%C+0.5 % PP	7.8	B
3%C +1 % PP	8.1	A
3%C+1.5%PP	8.15	A
2%C +0.5% PP	6	B
2%C +1 % PP	4.5	B
2%C+1.5 % PP	4.9	B

A = Failure at the interface region, B = Failure at interface along with partial substrate failure, C=Failure of repair material.

6 Conclusion

From these experimental investigations, the following results can be stated as:

1. 7 day Compressive strength of 98%F + 3%C along with 0.5%, 1%, 1.5% fiber addition trial combination had an increase in its strength by 15.8%, 40.24% and 52.4% than the conventional respectively.
2. 28 days Compressive strength of 98%F + 3%C along with 0.5%,1%,1.5% fiber addition combination showed an increase in its strength than all other combinations and it was found to be 6.13%,13.6%,21.7% increase than the conventional respectively.
3. The energy absorption capacity for 3 % C was found to be higher for a dosage of 0.5%, 1%, 1.5 % PP with an increase of 161.8%, 172%, 189.45% respectively than the conventional geopolymer mortar.
4. This higher impact resistance is due to the synthetic fiber (polypropylene) addition and proves its application in the pavement repair and in overlays.
5. Results from the bond strength test reveal that the FRGC specimens show a better interfacial bond with the old concrete.

On the whole, cementless (Geopolymer) production has two major environmental benefits. First is that they are produced from industrial wastes that pave the way to reuse them as well as prove to be an excellent solution to landfill problem and fly-ash removal. And also, ambient temperature curing lessen the water usage.

Thus polypropylene fiber reinforced geopolymer composite prove to be an eco-friendly alternative repair material to OPC.

References

[1] J. Davidovits, "Geopolymers: inorganic polymeric new materials", Journal of Thermal Analysis, vol.37, pp.1633-1656, 1991.

[2] E .Gartner, "Industrially Interesting Approaches to Low-CO2 Cements", Cement and Concrete Research, vol.34,no.9,pp.1489-1498, 2004.

[3] Cristina Zanotti, Paulo H. R. Borges, Aamer Bhutta, Yang Du, Nemkumar Banthia, "Bond strength of PVA fiber reinforced geopolymer repair to Portland cement concrete substrate", 9th RILEM- International Symposium on Fiber Reinforced Concrete, 2016.

[4] Abideng Hawa, Danupon Tonnayopas, Woraphot Prachasaree and Pichai Taneernanon, "Development and Performance Evaluation of Very High Early Strength Geopolymer for Rapid Road Repair", Advances in Materials Science and Engineering, vol.6, 2013.

[5] A. Z. Warid Wazien et al, "Potential of Geopolymer Mortar as Concrete Repairing Materials", Materials Science Forum, vol. 857, pp. 382-387, 2016.

[6] F.Pacheco-Torgal, J.P. Castro-Gomes, S. Jalali, "Adhesion characterization of tungsten mine waste geopolymeric binder. Influence of OPC concrete substrate surface treatment", Construction and Building Materials, vol.22,no.3, pp. 154-161, 2008.

[7]K. Kobayashi, T. Iizuka, H. Kurachi, K. Rokugo, "Corrosion protection performance of High Performance Fiber Reinforced Cement Composites as a repair material", Cement and Concrete Composites, vol.32,no.6,, pp. 411–420, 2010.

[8] Mohammed Haloob Al-Majidi, Andreas P. Lampropoulos, Andrew B. Cundy, Ourania T. Tsioulou, Salam Al-Rekabi, "A novel corrosion resistant repair technique for existing reinforced concrete (RC) elements using polyvinyl alcohol fibre reinforced geopolymer concrete (PVAFRGC)", Construction and Building Materials, vol.164, pp.603-619, 2018.

[9] A. Z.Warid Wazien et al, "Compressive and bonding strength of fly ash based geopolymer mortar", AIP Conference Proceedings,vol.1887, no.1, 2017.

[10] A. Z Warid Wazien et al, "Strength and Density of Geopolymer Mortar Cured at Ambient Temperature for Use as Repair Material", IOP Conference Series: Materials Science and Engineering, vol.133, 2016.

[11] T. Sujatha, K. Kannapiran , S. Nagan, "Strength assessment of heat cured geopolymer slender column", Asian Journal of Civil Engineering (building and housing),vol.13, no. 5, pp.635-646, 2012.

[12]Sakonwan Hanjitsuwan, Tanakorn Phoongernkham, "Alternative Repair Material made from fly ash-Portland concrete-commercial repair geopolymers", International Journal of Advances in Mechanical and Civil Engineering, vol.5, no.2, 2018.

[13] S.Pangdaeng, T. Phoo-ngernkham, V.Sata, P. Chindaprasirt, "Influence of curing conditions on properties of high calcium fly ash geopolymer containing Portland cement as additive", Materials & Design, vol.53, pp.269-274, 2014.

[14] Prinya Chindaprasirt , Pre De Silva, Kwesi Sagoe-Crentsil, Sakonwan Hanjitsuwan, "Effect of SiO2 and Al2O3 on the setting and hardening of high calcium fly ash-based geopolymer systems", Journal of Material Sciences,vol.47,pp.4876-4883, 2012.

[15] Tanakorn Phoo-ngernkham, Vanchai Sata, Sakonwan Hanjitsuwan, Charoenchai Ridtirud,Shigemitsu Hatanaka,Prinya Chindaprasirt, "High calcium fly ash geopolymer mortar containing Portland cement for use as repair material", Construction and Building Materials, vol.98,pp.482-488, 2015.

[16] ASTM standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete (C618–05).In: Annual book of ASTM standards, concrete and aggregates, American Society for Testing Materials, vol. 04.no.02, 2005.

[17] Pailyn Thongsanitgarn, Watcharapong Wongkeo, Arnon Chaipanich, Chi Sun Poon, "Heat of hydration of Portland high-calcium fly ash

cement incorporating limestone powder: Effect of limestone particle size", Construction and Building Materials, vol.66, pp.410–417, 2014.
[18] K.P.Rekha,R,Hazeena , "Strength and durability of Fibre Reinforced Geopolymer concrete", International Journal of Scientific & Engineering Research, vol. 5, no.7, pp.412-416,2014.
[19] V .Arumugam,T.Bhagavathi Pushpa, K.M.Basanth Babu,"Effect of Polypropylene Fibers in Geopolymer Concrete ", International Journal of Engineering Science and Computing, vol. 8,no.6,pp.18125-18131, 2018.
[20] B. Vijaya Rangan, Djwantoro Hardjito, Steenie E. Wallah, Dody M.J. Sumajouw, "Studies on fly ash-based geopolymer concrete", Geopolymer: green chemistry and sustainable development solutions,1987.
[21] M.C. Nataraja, T.S. Nagaraj , S.B. Basavaraja, "Reproportioning of steel fibre reinforced concrete mixes and their impact resistance", Cement and Concrete Research, vol.35,no.12, pp.2350 – 2359, 2005.
[22]G Murali, A S Shanthi , G Mohan Ganesh, "Empirical relation between the Impact Energy and Compressive strength for Fiber Reinforced Concrete", Journal of Scientific & Industrial Research, vol 73, pp. 469-473, 2014.
[23] ASTM C882/C882M-13a, Standard Test Method for Bond Strength of Epoxy resin Systems Used with Concrete by Slant Shear, ASTM International, West Conshohocken, PA, 2013.
[24] M.M. Springkel, C .Ozyildirim, "Evaluation of high performance concrete overlays placed on Route 60 over Lynnhaven Inlet in Virginia", Virginia transportation Research council,2000.
[25] Bassam A. Tayeh , B. H. Abu Bakar , M. A. Megat Johari ,Yen Lei Voo, "Evaluation of Bond Strength between Normal Concrete Substrate and Ultra High Performance Fiber Concrete as a Repair Material", Procedia Engineering, vol.54, pp.554 – 563, 2013.
[26] Ghasan F. Huseien, Jahangir Mirza , Mohammad Ismail, S.K. Ghoshal, Mohd Azreen Mohd Ariffin, "Effect of metakaolin replaced granulated blast furnace slag on fresh and early strength properties of geopolymer mortar", Ain Shams Engineering Journal, vol.9,no.4,pp.1557-1566, 2016.
[27] Luxia Song, Zhen Li, Ping Duan, Min Huang, Xiaofei Hao, Yongsheng Yu, "Novel low cost and durable rapid-repair material derived from industrial and agricultural by-products", Ceramics International, vol.43,no.16,pp.14511-14516,2017.
[28] Zuhua Zhang, John L. Provis, Andrew Reid, Hao Wang," Geopolymer foam concrete: An emerging material for sustainable construction", Construction and Building Materials,vol.56, pp.113–127, 2014.

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