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NDT Studies on Geopolymer Concrete with Addition of Natural Fibers

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Abstract

Modern day construction activities are not proved to be enviro-friendly and most of the building materials we use for the construction purpose consumes lot of natural resources and have huge carbon foot print. Innovations in civil engineering industry is also taking place apart from usage of regular materials, once such innovative material that has potential to reduce the carbon foot print is Geopolymer. In our country the research in Geopolymer concrete is rapidly picking up and many materials were tested as impregnation for Geopolymer concrete. This study is an attempt made by authors to test the NDT study based strength of Geopolymer concrete with and without addition of various natural fibers. It is found in the study that impregnation of various fibers in Geopolymer adds more strength to the concrete and also increases the density of concrete.

Keywords: *NDT studies, Geopolymer concrete, Coir fiber, Fiber reinforce concrete*

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INTRODUCTION

The cement industry has been making significant progress in reducing CO_2 emissions through improvements in process technology and enhancements in process efficiency, but further improvements are limited because CO_2 production is inherent to the basic process of calcinations of limestone. So it is essential to find a substitute material for cement which can be eco-friendly. In 1978, Joseph Davidovitis developed inorganic polymeric materials and coined the term "Geopolymer" for it. It was discovered that various calcined clays could be activated with alkaline solutions to produce hardened ceramic like products at room temperature. Geopolymer is used as the binder to completely replace the ordinary Portland cement in producing Geoploymer concrete (GPC). Geopolymer has the potential to replace Ordinary Portland Cement Concrete (OPCC) and produce fly ash based Geopolymer Cement Concrete (GPCC) with excellent physical properties, mechanical properties, fire resistance and acid resistance [1].

Much of the previous development of alkali-activated materials has been based on activated slags. But, there is a significant potential for utilization of other by-products. An enormous amount of fly ash and other by product materials is generated from power plants and there is a constant need to find new uses for them. In the US, approximately 49% of the utility wastes are simply landfilled, 41% are contained in surface impoundments, and about 10% are disposed of by discharging into old quarry operations. Increasingly, the alkali-activated materials are stored "on site" due to reduced costs to the utilities. Ultrasonic pulse velocity method is usually very helpful in detecting the presence of cracks in a structural element. The pulses are not transmitted through large air voids in a material. Hence if a void lies directly in the pulse path, the instrument will indicate the time taken by the pulse that circumvents the void by the quickest route. It is thus possible to detect large voids when a grid of pulse velocity measurements is made over a region in which these voids are located. A viscous material, such as a jelly or grease, is commonly used as a coupling agent to ensure that the vibrational energy enters the test object and can be detected by the receiving transducer (PUNDIT, 1992). A number of researchers have developed theoretical models for the prediction of relationships between pulse velocity and physico-mechanical properties, such as modulus of elasticity, compressive strength, density, porosity, and permeability [2].

Concrete is a tension-weak building material, which is often crack ridden connected to plastic and hardened states, drying shrinkage, and the like. Moreover, concrete suffers from low tensile strength, limited ductility and little resistance to cracking. The abundant production of fly ash from coal based thermal power plants as waste products becoming problem for their disposal and it is also hazardous to the environment. The inclusion of fly ash in glass fibre reinforced concrete reduces the environmental pollution and improves the workability and durability properties of concrete [3].

Geopolymer is a type of amorphous alumina-Hydroxide product that exhibits the ideal properties of rock-forming elements, i.e., hardness, chemical stability and longevity. Geopolymer binders are used together with aggregates to produce Geopolymer concretes which are ideal for building and repairing infrastructures and for pre casting units, because they have very high early strength, their setting times can be controlled and they remain intact for very long time without any need for repair.

The properties of Geopolymer include high early strength, low shrinkage, freeze-thaw resistance, sulphate resistance and corrosion resistance. These high-alkali binders do not generate any alkali-aggregate reaction [4]. Concrete is one of the most widely used construction materials; it is usually associated with Portland cement as the main. The global warming is caused by the emission of greenhouse gases, such as CO_2, to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global component for making concrete. The demand for concrete as a construction material is on the increase. It is estimated that the production of cement will increase from about from 1.5 billion tons in 1995 to 2.2 billion tons in 2010 [5]. Addition of glass fibers resulted in decrease of the mechanical strength of Geopolymer concrete both in ambient curing and in heat curing at all ages. Compressive, split tensile and flexural strength of heat cured glass fiber reinforced Geopolymer concrete is much higher than that of ambient cured glass fiber reinforced Geopolymer concrete. In ambient curing, the strength increases as the age of concrete increases from 7 to 28 days. The strength of heat cured glass fiber reinforced Geopolymer concrete does not increase substantially after 7 days [6].

Geopolymer concrete can be widely used in the manufacture of precast structures. It can be used in areas where faster strength achievement is needed. Concrete and helps to prevent global warming and to utilize the fly ash effectively. Fibre reinforced Geopolymer concrete completely eliminates the use of cement. The Geopolymer concrete composites have relatively higher strength in short curing time (one day) than the Geopolymer concrete and ordinary Portland cement concrete [7]. In environmental aspect, waste from steel industries causes bountiful hazards to the environment and to human health. Geopolymer concrete is a new material that does not need the presence of Portland cement as a binder. Instead, the material such as fly ash (FA) is activated by alkaline liquids to produce the Geopolymeric binder. The contribution of cement industry to the CO_2 emissions is about 5% of the global CO_2 emissions and one ton of CO_2 is released in the atmosphere from one ton production of Portland cement [8].

In India around 960 million tonnes of solid waste is being generated annually as by-products during industrial, mining, municipal, agricultural, and other processes. It is important to use develop technologies for the utilization of solid waste consumption in concrete. Concrete preferred for construction, which is very durable require little or no maintains. The assumption is largely true except when it is subjected to highly aggressive environment. We build concrete structure in highly polluted urban and many other hostile conditions where other construction materials are found to be nondurable [9]. Geopolymer binders might be a promising alternative in the development of acid resistant concrete. Since Geopolymers are a novel binder that relies on alumina-silicate rather than calcium silicate hydrate bonds for structural integrity, they have been reported as being acid resistant [10].

MATERIAL AND METHODS

Fly Ash

Fly ash is one of the most abundant materials on the Earth. It is also a crucial ingredient in the creation of Geopolymer concrete due to its role in the Geopolymerization process. Fly ash is a powdery pozzolan. A pozzolan is a material that exhibits cementitious properties when combined with calcium hydroxide. Fly ash is the main by product created from the combustion of coal in coal-fired power plants. There are two “classes” of fly ash, Class F and Class C. Each class of fly ash has its own unique properties. In this project class F Fly ash was used. It was obtained from local power plant. The chemical composition of fly ash is shown in Table 1.

Table 1: *Chemical Composition of Fly Ash used in the Study.*

Chemical composition	(%)
SiO_2	54.02
Al_2O_3	22
Fe_2O_3	9.3
CaO	2.62
MgO	2.4
SO_3	0.88
K_2O	1.14
Na_2O	2.12

Alkaline Activator

Generally alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature. When the solution mixed together the both solution start to react, i.e., (polymerisation takes place) it liberate large amount of heat so it is recommended to leave it for about 24 h thus the alkaline liquid is get ready as binding agent.

Sodium Hydroxide

Sodium hydroxide pellets are taken and dissolved in the water at the rate of 16 molar concentrations. It is strongly recommended that the sodium hydroxide solution must be prepared 24 h prior to use and also if it exceeds 36 h it terminates to semi solid liquid state. So the prepared solution should be used within this time [11].

Molarity Calculation

The solids must be dissolved in water to make a solution with the required concentration. The concentration of Sodium hydroxide solution can vary in different Molar. The mass of NaOH solids in a solution varies depending on the concentration of the solution. For instance, NaOH solution with a concentration of 16 Molar consists of 16 x 40 = 640 g of NaOH solids per litre of the water, were 40 is the molecular weight of NaOH.

EXPERIMENTAL PROGRAMME

Testing the Concrete Specimens

150´150 mm cubes and 150 mm diameter 300 m high were cast out of which, three cubes were used to determine the compressive strength and cylinders were used to determine the split tensile strength at 28 days for M20 grades of Geopolymer Concrete. And also tested the specimens using rebound hammer and UPV test. The coir fibers were added in different ratios that are 0.5, 1.0, and 1.5%, respectively (Figure 1). The coir fibers added in different lengths 1, 2, and 3 cm (Tables 2–4). All Geopolymer concrete were made with mix design procedure using IS 10262-2009 [12]. It is recommended to have necessary precaution on workers because of acidic nature of the concrete.

The aggregates were prepared in saturated-surface-dry (SSD) condition. Geopolymer concrete can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. Then the components of concrete ingredients are collected and mixed with the manual mixing. Then Alkaline liquid were then added to the mixing and the mixing was done for another 5 min. After the mixing, the specimen are filled the demoulding process is done after 24 h.

RESULT AND DISCUSSIONS

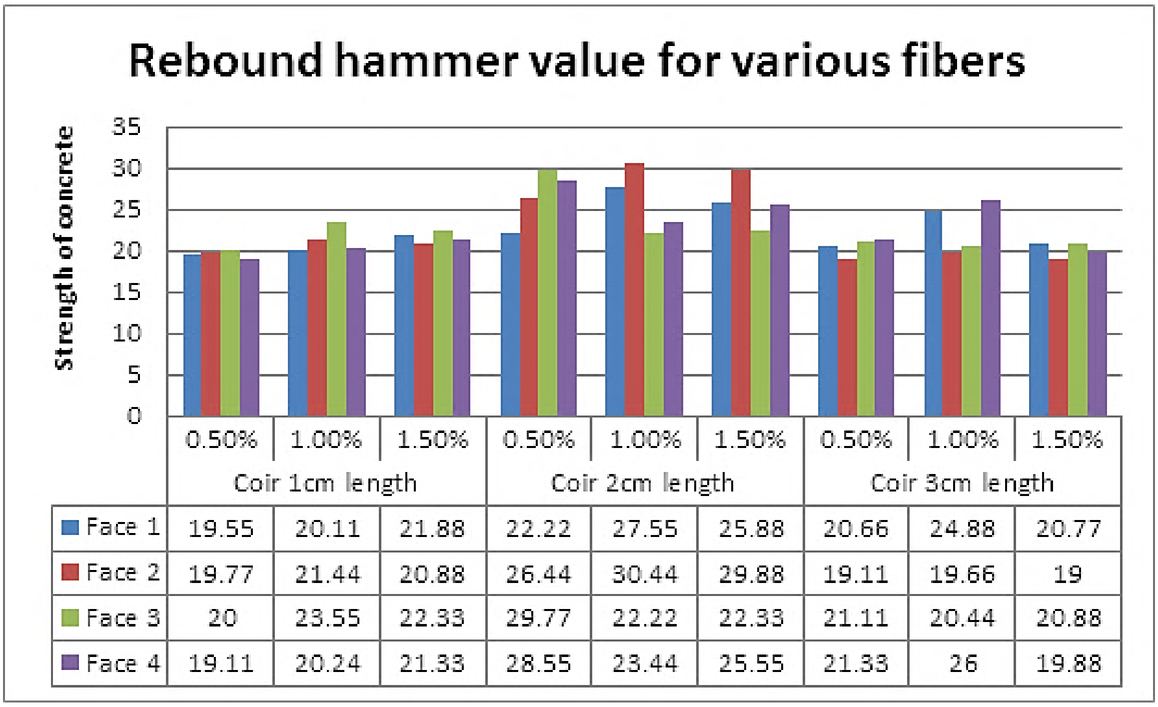

Fig. 1: *Strength Values obtained in Geopolymer with various Fibers (Rebound Hammer Values).*

Table 2: *UPV Test Result 1 cm Long Fibers.*

S. No.	Mix ID (%)	UPV reading μsec	Velocity (L/T) Km/sec	Average velocity Km/sec
1	0.5	24.5	6.12	4.58
		35.2	4.26	
		27.3	5.49	
		40.5	3.70	
		41.4	3.62	
		34.5	4.34	
2	1.0	43.5	3.4	4.69
		44.2	3.39	
		32.9	4.55	
		31.2	4.80	
		26.1	5.74	
		24.1	6.22	
3	1.5	34.2	4.38	4.26
		32.9	4.55	
		43.8	3.42	
		41.6	3.61	
		39	3.84	
		25.9	5.79	

Table 3: *UPV Test Result 2 cm Long Fibers.*

S. No.	Mix ID (%)	UPV reading µsec	Velocity (L/T) Km/sec	Average velocity Km/sec
1	0.5	42.3	3.54	4.25
		40.6	3.69	
		38.0	3.94	
		33.8	4.43	
		30.7	4.48	
		27.6	5.43	
2	1.0	37.2	4.03	5.61
		36.2	4.14	
		35.1	4.27	
		22.1	6.78	
		19.0	7.89	
		22.9	6.55	
3	1.5	30.0	4.83	3.28
		39.6	3.78	
		38.9	3.83	
		40.8	3.67	
		44.3	3.38	
		41.7	3.59	

Table 4: *UPV Test Result 3 cm Long Fibers.*

S. No.	Mix ID (%)	UPV reading µsec	Velocity (L/T) Km/sec	Average Velocity Km/sec
1	0.5	18.9	7.93	5.53
		24.9	6.02	
		28.1	5.33	
		37.9	3.95	
		34.7	4.32	
		44.8	3.34	
2	1.0	45.4	3.30	4
		39.6	3.78	
		43.8	4.42	
		35.7	4.20	
		40.6	3.69	
		32.4	4.62	
3	1.5	55.2	2.71	3.61
		49.6	3.02	
		32.3	4.64	
		39.5	3.79	
		41.7	3.59	
		37.9	3.95	

CONCLUSION

In this study it is found that by addition of natural fibers in the concrete the strength of Geopolymer concrete increased to more than 60%, the problem faced during the impregnation is the failure of coir fibers during the thermal curing that is required for Geopolymer concrete. This can be avoided by naturally curing the Geopolymer concrete in the sunlight for prolonged period. The strength characteristics were found via the NDT studies (Rebound hammer and UPV studies) which proved that the concrete with the addition of natural fibers have good density, less voids and also have more strength compared with the Geopolymer concrete without fibers. The addition of fibers also to be optimised, in the UPV studies its shown that increase in the fiber content creates more voids which and hindrance which may reduce the quality of concrete, an optimal dosage of 0.5–1% by weight of fly ash is suggest for proper production and curing of Geopolymer concrete.

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