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Strength Properties of Fly Ash Based Geopolymer Concrete with Sea Sand

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ABSTRACT: *The production of every ton of cement contributes to production of one ton of CO_2. With the development of infra activities, the power sector activities are also increasing. The coal based power plant produces huge quantity of fly ash, which creates its disposal problems. However to some extent, the fly ash is used as partial substitution to cement. The alkali activated fly ash concrete (Geopolymer Concrete) proposed by Devidovits, shows considerable promise for application in construction industry as an alternative to the portland cement for precast concrete. Day by day the scarcity of river sand is big problem arrising to construction industry. On the other hand the sea sand is availibile in huge quantity, but the presence of salt and chloride affects strength and durability of cement concrete. In present experimental work the sea sand (Treated and untreated) is used as an alternative to river sand and studied the properties of cement concrete and geopolymer concrete. The results show that the untreated sea sand affects the compressive strength in geopolymer concrete same as cement concrete but treated sea sand gives similar results as of river sand concrete.*

Keywords: *Alkali Activated Concrete, Fly Ash, River Sand, Sea Sand etc.*

I. INTRODUCTION

Development of contry mainly depends on the availability of infrastructure and concrete plays a vital role in the construction of this infrastructure. The concrete is mainly composed of portland cement, aggregate and water. The need of infrastruructure provokes the demand of cement more and more. The world wide consumption of concrete is estimated to be about 11.5 billion tons per year and by year 2050 it is expected to reach to 18 billion tons of concrete per year (1). This issue has a dark side of concrete. The manufacturing of portland cement releases carbon dioxide (CO_2) which is a significant contribution to green house effect. One of the efforts to produce more environmental friendly concrete is to replace the amount of Portland cement in concrete with by-product materials such as fly ash.

Another effort to make environmental friendly concrete is to develop inorganic alumina-silicate polymer, called geopolymer, synthesized from materials of geological origin or by-product materials such as fly ash that are rich in silicon and aluminium (2). Fly ash, one of the source materials for geopolymer binders, is available abundantly world wide, but to date its utilization is limited. The fly ash generation in India through thermal power plants in 2014-15 was about 185 million tons and utilization was 55.69% (3). In the future, fly ash production will increase, especially in countries such as India and China. It is estimated that by the year 2020-21 in India the production of the fly ash will be about 1373 million tons annually (ICC 2012). Accordingly, efforts to utilize this by-product material in concrete manufacture are important to make concrete more environmental friendly. For instance, every million ton of fly ash that replaces Portland cement helps to conserve one million tons of lime stone, 0.25 million tons of coal and over 80 million units of power, not withstanding the abatement of 1.5 million tons of CO_2 to atmosphere.

The worldwide concrete consumption is about 11.5 billion tons and any type of concrete the fine aggregate is very important nonexcludable ingredient. From many decades the river sand is used as fine aggragate but dredging of sand from river beds is hazardous to environment. This has made the government to restrict the use of river sand in construction. Such cases lead to use of crushed sand an alternative to river sand due to angular shape and rough texture which gives better bond strength. But in crushed sand-concrete the water required is more and the workability is less as compared to river sand-concrete. Less workable concrete affects on the strength of concrete. The workability can be increased by using admixtures but finaly the cost of concrete gets increased.

On the other hand, the sea sand is available in abundant quantity but due to presence of salt and chloride it can not be used as fine aggregate in concrete. Because the salt and chlorides affects on the strength and durability of portland cement concrete. But with the geopolymer concrete the situation is different. In cement concrete the reaction is hydration and in geopolymer concrete the reaction is polymerisation. The nature of these two reactions are exact opposite to each other. The work is carried out to study the effect of treated and untreated sea sand in cement concrete as well as geopolymer concrete.

II. MATERIALS AND METHODOLOGY

In this investigation, two types of concrete were used, that is cement concrete and geopolymer concrete. For cement concrete, locally available Ultratech 53 grade Portland cement were used as binding material. For geopolymer concrete the unprocessed fly ash, 90 % particle smaller than 45µ was used as a source material, which is a product from coal based Sofiya Thermal Power plant, Amravati, India. The chemical properties of fly ash are given in Table-1. Basalt aggregate passing from 20 mm sieve nominal size were used as a coarse aggregate. Locally available river sand and sea sand (Treated and Untreated) collected from "Gaymukh Retibazar Thane Greek" was used as a fine aggregate. For computing the effect of treated sea sand and untreated sea sand on compressive strength of cement concrete and geopolymer concrete the fineness modulus (FM) of both sands were adjusted by conducting several trials of sieve analysis so that the FM of river sand and sea sand will remain same. The proportion of ingredients was kept similar, only river sand replaced totally by sea sand. The physical properties of fine and coarse aggregates are shown in Table-2. The water cement ratio for cement concrete with river sand (CRS) and cement concrete with treated sea sand and untreated sea sand (CTS, CUS) were kept same, such as 0.5. The sodium hydroxide (NaOH with 98% purity) flake form, and sodium silicate (Na_2SiO_4 with Na_2O = 14.3%, SiO_2 = 32.9%, H_2O = 52.8% and specific gravity 1.58) in liquid form were used as an alkaline activator. For making one liter of 8, 10 and 12 molar solution; the 320gm, 400gm and 480gm NaOH were dissolved in water. The ratio of Na_2SiO_3-to- NaOH was kept 2. The alkaline activator solution was prepared before one day prior to its application.

Table 1: Composition of Fly Ash (Mass %)

SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	TiO_2	MgO	P_2O_5	SO_3	LOI*
61.85	27.36	5.18	1.47	0.08	0.63	1.84	1.0	0.54	0.05	1.0

*Loss of Ignition

The mix proportion for river sand concrete and sea sand concrete were kept same to identify the effect of treated and untreated sea sand on cement concrete and geopolymer concrete. The mix proportion for cement concrete and geopolymer concrete are shown in Table 3. In Table 4, the mix 1, 2 and 3 is for cement concrete with river sand (CRS), cement concrete with treated sea sand (CTS) and cement concrete with untreated sea sand respectively. Similarly the mix 4 to 12 is for geopolymer concrete with river sand, treated sea sand and untreated sea sand with 8, 10 and 12 molarity of NaOH. The procedure of mixing and casting of geopolymer was similar to that of cement concrete. After 24 hours from casting, all cubes of geopolymer concrete were demolded and cured at 60°C, for period of 24 hours in hot air oven. After specified period of curing, oven is switched off and cubes were allowed to cool up to room temperature then specimens were removed from oven and kept in ambient condition up to testing. The casting, demolding and curing of cement concrete was done as per our conventional method. The cement concrete cubes and geopolymer concrete cubes were tested for compressive strength at the age of 28 days of casting.

Table 2: Properties of Fine and Coarse Aggregate

Sr. No.	Properties	Results		
		River Sand	Sea sand	Coarse Agg.
01.	Particle Shape, Size	Rounded, 4.75mm	Rounded, 4.75mm	Angular, 16 mm
02.	Fineness Modulus	2.0	1.99	6.0
03.	Specific Gravity	2.63	2.67	2.71
04.	Silt /Dust Content	3.3 %	2.1 %	Nil
05.	Surface Moisture	Nil	Nil	Nil
06.	Water absorption	1.43 %	1.7 %	2.835 %

Table 3: Mix Details of Cement Concrete and Geopolymer Concrete

Sr. No.	Materials	Quantity (kg/m^3)	
		Cement Concrete	Geopolymer Concrete
1	Cement	330	--
02	Fly ash	--	330
03	Fine Aggregate	727	727
04	Coarse Aggregate	1350	1350
05	Water / Cenent Ratio	0.5	--
06	Solution / Fly Ash Ratio	--	0.4
07	Na_2SiO_3 Solution	--	88
08	NaOH Solution (8, 10 & 12 molar)	--	44

III. TESTING OF CONCRETE

The Compression test was carried out at 28 days as per I.S. 516-1975. The compression testing machine of 3000 kN capacity was used. Results of compressive strength of Cement concrete and geopolymer concrete are presented in Table 4, and the graphical variation is shown in fig. 1.

Table 4: Details of Mix and Compressive Strength

Mix	Notation	Types of Curing	Molarity of Solution	Curing Temp. (^{o}C)	Curing Duration	Comp. Strength (N/mm^2)
01	CRS	Water	--	--	28 Days	22.8
02	CTS	Water	--	--	28 Days	22.5
03	CUS	Water	--	--	28 Days	18.3
04	GRS1	Oven	08	60^{o}C	24 Hrs	18.2
05	GTS1	Oven	08	60^{o}C	24 Hrs	18.98
06	GUS1	Oven	08	60^{o}C	24 Hrs	16.5
07	GRS2	Oven	10	60^{o}C	24 Hrs	20.6
08	GTS2	Oven	10	60^{o}C	24 Hrs	20.8
09	GUS2	Oven	10	60^{o}C	24 Hrs	17.2
10	GRS3	Oven	12	60^{o}C	24 Hrs	24.9
11	GTS3	Oven	12	60^{o}C	24 Hrs	24.4
12	GUS3	Oven	12	60^{o}C	24 Hrs	20.1

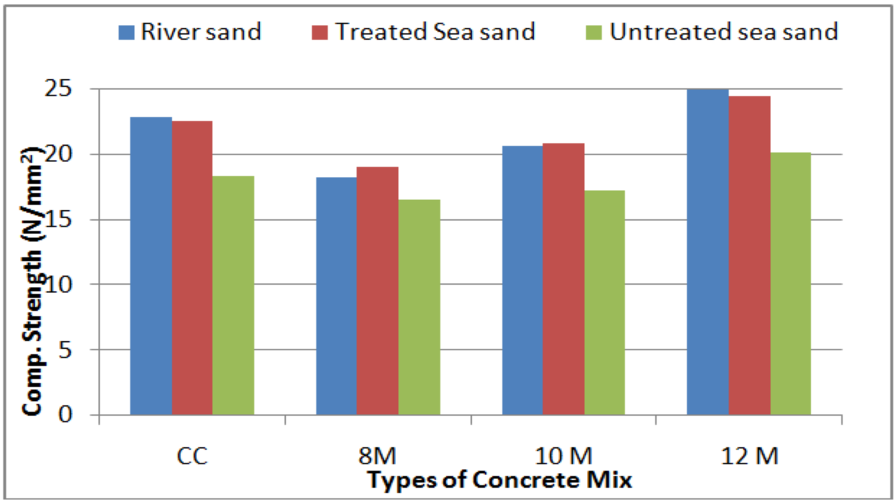

Figure 1: Variation of Compression Strength.

IV. RESULTS AND DISCUSSION

The results of cement concrete (CC) and geopolymer concrete shows that the river sand and treated sea sand gives bettor results than untreated sea sand. In the mix of cement concrete and geopolymer concrete, the compressive strength of river sand concrete and treated sea sand concrete found similar. The results of geopolymer concrete also shows that the geopolymer concrete with untreated sea sand gives less compressive strength than that of river sand concrete for same other ingredients. In geopolymer concrete, it is found that the compressive strength of geopolymer concrete increases when increasing the molarity of NaOH solution. In case of geopolymer concrete with untreated sea sand the rate of increase of compressive strength decreases when increasing the concentration of molarity of NaOH solution as compared to mix with river sand and treated sea sand

V. CONCLUSION

This paper presents the suitability of treated and untreated sea sand in cement concrete and geopolymer concrete, on the basis of compressive strength. From the experimental results, the following conclusions are drawn:

a) The river sand and treated sea sand gives similar strength in cement concrete and geopolymer concrete also.
b) Untreated sea sand gives less strength as compared to treated sea sand and river sand in cement and geopolymer concrete.
c) When concentration of NaOH solution in terms of molarity the compressive strength of geopolymer concrete get increase for all types of sand, but rate of increase found less in untreated sea sand.
d) Effect of unwashed sea sand in geopolymer concrete was similar as in cement concrete.
e) Due to the affect of chloride and salt, the 18.67 % compressive strength decreases in cement concrete.
f) In case of 8M, 10M and 12M of geopolymer concrete, the 13.07%, 13.13% and 17.62% strength reduce due to effect of chloride and salt in untreated sea sand.

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