Experimental Study on Geopolymer Concrete by Partially Replacement of Fly Ash with Waste Kota Stone Powder

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Abstract: - ***This The demand of concrete is increasing day by day and cement is used for satisfying the need of development of infrastructure facilities, 1 tone cement production generates 1 tone CO_2, which adversely affect the environment. In order to reduce the use of OPC and CO_2 generation, the new generation concrete has been developed such as Geopolymer Concrete. It uses Fly ash and Alkaline Solution as their binding materials Geopolymer requires oven curing temperature 60°C for a period of 24 hours. The present work is to study the effect of waste Kota stone powder on Fly ash based Geopolymer Concrete as partial replacement with fly ash. The alkaline solution used for present study is sodium silicate (Na_2SiO_3) and 12M sodium hydroxide solution (NaOH) and various sodium silicate to sodium hydroxide ratio 2.0, 2.5 and 3.0. The casted cube and cylinder will be cured in oven heated at 60°C for 24 hours and to ascertain the behavior of Geopolymer Concrete mixed with Kota stone powder as partial replacement at 0%, 5% and 10% with fly ash, thereby measuring the influence of compressive strength (cube and cylinder) after 7 days, 14 days, and 28 days of curing, split tensile strength after 28 days of curing and porosity test after 28 days.***

Index Terms - Geopolymer, molarity of sodium hydroxide, sodium silicate to sodium hydroxide ratio, Kota stone replacement.

I. INTRODUCTION

Nowadays, the increase in the people's attention on the conservation of natural resources and minimization of environment depletion has led to look at the alternatives to accustomed construction materials. Currently, ordinary Portland cement-based concrete is the leading construction material across the world, with the cement usage being 4.0 billion tons per annumn and growth rate being 4% per annumn [1]. The major problems associated with the Portland cement are its production, which is energy consuming and more significantly it releases very high volume of carbon dioxide in to the atmosphere. At the same time the disposal of industrial wastes such as y ash, ground granulated blast furnace slag, mine waste, red mud etc., has become a big problem, it requires large areas of useful land and has huge impact on the environment. In these circumstances geopolymer concrete is found to be one of the better alternatives in terms of reducing the global warming, as it can reduce the CO_2 emissions caused by cement industries by about 80% [2]. Geopolymer concrete (GPC) is a sustainable material which not only utilises industrial wastes such as fly ash effectively but also serves as a better alternative to ordinary Portland cement concrete [3].

Geopolymer concrete is a new form of concrete which is produced by the alkali activation of material rich in aluminosilicates [4]. Geopolymer binders can be produced from variety of natural materials and industrial by-products like metakaolin, fly ash, bottom ash, ground granulated blast furnace slag, red mud, etc. Of these, fly ash and bottom ash are a widely used source material due to its low cost, large availability and chemical composition which is suitable to make geopolymer.

The geopolymer technology provides a new good and green solution to the utilization of fly ash, avoiding its negative impact on environment and ecology. The alumina and silica in fly ash can be activated with alkali to form geopolymer. Moreover, the toxic trace metal elements can be trapped and fixed in the geopolymer structure [5]. Fly ash-based geopolymer usually show mechanical strength and durability nearly comparable to hydrated Portland cement and can be used as a class of green cement with natural resource efficiency [6].

The sodium hydroxide and sodium silicate based geopolymer concrete is most explored combination of the geopolymer concrete. On the other side Potassium hydroxide and Potassium silicate-based research is very limited. The combination of various alkaline solutions is done by few researchers. Potassium hydroxide when mixed with water gives less heat while solution is prepared, therefore it can be used after 4-5 hours. As it generates less heat during the making of solutions, it makes potassium hydroxide safer than sodium hydroxide.

The contribution of Ordinary Portland Cement (OPC) production worldwide to green-house gas emission is estimated to be approximately 1.35 billion tons annually or approximately 7 of the total greenhouse gas emission to the earth's atmosphere. Also, it has been reported than many concrete structures, especially those built in corrosive environment start to deteriorate after 20 to 30 years, even though they have been designed for more than 50 years of service life. Thus, durability of structure become a critical issue. Thus, the Portland cement industry does not quite fit the contemporary desirable picture of a sustainable eco-friendly industry.

There is a need to find an alternate binder which should be similar or superior to that of Portland cement use in concretes in respect of parameters such as: processing conditions for production of concrete of concrete mixes, mechanical and durability properties, long term chemical stability of the binding system with common filler aggregate system such as sand, crushed natural stones, etc.

The purpose of the current study was to compare effect of using different alkaline activator ratio to the compressive strength of cube and cylinder, split tensile strength and porosity where some amount of the fly ash is replaced with the waste kota stone powder.

II. MATERIALS: -

Fly ash

In the present experimental work, low calcium, ASTM class F fly ash obtain from the thermal power station, Gandhinagar was used as the base material. The chemical composition of fly ash is shown in Table 1

Table -1: Chemical composition of fly ash

Sr. No.	TEST NAME	RESULT (%)	Specification As per IS:3812(part 1)-2013
1	SO_3	0.54	Max.: 3.0
2	Na_2O	0.58	Max.: 1.5
3	SiO_2	61.88	Min.: 35
4	$SiO_2+Al_2O_3+Fe_2O_3$	92.12	Min.: 70
5	Reactive Silica	35.38	Min.: 20
6	MgO	1.58	Max.: 5.0
7	Total chlorides	0.03	Max.: 0.05

Alkaline Liquids

A combination of sodium silicate and sodium hydroxide was chosen as the alkaline liquid. The sodium hydroxide (NaOH) solids were a commercial grade from pellets with 98-99% purity. The sodium hydroxide (NaOH) solution was prepared by dissolving the flakes or pallets in water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. in this experimental work, NaOH solution with a concentration of 12M considered of 12 x 40 = 480grams of NaOH solids (in pellet form) per liter of the solution, where 40 is the molecular weight of NaOH. The alkali activator was prepared 24 hours prior to be used by dissolving NaOH pellets in distilled water to ensure the heat produced from the reaction is dissipated.

Aggregates

Generally, locally available coarse aggregate with combination of 20mm (70%) and 10mm (30%) are used in the present work. Also, natural available river sand of Zone II is used as a fine aggregate.

Kota Stone Powder

Kota Stone is a fine-grained variety of limestone, quarried at Kota district, Rajasthan, India. While the cutting of the Kota stone, very fine powder dust produced which is called Kota stone powder. The Kota stone powder is like the waste material which is full of lime, silica and alumina. In present work, used Kota stone powder is very fine, which pass through 90-micron sieve. From the past research its clearly shows that the lime work as the binder material as in geopolymer concrete and which replace by few amount of binder material. In present work fly ash is replace with 0%, 5%, and 10% of Kota stone powder. The chemical composition of kota stone powder are shown in Table 2.

Table -2: Chemical composition of kota stone powder

Chemical Composition	Percentage
LIME(CaO)	37.86%
SILICA(SiO_2)	26.67%
ALUMINA(Al_2O_3)	3.4%
OTHER OXIDES LIKE Na, Mg	1.9%

III. Methodology

The laboratory work has been carried out to investigate maximum compressive and split tensile strength of geopolymer concrete with different alkali solution ratio and different dosage of kota stone powder replacement. In this study also, the curing temperature is constant as 60°C and molarity of NaOH is 12M. There is no standard mix design procedure available for geopolymer concrete using fly ash and alkaline liquid. The following table 3 shows the mix design of geopolymer concrete.

Table 3 Mix design

Na_2SiO_3/NaOH	2			2.5			3		
NaOH (kg/m^3)	60			51.42			45		
Na_2SiO_3 (kg/m^3)	120			128.571			135		
Total water (kg/m^3)	116.946			117.028			117.185		
Aggregate (kg/m^3)	1243.57			1241.97			1240.77		
Sand (kg/m^3)	632.7			631.9			631.3		
Fly ash (kg/m^3)	450	427.5	405	450	427.5	405	450	427.5	405
Kota Stone Powder (kg/m^3)	0	22.5	45	0	22.5	45	0	22.5	45

IV. Experimental Study And Test Result

For compressive strength test, cube specimens of dimensions 150mm x 150mm x150 mm were casted, then cubes are putted in oven for 24 hours at 60°C after unmolding cube. The cubes are tested for compressive strength on compressive testing machine after 7day, 14day and 28day. For split tensile test, cylinder specimens of dimeter and height 150mm x 300 mm are casted, then cylinder are putted in oven for 24 hours at 60°C after unmolding. The cylinder is tested for split tensile strength after 28day.

For the porosity test; the cubes are casted and after 28 days the cube is firstly, dried in oven at 100°C for 24 hours and measure weight than after 2-hour heating in oven again measure the weight of cube, if the difference between weight is less than 0.5% taken as the initial dry weight (W_d). After that cube placed in air for 30 min to make it in room temperature. Place cube in water for 30 min and measure weight of submerged cube and taken as submerged weight (W_s). Calculate porosity from following equation:

$$P = [\, 1 - ((W_d - W_s) / \rho_w) / V_T)] \times 100$$

Where,

P = porosity

W_d = oven dry weight, g

W_s = submerged weight, g

ρ_w = density of water, g/cm^3

V_T = total volume, cm^3

Table 4 Test result (Compressive strength and split tensile strength)

Mix Proportion	Compressive strength (N/mm^2) Cube			Cylinder			Split tensile strength (N/mm^2)
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days	28 Days
2A0	22.30	34.60	38.74	18.20	27.07	32.20	2.12
2A5	24.07	38.52	45.69	20.65	29.97	38.10	2.31
2A10	27.04	41.18	49.11	21.45	31.60	40.95	2.45
2.5A0	30.15	42.37	49.93	24.76	33.92	41.50	2.71
2.5A5	34.70	44.30	55.41	27.24	35.39	44.37	3.13
2.5A10	36.87	49.08	57.70	30.95	40.84	48.31	3.48
3A0	24.56	4013	42.34	20.09	30.92	34.12	2.33
3A5	30.62	42.01	48.46	23.11	32.46	39.47	2.65
3A10	34.28	46.84	51.01	27.12	35.40	43.75	3.01

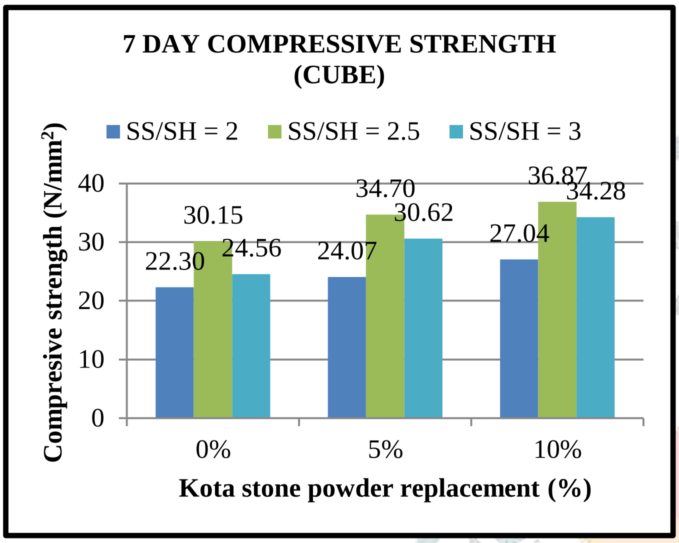

Chart -1: 7 Day compressive strength (Cube) (N/mm^2)

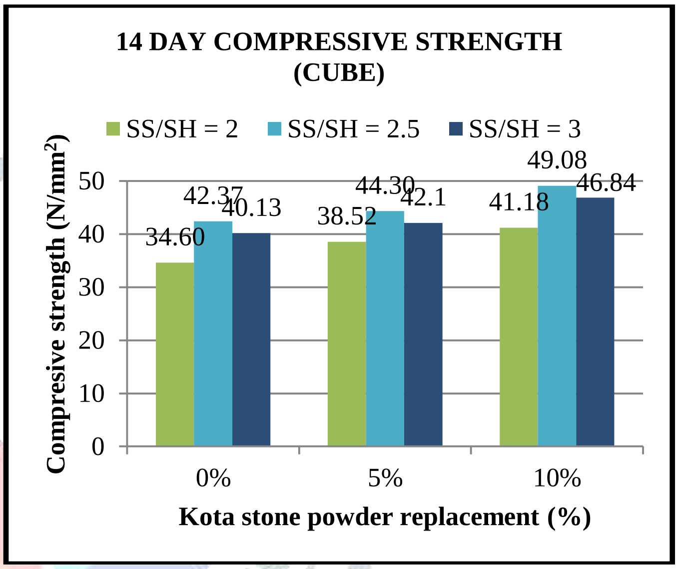

Chart -2: 14 Day compressive strength (Cube) (N/mm^2)

Table 5 Test Result: (Compressive strength Ratio (Cylinder/Cube) and Porosity)

Mix Proportion	Cylinder / Cube Compression Strength 7 Days	14 Days	28 Days	Porosity (%) 28 Days
2A0	0.82	0.78	0.83	5.29
2A5	0.86	0.78	0.82	4.72
2A10	0.79	0.77	0.85	4.57
2.5A0	0.82	0.80	0.83	4.58
2.5A5	0.79	0.81	0.81	4.01
2.5A10	0.84	0.83	0.84	3.60
3A0	0.82	0.77	0.81	4.91
3A5	0.79	0.77	0.85	4.33
3A10	0.79	0.78	0.87	4.15

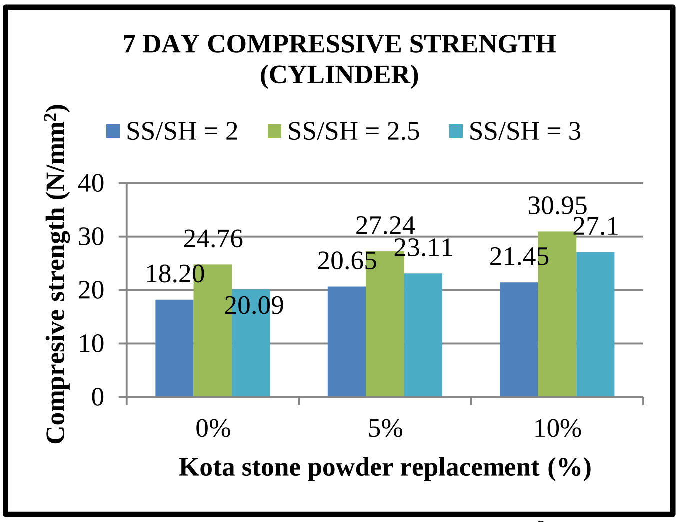

Chart -3: 28 Day compressive strength(Cube) (N/mm^2)

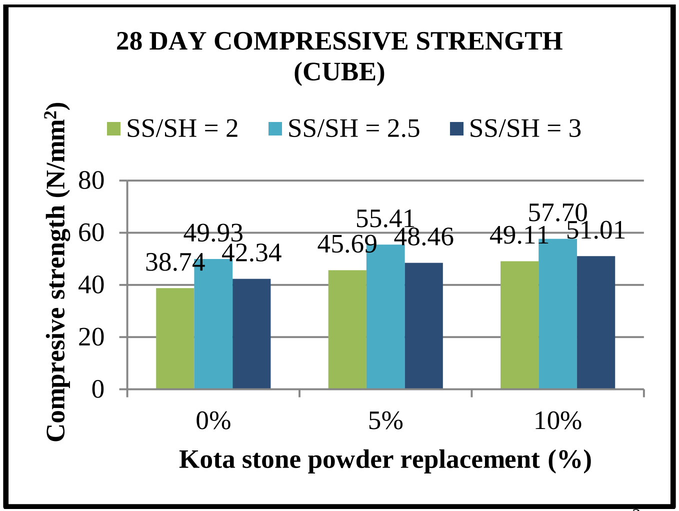

Chart -4: 7 Day compressive strength(Cylinder) (N/mm^2)

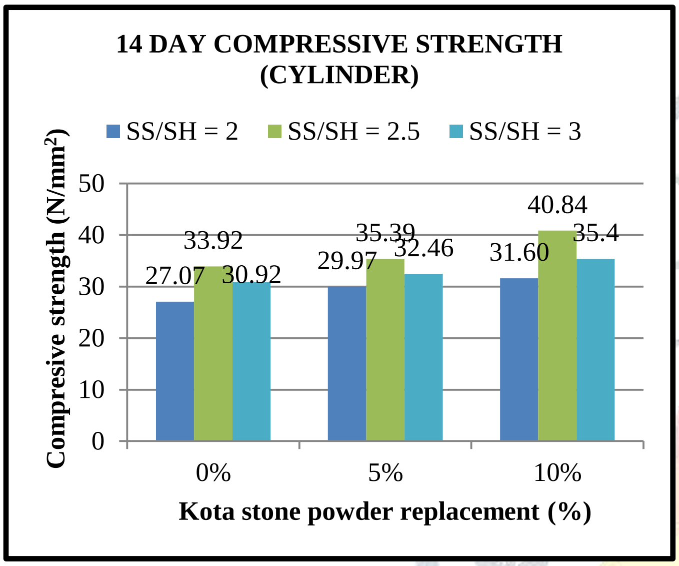

Chart -5: 14 Day compressive strength(Cylinder) (N/mm^2)

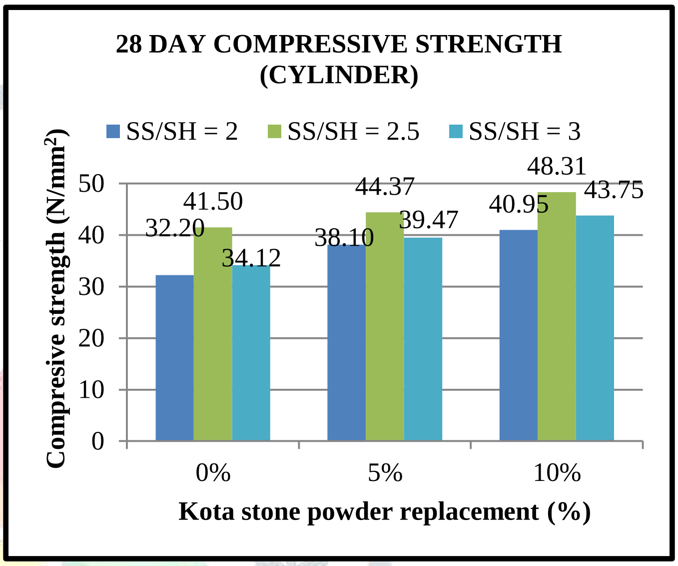

Chart -6: 28 Day compressive strength(Cylinder) (N/mm^2)

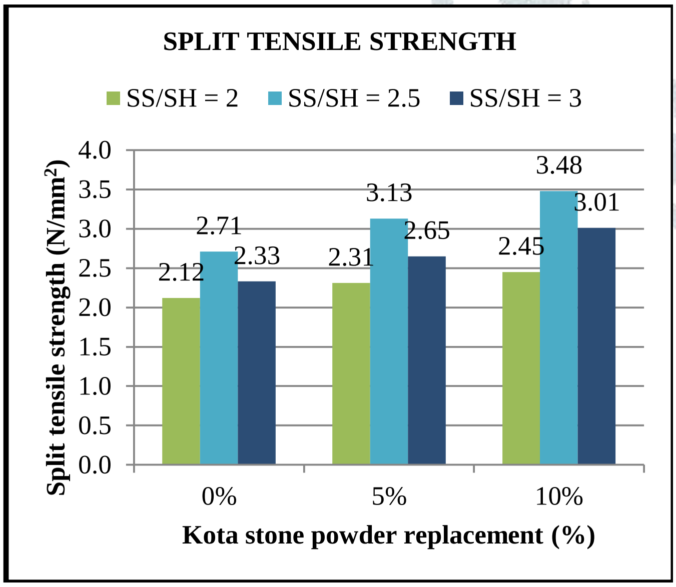

Chart -7: Split tensile strength (N/mm^2)

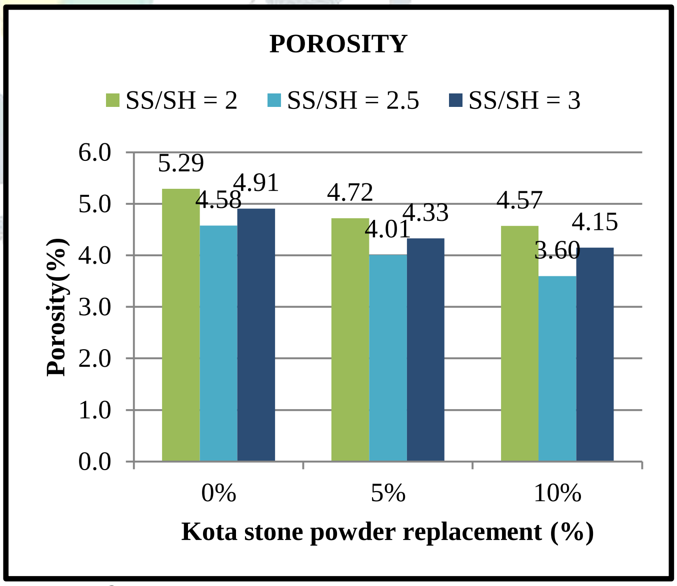

Chart -8: Porosity (%)

V. CONCLUSION

Geopolymer concrete is beneficial for environment (produce 80% less CO_2 gas). Moreover, it is great in compression as well as in tension; Here, I show some results of compressive strength and split tensile strength and porosity with changes in materials especially Sodium Silicate (SS) and Sodium Hydroxide (SH) as well as in Kota stone powder replacement. The results are as impressive as expected.

- With 10% replacement of fly ash by kota stone powder gives maximum strength for variation SS/SH=2, SS/SH = 2.5 & SS/SH=3 the compressive strength are respectively 49.11N/mm^2, 57.70 N/mm^2 and 51.01N/mm^2 at 28days for cube specimens which are respectively 27%, 16% and 20% increment to normal mix of SS/SH=2, SS/SH= 2.5 and SS/SH=3.
- With 10% replacement of fly ash by kota stone powder gives maximum strength for variation SS/SH=2, SS/SH = 2.5 & SS/SH=3 the compressive strength are respectively 40.95 N/mm^2, 48.31 N/mm^2 and 43.75 N/mm^2 at 28days for cylinder specimens which are respectively 18%, 22% and 16% increment to normal mix of SS/SH=2, SS/SH= 2.5 and SS/SH=3.
- With 10% replacement of fly ash by kota stone powder gives maximum strength for variation SS/SH=2, SS/SH = 2.5 & SS/SH=3 the split tensile strength are respectively 2.45 N/mm^2, 3.48 N/mm^2 and 3.01 N/mm^2 at 28days for cylinder specimens which are respectively 16%, 28% and 29% increment to normal mix of SS/SH=2, SS/SH= 2.5 and SS/SH=3.
- With 10% replacement of fly ash by kota stone powder gives minimum porosity for variation SS/SH=2, SS/SH = 2.5 & SS/SH=3 the porosity value are respectively 4.57%, 3.6% and 4.15% at 28days for cube specimens which are respectively 14%, 21% and 15% decrees to normal mix of SS/SH=2, SS/SH= 2.5 and SS/SH=3.
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