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A STUDY ON CONVENTIONAL CONCRETE & GEOPOLYMER CONCRETE

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ABSTRACT: - Ordinary Portland cement (OPC), along with steel is the main construction material used in reinforced concrete structures. However, the manufacturing of Portland cement and the concrete production are both energy intensive and result in considerable CO2 emissions. Cement production alone is estimated as being responsible for 6-10% of total CO2 production worldwide, with the production of 1 ton of cement producing 1 ton of CO2. As considerable quantities of Portland cement are manufactured worldwide, even a small reduction in its production could result in significant environmental benefits in terms of CO2 emission The use of inorganic residual products from certain manufacturing industries has been used for long as partial replacement for Portland cement. These are most notably fly-ash, rice husk ash, ground granulated blast-furnace slag, waste paper sludge ash, micro-silica etc. There is considerable possibility for the advancement of cement-free binders and represents an area which could impact significantly on the drive for more sustainable construction materials and practices.

Geopolymer concrete has glorious resistance to chemical attack and shows promise within the use of aggressive environment where the sturdiness/durability of Portland cement concrete is also a concern. This can be applicable in aggressive marine environments, environment with high carbon or sulphate rich soils. Similarly in highly acidic environment, geopolymer shows superior acid resistance and may be appropriate for applications like mining, some manufacturing industries and sewer system.

Keywords: Geopolymer, Compressive strength, water, aggregate, sand, cement.

General:
It is recognized that alkali additions to fly-ash or slag can activate these materials to set and harden in their own right thereby forming alkali-activated systems; however, the focus of this study is on the use of chemical pre-treatment of fly-ash to form a geopolymer which will set and harden and could be offered as a viable alternative to Portland cement. This differs basically from other types alkaline activated material (such as activated slag) since the product is polymer instead of calcium silicate hydrate (C-S-H) gel. Considerable research has now been published on the development of geopolymeric binders and their properties. However, the geopolymers developed have a wide range of mix designs and additives. The research to date has focused on the properties of these materials, with different variations in performance noted. Little research has been done to understand the chemistry behind these variations and in characterizing the components of fly ash and the additives and how their interaction and relative concentrations determine the performance & properties of geopolymer concrete produced.

Geopolymer Concrete:
Geopolymer concrete is produced using source materials which show pozzolanic properties that are rich in silica and alumina. The cement-based concrete utilizes the formation of calcium-silica hydrates (C-S-Hs) for matrix formation and strength whereasgeopolymer concrete involves the chemical reaction of alumino-silicate oxides with alkaline solutions withpolysilicates yielding polymeric Si–O–Al bonds. In this research work, low calcium fly ash (ASTM Class-F) is used as source material in addition with sodium hydroxide and sodium silicate to for mgeopolymer paste as the binder, which produces geopolymer concrete. The production of geopolymer concrete is done using the usual concrete technology methods. The aggregate's role and influence are considered to be same as in the Portland cement concrete. The combined aggregates mass (fine and coarse aggregates) should be somewhere in the range of 70% and 80% of the mass of the geopolymer concrete. The silica and alumina in the Class-F fly ash are activated by a combination of sodium hydroxide and sodium silicate solutions to form the geopolymer paste which binds the aggregates and unreacted materials.

$$\text{Si}-\text{Al Material} + \text{Chemical Additives } (NaOH + Na_2SiO_3) + \text{Water}$$
$$?$$
$$\text{Geopolymer Binder} + \text{Water}$$

Properties of Geopolymer Concrete:
Geopolymer concrete gains high-early characteristics strength, when cured by heat or steam, although ambient temperature curing can be done. It has been used for the production of precast railway sleepers, precast bridge components and other precast building components. The early strength gained is a characteristic which can best exploit in the precast industry where steam curing or heated bed curing is common practice and is employed to maximize the speed of production of elements.

Geopolymer concrete has glorious resistance to chemical attack and shows promise within the use of aggressive environment where the sturdiness/durability of Portland cement concrete is also a concern. This can be applicable in

aggressive marine environments, environment with high carbon or sulphate rich soils. Similarly in highly acidic environment, geopolymer shows superior acid resistance and may be appropriate for applications like mining, some manufacturing industries and sewer system.
The mechanical properties offered by geopolymer suggest its use in structural applications is beneficial with enhanced durability and fire resistance perspective. As its high strength is due to elevated curing temperature leads geopolymer concrete to its applications.
Collection of typically required materials such as Fly Ash and Alkaline Liquids:
a. Fly Ash:
In this research work Class-F Fly Ash is used as 100% replacement of cement in concrete and it is passed from 90 micron IS Sieve. The fly ash used in this study is collected from ULTRATECH Cement Limited (R.M.C. Plant), Govindpura, Bhopal and ordered from Satpura Thermal Power Station, Sarni (M.P.). It is the second largest power plant in Madhya Pradesh, contributing to approximately 8.85% of total electricity generation from Madhya Pradesh with total capacity is 1,330 megawatts. The production of fly ash in this plant from August 2016 to June 2018 is 2,701,562 MT and only 899,369 MT (33.29 %) is utilized. Total quantity of fly ash collected from R.M.C. Plant is 45 kg. These days it is commonly used in cement factories. It is a waste industrial material obtained by complete combustion of coal. It is a burnt and powdery derivative of inorganic mineral matter. The fly ash contains 75 - 95 % of silica and alumina, therefore it has cementing properties. Worldwide production of the fly ash is more than 2 billion ton and only in India it is 40 million ton.
i) Compressive Strength of Class-F Fly Ash:

The ratio of load per unit area is known as compressive strength. It is determined by Greek later sigma (σ).

$$\text{Compressive strength } (\sigma) = P / A$$

Where,
P = Maximum applied load (kN)
A = Bearing surface of area (mm2)
Compressive strength of fly ashis obtained by the reference of IS 4031 (Part 6) - 1988.
Vibrating machine confirming to IS: 10080 - 1982.
Poking rod confirming to IS: 10080 - 1982.
Cube moulds shall be of 70.60 mm size confirming to IS: 10080 - 1982.

- The intensity of the load should be 1.9 kN/sec.

Here, the curing was done at 90ºC for 48hrs.Following tests results are obtained:

Figure Dry Mix of Fly AshMortarFigure3.19: Wet Mix of Fly Ash Mortar

No.	Veight of bes (gm)	Load Applied (kN)	ompressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
For 3 Days				
1	83 gm	215.60	43.26	43.22
2	01 gm	213.68	42.87	
3	95 gm	216.97	43.53	
For 7 Days				
1	06 gm	281.37	56.45	55.40
2	93 gm	270.45	54.26	
3	11 gm	276.58	55.49	
For 28 Days				
1	98 gm	327.87	65.78	65.96
2	87 gm	329.62	66.13	
3	97 gm	328.87	65.98	

Table Compressive Strength of Fly Ash Mortar

Figure Dry Mix of Fly AshMortarFigure3.19: Wet Mix of Fly Ash Mortar

Figure Test Samples of Fly Ash Mortar

Figure 3 Curing of Cubes

Figure Testing of Cubes

The physical properties of Class-F fly ash are shown in Table below:

Class of Fly Ash		Class-F
IS Code		IS 3812 - 2003
***Specific Gravity**		2.15
***Standard Consistency**		22 %
Fineness		326.80 m^2/kg
***Setting Time (In Summer)**	**Initial Setting Time**	22 min
	Final Setting Time	240 min
***Setting Time (In Rain)**	**Initial Setting Time**	86 min (1 hr 26 min)
	Final Setting Time	730min (45 hr 30 min)
Soundness	**Auto Clave**	0.05 %
***Compressive Strength of Cement (N/mm^2)**	**days (Avg. of three)**	43.22
	days (Avg. of three)	55.40
	3 days (Avg. of three)	65.96

(Source: ULTRATECH Cement Ltd. (R.M.C. Plant), Govindpura, Bhopal, M.P.)

(* Results from Tests)
Table Physical Properties of Fly Ash

RESULT ANALYSIS AND DISCUSSION

Result Analysis:
Introduction:
Various tests were performed on the prepared samples. Results were extracted from all these experiments are summarized below on the basis of following sub-heads:
1. Abbreviations used for each mix trails for the ease of the determination of an optimum trail. It is shown in the table below:

Mix Description	Abbreviations used for Each Trail
Conventional Concrete (OPC 53 Grade Cement Concrete)	CC
Geopolymer Concrete (85 % Fly Ash + 15% Chemical Additives)	GC 1
Geopolymer Concrete (80 % Fly Ash + 20% Chemical Additives)	GC 2
Geopolymer Concrete (75 % Fly Ash + 25% Chemical Additives)	GC 3

Table Abbreviations Used for Each Trial Mixes
Here, every trial is sub divided into three batches and ever batch consists of three cubes.

Abbreviations used for Each Trail	Abbreviations used for Each Batch
CC	B1
	B2
	B3
GC 1	B4
	B5
	B6
GC 2	B7
	B8
	B9
GC 3	B10
	B11
	B12

Table Abbreviations Used for Each Sub Divided Trial Mixes
2. As we can see from the Table 4.1, the percentage of fly ash is decreasing by 5% and 5% increase of chemical additives in geopolymer concrete in each trial mix respectively to compare the compressive strength.

Compressive Strength Test of Cement (OPC 53 Grade Cement Mortar Cubes) and Fly Ash (Fly Ash Mortar Cubes):
The compressive strength of fly ash and cement is obtained by casting of fly ash and cement mortar cubes in 70.6 × 70.6 × 70.6 mm size moulds. Total 18 cubes were casted nine of cement mortar and nine of fly ash mortar. The cubes were then cured and tested at 3, 7 and 28 days.
The results are shown below:

ays at Testing is Done	verage Strength of 100 % Cement Mortar (N/mm^2)	Average Strength of 100 % Fly Ash Mortar (N/mm^2)
3 Days	30.41	43.22
7 Days	41.28	55.40
28 Days	57.14	65.96

Table Comparison b/w Average Compressive Strength of Cement Mortar and Fly Ash Mortar

The results of compressive strength test of cement mortar and fly ash mortar shows that by adding chemical additives (Sodium Hydroxide flacks and Sodium Silicate) to fly ash, helps in activating the binding property in the fly ash and as a result the compressive strength of fly ash mortar cubes is much more as compared to cement cubes.

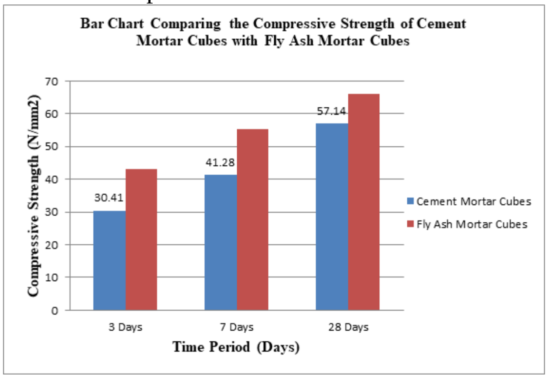

Figure Bar Chart Comparing the Average Compressive Strength b/w of Cement Mortar and Fly Ash Morta

Compressive Strength Test Using Universal Testing machine (UTM):
First of all the results of the conventional concrete cubes were obtained than after further geopolymer concrete trial cubes were tested and their compressive strength values were determined and compared with conventional concrete cubes compressive strength. The specimens are weighed before testing and the test was performed on universal testing machine (UTM). The average 3, 7 and 28 days strength results are shown in different tables for each trial. The unit of compressive strength is Newton per millimeter square (N/mm2).
a. Conventional Concrete Cubes (OPC 530 Grade Cement Concrete):
In conventional concrete, there is no other replacement of any material. It is a normal concrete, consist of cement, fine aggregate, coarse aggregate and water. There are three batches (B1, B2 and B3) in this trail mix (CC) with 100% of cement, each batch consists of three cubes, and total nine cubes were casted. The weights of the specimens were also checked before testing. One cube from each batch was tested for 3, 7 and 28 days compressive strength respectively. The strength of conventional concrete samples was determined and the results of other mix trails were compared with it.
b. Geopolymer Concrete Cubes (85 % Fly Ash + 15% Chemical Additives):
There are three batches (B4, B5 and B6) in this trail mix (GC 1) with 100% of cement replacement by fly ash (85%) with chemical additives (15%), each batch consists of three cubes, total nine cubes were casted. The weights of the specimens were also checked before testing. One cube from each batch was tested for 3, 7 and 28 days compressive strength respectively.
c. Geopolymer Concrete Cubes (80 % Fly Ash + 20% Chemical Additives):
There are three batches (B7, B8 and B9) in this trail mix (GC 2) with 100% of cement replacement by fly ash (80%) with

chemical additives (20%), each batch consists of three cubes, total nine cubes were casted. The weights of the specimens were also checked before testing. One cube from each batch was tested for 3, 7 and 28 days compressive strength respectively.

d. Geopolymer Concrete Cubes (75 % Fly Ash + 25% Chemical Additives):

There are three batches (B10, B11 and B12) in this trail mix (GC 3) with 100% of cement replacement by fly ash (75%) with chemical additives (25%), each batch consists of three cubes, total nine cubes were casted. The weights of the specimens were also checked before testing. One cube from each batch was tested for 3, 7 and 28 days compressive strength respectively.

Total 36 cubes i.e. nine specimens for each trail mix (three for 3 days, three for 7 daysand three for 28 days) were tested. Results of trials GC 1, GC 2 and GC 3 were compared with CC (Conventional Concrete). The average weight of specimens and average compressive strength are mentioned in the result in tabular form and the percentage increment or decrement of strength of trials GC 1, GC 2 and GC 3 are also shown, when compared to trail mix CC in the table. Following compressive strength results were obtained by testing cubes under compression in universal testing machine (UTM).

Conclusion:

In this research work it has been concluded that,

- The mean compressive strength of fly ash mortar using chemical additives (NaOH Flacks and Na_2SiO_3) was found more as compared to cement mortar.
- The compressive strength of geopolymer concrete tends to increase with increase of percentage of chemical additives (NaOH Flacks and Na_2SiO_3) and also increases with the increase in concentration of NaOH (NaOH Flacks + Water) i.e. more the concentration high will be strength.
- The compressive strength of GC 1 (geopolymer concrete with 15% chemical additives) at 5 N found to be satisfactory and can be opted as low grade concrete (M15 to M20). In case of GC 2 (geopolymer concrete with 20% chemical additives) at 10 N, the compressive strength was observed optimum and fall under the category of standard grade of concrete (M25). Whereas, in case of GC 3 (geopolymer concrete with 25% chemical additives) at 14 N, the compressive strength was observed very good and also fall under the category of standard grade of concrete (M30 - M40).
- The compressive strength of GC 4 (geopolymer concrete with 25% chemical additives) observed to be increased by 35.59 % in 3 days, 57.68 % in 7 days and 37.02 % in 28 days as compared to CC (OPC 53 grade cement concrete).
- The geopolymer concrete is also light weight concrete as it has been observed that the weight of geopolymer concrete cubes was found to be less by 6 % to 12 % as compared to OPC 53 grade cement concrete cubes.
- The geopolymer concrete (fly ash + chemical additives) is more preferable for precast constructions and concrete road constructions.
- Cement industries are the main source of carbon dioxide (CO_2) emissions. The usage of cement for concrete is reduced by using these supplementary materials such as fly ash, rice husk, waste paper sludge ash, ground granulated blast furnace steel slag, palm oil boiler ash and metakaolin etc. with chemical additives, thus the amount of CO_2 gas emission can be reduced up to some extent, due to which greenhouse effect can be controlled so that we can safeguard our environment. The fly ash is environment friendly waste product and there is no objection in using this material to replace the cement in the concrete.

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