A tentative Investigation on M-40 Grade Geopolymer Concrete using Fly Ash

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***Abstract*: We are facing environment problem due to maximum use of natural construction material, to reduce this type of problem this paper is an idea of reformation and use of eco-friendly, pollution free construction material i.e. Fly Ash. Fly Ash plays an important role in the activation process of Geopolymer because of Quantity and fineness. Due to higher finess shows higher workbability, strength with early duration of heating. In this study the strength properties of concrete of M-40 grade can be analyzed by replacing cement by pozzolanic materials like Fly Ash and activated by highly alkaline solutions to act as a binder in mix. An investigation has been carried out for the mix design procedure and gradation of Geopolymer concrete is proposed the basis of fineness and quantity of Fly Ash, quantiy of fine aggregates, quantity of water, grading of fine aggregate, fine to total aggregate ratio. Sodium silicate solution with Na_2O = 16.37%, SiO_2 = 34.35% and H_2O = 49.28% and sodium hydroxide solution having 13M concentration were maintained throughout. Strength properties involve Compressive strength, Tensile strength and Flexural strength. Mixes are tested with the test for 3 days, 7 days and 28 days. The study shows that the use of waste material like Fly Ash in concrete is feasible.**

***Keywords*: Sodium silicate, sodium hydroxide, sustainable development, Geopolymer concrete, Fly Ash, marble waste, construction technology.**

I. INTRODUCTION

Road Construction is the backbone of any country infrastructural development and it derives its basic ingredients, which are cement, aggregate and sand from natural resources. In the current scenario, the construction works is on boom, which leads to various environmental hazards. The Road and and Building construction industry has ruined the ecological balance up to a great extent by taking away the natural stock of rock.

To reduce the use of natural material as the main source of concrete, artificially manufactured and industrial waste is an alternative for construction industries. Fly Ash considered as a waste material which could have a promising future in construction industries as partial or full substitute of Coarse Aggregate. The use of Fly Ash in concrete provides potential environment as well as economic benefits for all construction industries, particularly in those areas where a considerable amount of Fly Ash is available. The chances of pollution due to Fly Ash will be reduced and it will be cost effective for construction. The use of waste material in new construction helps to save of energy. The use of Geopolymer using Fly Ash in concrete mix can also solve the problem of disposing these waste materials.

The use of secondary material or industrial waste in construction field for production of concrete contributes to reducing the consumption of natural resources. Various by-product materials such as Fly Ash are considered as waste material. They have been intensively used in construction industries for partial replacement of cement.

A. Need for Geopolymer Concrete Using Fly Ash

Portland cement is under critical review due to high amount of carbon dioxide (CO_2) released into atmosphere. However it is necessary to search for another low emission binding agent for Road and Building concrete to reduce the environmental impact caused by manufacturing of cement. This is done by using the by products as binder's. The new technology Geopolymer concrete using Fly Ash is a promising technique.
In terms of reducing the global warming the geo-polymer technique could reduce the CO2 emission to the atmosphere.

B. Fly Ash Based Geopolymer Concrete

Fly Ash based Geopolymer is used as binder, instead of Portland or any other hydraulic cement paste, for producing concrete. The Fly ash based Geopolymer paste binds the aggregates coarse and fine and other un-reacted materials together to form the Geopolymer concrete. The manufacture of Geopolymer concrete is carried out using the usual concrete technology methods. As in the OPC concrete, the aggregates use the largest volume, i.e. about 75-80 % by mass, in Geopolymer concrete. The silicon and the aluminium in the low calcium Fly Ash are activated by a combination of Sodium Hydroxide and Sodium Silicate Solutions to form the Geopolymer paste that binds the aggregates and other un-reacted materials.

C. Purpose to use economical and ecofriendly alternative materials

1. Climate Changes.
2. Increased demand for road with increase in population
3. Reduction of good quality material for road & building construction.

4. The problem of creation and disposal of non-decomposing materials.
5. Increased cost and to achieve economy.
6. Limited natural resources for road construction.
7. To reduce bad impact on environment due to increasing construction demand.

D. Fly Ash

Coal Fly Ash has been used for many years in highway construction as a fill material, in concrete, lean mix sub-bases and in more recent years as a binder and aggregates in hydraulically bound materials around more than 100 million tonnes of Fly Ash accumulated every year at the thermal power plant. Its use reduces material being sent to landfill and preserves virgin aggregate reducing overall greenhouses gas emissions.

Advantages
1. Fly Ash is a light wt. material as compared to commonly used filler material.
2. Easy to handle and compact.
3. Higher Value of CBR.
4. High permeability ensures free and efficient drainage.
5. Can replace a part of cement and sand in concrete pavements thus making highway construction more economical.

Disadvantages
1. The quality of Fly Ash affects quality and strength of cement concrete.
2. Poor quality Fly Ash increases permeability of concrete.

E. Scope of Work

The research utilized low Calcium Fly Ash as the base material for production Geopolymer Concrete. The Fly Ash was obtained from only one source, main purpose of the study was behaviour and the engineering properties of Fly Ash based Geopolymer concrete. As far as possible, the Technology and the equipment currently used to manufacture concrete were also used to make the Geopolymer concrete. The concrete properties studied included the compressive and indirect tensile strengths, the elastic constants, the stress-strain relationship in compression, and the workability of fresh concrete.

II. METHOD

F. Mix Design

Trial Mix Design Procedure for Fly Ash Based Geopolymer Concrete Mix -1

S. No.	Description	Quantity
1	Unit wt. of Geopolymer Concrete =	2400 Kg/m^3
2	Percentage of Combined Aggregate =	75%
3	Mass of Total Aggregates = 0.75 x 2400	1800 Kg/m^3
4	% of 10mm Coarse Aggregate =	70%
5	Mass of 10mm Coarse Aggregate = 0.7 x 1800 =	1260 Kg/m^3
6	% of 4.75mm sieve passing sand =	30%
7	Mass of 4.75mm sieve passing sand =	540 Kg/m^3
8	Mass of Low Calcium Fly Ash and Alkaline Liquied = 2400-1800	600 Kg/m^3
9	Liquied to Fly Ash ratio	0.45
10	Mass of Fly Ash 600/1+0.45	413.8 Kg/m^3
11	Mass of Alkaline liquid = 600-413.8	186.2 Kg/m^3
12	NaOH solution to Na_2SiO_3 solution ratio	01:02.0
13	Mass of NaOH solution = 186.2/3 =	62.1 Kg/m^3
14	Mass of Na_2SiO_3 Solution = 186.2 – 62.1	124.1 Kg/m^3

Quantity of Materials per cum of Geopolymer Concrete Mix:

1	Fly Ash	331.04 Kg/m^3
2	Metakaolin	82.76 Kg/m^3
3	Fine Aggregates (Passing through 4.75mm sieve size throughout.	540 Kg/m^3
4	Mass of NaOH Solution	1260 Kg/m^3
5	Mass of Na_2SiO_3 Solution	62.1 Kg/m^3
6	Mass of Na_2SiO_3 Solution	124.1 Kg/m^3
7	Liquied to Fly Ash Ratio	0.45

Trial Mix Design Procedure for Fly Ash Based Geopolymer Concrete Mix -2

S. No.	Description	Quantity
1	Unit Wt. of Geopolymer Concrete =	2400 Kg/m^3
2	Percentage of Combined Aggregate =	75%
3	Mass of Total Aggregates = 0.75 x 2400	1800 Kg/m^3
4	% of 10mm Coarse Aggregate =	70%
5	Mass of 10mm Coarse Aggregate = 0.7 x 1800 =	1260 Kg/m^3
6	% of 4.75mm sieve passing sand =	30%
7	Mass of 4.75mm sieve passing sand =	540 Kg/m^3
8	Mass of Low Calcium Fly Ash and Alkaline Liquied = 2400-1800	600 Kg/m^3
9	Liquied to Fly Ash Ratio	0.45
10	Mass of Fly Ash 600/1+0.45	413.8 Kg/m^3
11	Mass of Alkaline Liquid = 600-413.8	186.2 Kg/m^3
12	NaOH solution to Na_2SiO_3 solution ratio (Alkaline Activator (ratio)	01:2.5
13	Mass of NaOH solution = 186.2/3.5 =	53.2 Kg/m^3
14	Mass of Na_2SiO_3 Solution = 186.2 – 62.1	133 Kg/m^3

Quantity of Materials per cum of Geopolymer concrete Mix

1	Fly Ash	331.04 Kg/m^3
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3	Fine Aggregates (Passing through 4.75mm sieve size throughout.	540 Kg/m^3
4	Mass of NaOH Solution	1260 Kg/m^3
5	Mass of Na_2SiO_3 Solution	53.2 Kg/m^3
6	Mass of Na_2SiO_3 Solution	133 Kg/m^3
7	Liquied to Fly Ash Ratio	0.45

G. Mix Proportions:

There are three mix uses, for each mix 27 cubes of 150mm, 27 cylinders of diameter 150mm x height 300mm and 27 beams of 500mm x 100mm x 100mm casted.

H. Mixing and Casting:

1. Preparing Geopolymer concrete, used the conventional method for casting of normal concrete cubes.
2. Mix sodium hydroxide solution and sodium silicate solution at least 20 minutes prior to adding the the liquid to the dry materials.
3. To study compressive strength, split tensile and flexural strength, three different mixes were developed in this study for each mix 27 cubes of 150mm, 27 cylinders of diameter 150mm x height 300mm and 27 beams of 500mm x 100mm x 100mm casted.

I. Testing of Specimen

There are the following tests are conducted on fresh and harden concrete, the specimens were tested as per IS 516:1959 and strength was calculated for 3, 7, 28 days:

Compressive Strength = Average Load/Area of Cross Section

1. Compressive Strength Test
2. Split Tensile Strength Test
3. Flexural Strength Test

Compressive Strength:

Activator Ratio	Compressive Strength for 3 days	Average value in N/mm^2 for ratio 1:2	1:2.5	1:3
1:2	16, 15, 15.5	6.9	7.48	8.52
1:2.5	17, 17.5, 16			
1:3	19, 18, 20.5			

Compressive Strength Value for 3 days.

Activator Ratio	Compressive Strength for 7 days	Average value in N/mm² for ratio		
		1:2	1:2.5	1:3
1:2	16.5, 15.5, 16	7.1	7.48	8.67
1:2.5	16, 17, 17.5			
1:3	18, 20, 20.5			

Compressive Strength Value for 7 days.

Activator Ratio	Compressive Strength for 3 days	Average value in N/mm² for ratio		
		1:2	1:2.5	1:3
1:2	15.5, 15.5, 16	7.0	7.48	8.44
1:2.5	17, 17.5, 16			
1:3	18, 18.5, 20.5			

Compressive Strength Value for 28 days.

Split Tensile Strength:

Activator Ratio	Tensile Strength for 3 days	Average value in N/mm² for ratio		
		1:2	1:2.5	1:3
1:2	16, 15, 17	7.1	7.48	8.67
1:2.5	16, 17, 17.5			
1:3	18, 20.5, 20			

Tensile Strength Value for 3 days.

Activator Ratio	Tensile Strength for 7 days	Average value in N/mm² for ratio		
		1:2	1:2.5	1:3
1:2	15.5, 16.5, 15	7.0	7.78	8.96
1:2.5	17, 18, 17.5			
1:3	20, 20, 20.5			

Tensile Strength Value for 7 days.

Activator Ratio	Tensile Strength for 28 days	Average value in N/mm² for ratio		
		1:2	1:2.5	1:3
1:2	16, 16, 15.5	7.0	7.48	8.67
1:2.5	17, 16.5, 17			
1:3	20, 20.5, 18			

Tensile Strength Value for 28 days.

Flexural Strength:

Activator Ratio	Flexural Strength for 3 days	Average value in N/mm² for ratio		
		1:2	1:2.5	1:3
1:2	16.5, 15.5, 16	7.1	7.48	8.67
1:2.5	16, 17, 17.5			
1:3	18, 20, 20.5			

Flexural Strength Value for 3 days.

Activator Ratio	Flexural Strength for 7 days	Average value in N/mm² for ratio		
		1:2	1:2.5	1:3
1:2	16.5, 15.5, 16	7.1	7.48	8.67
1:2.5	16, 17, 17.5			
1:3	18.5, 20, 20.5			

Flexural Strength Value for 7 days.

Activator Ratio	Flexural Strength for 28 days	Average value in N/mm² for ratio		
		1:2	1:2.5	1:3
1:2	16.5, 15, 16	7.0	7.48	8.74
1:2.5	17, 17, 16.5			
1:3	18.5, 20.5, 20			

Flexural Strength Value for 28 days.

III. CONCLUSION

- Compressive strength, Split tensile strength, Flexural strength of Fly Ash based Geopolymer Concrete specimens increased in Activator ratio i.e., 1:2, 1:2.5, and 1:3.
- Strength of all Geopolymer concrete specimens improved with the increase 1 curing time.
- The percentage increased in compressive strength with the control specimen for ratios 1:2, 1:2.5, 1:3 is 8.4%, 13.90%, for 3 days, 5.35%, 15.90% for 7 days and 6.85%, 12.83% for 28 days.
- The Flexural strength percentage increased ratio1:2, 1:2.5, 1:3 is 5.35%, 15.90% for 3 days, 5.35%, 15.90% for 7 days and 6.85%, 16.84% for 28 days.
- The percentage increased in split-tensile strength with the control specimen for ratios 1:2, 1:2.5, 1:3 is 5.35%, 15.90% for 3days, 11.14%, 15.16% for 7 days and 6.85%, 15.90%, for 28 days.

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