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Eco-friendly Blocks by Blended Materials

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ABSTRACT

In spite of broad improvements in construction technology, cement is still stayed as binding material for construction purposes. Cement industries are the main sources for the contribution of carbon dioxide (CO_2) into the atmosphere. So, there is a need to use new materials as binders (green binders) in substitute for cement, which leads to reducing the production of cement. In this study, fly ash and ground granulated blast furnace slag (GGBS) are used as source materials. Since fly ash and GGBS are industrial wastages which are non-renewable in nature, quarry dust is used as the partial replacement which is 50% in weight with fine aggregate. Soluble activators like sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) of 12M are used instead of water at the ratio of 1:2.5. Different mix proportions are considered in this study such as F80G20, F70G30 and F60G40. The results of mix proportion were compared with conventional concrete of M20. The results were drawn for different strength tests such are compressive strength test, split tensile strength test and flexural strength test. From the results, it is concluded that F60G40 mix has high compressive strength, split tensile strength and flexural strength compared to remaining mixes along with conventional concrete.

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1. INTRODUCTION

The worldwide utilization of cement is second just to water. For the production of 1 ton of cement nearly 1 ton of CO_2 is emitted, which adversely affects the environment and leads to global warming [1]. The yearly rate of increment of cement generation is around 3%. The three major concerns associated with the cement production are environ-eco issues, sustainability issues, and intense energy needs. Many industrial by-products / pozollanas such as fly ash, ground granulated blast furnace slag, silica fume, metakaolin, rice husk ash etc. perform the function of supplementary cementitious materials (SCM) [2-4]. Therefore, it is necessary to go beyond the current approach of the cement industry, that of increasing the replacement levels of OPC and maximizing the use of industrial by-products as SCMs to an approach based on 'Complete Elimination' of OPC by synthesizing altogether alternate binders which are eco-friendly, sustainable and less energy intensive**.** In this direction, geopolymer technology is a promising field for the synthesis of a new generation, non-conventional, novel OPC free binders. The increasing percentage of GGBS will reduce the heat of hydration. Since geopolymer concrete is a self-compacting concrete, it doesn't need water curing [5].

1. 1. Literature Review By the experimental investigation, Vignesh et al. [6] concluded that increased percentage of GGBS in total amount will give more strength; i.e., 70% of compressive strength will attain within 4 hours. Construction of green buildings is more necessary in nowadays, so in this situation, geopolymer concrete acts as a revolutionary building material to decrease the impact on the environment.

Maneeshkumar et al. [7] said that the geopolymer concrete gains high compressive strength at an early age. By using geopolymer concrete in precast structures, failures during transportation can be reduced. Geopolymer concrete plays a major role at beam-column joints due to its high strength; so, the structural failures can be minimal.

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Rajini et al. [8] concluded that the rate of gain of strengths is fast at 7 days and the rate decreases with increase in age. The objective of the study is to find the mechanical properties of geopolymer concrete by using low calcium fly ash.

Bhikshma et al. [1] said that geopolymer concrete is more viscous and has high workability compared to conventional concrete. Fly ash based geopolymer concrete have more strength with durability. The increase in the ratio of alkaline activators will give high compressive strength.

Mohammed et al. [9] concluded that fly ash with more fineness increases the compressive strength due to the filling of voids. As fly ash is rich in alumina and silica content, this reacts with an alkaline solution and binds the aggregates to form better concrete.

1. 2. Geopolymer Technology Geopolymer material was acquainted by Davidovits in 1978 with a wide scope of materials portrayed by chains or systems of inorganic particles. Geopolymer include alumina silicate materials which can totally supplant OPC in the concrete mix. These geopolymers depend on thermally actuated characteristic materials (Clay) or industrial by-items (like fly fiery remains or slag) which break down into basic enacted arrangement and polymerizes into sub-atomic fastens and systems to make solidified fastener. The antacid fluids are concentrated watery salt hydroxide or silicate arrangement, which are dissolvable soluble base metals. High soluble fluids are utilized to incite the silicon and aluminum particles in the source materials to disintegrate and frame the geopolymeric fastener [2-4].

1. 3. Ternary Blended Geopolymer Blocks The blocks are a blend of FA, GGBS, and Quarry dust and nearby sand. In this way, they are delicate to the environmental change. The advancement of another establishing operator with low carbon dioxide discharge is considered as an intriguing issue. Business and modern usage of soluble base initiated aluminosilicate bonds, known as 'geopolymer' have a place with a gathering of materials with expanded enthusiasm because of low CO_2 outflow and vitality utilization. The silica-rich materials, for example, earth or kaolin, fly

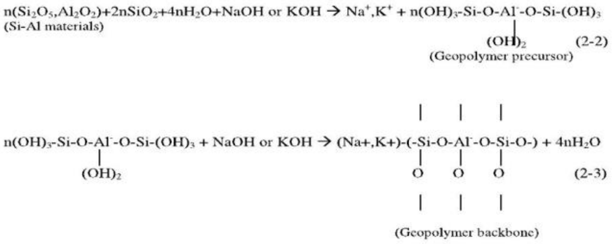

Figure 1. Schematic formation of Geopolymer material

powder, and GGBS can be utilized as a puzzolanic material to respond with the fluid antacid activator. Fly fiery debris gives the best chance to business use of this innovation because of the abundant overall crude material supply, which is obtained from coal-let go power era.
Ternary mixed geopolymer is utilized as a part of the accompanying applications:

- Used in modern segments.
- Fireproof areas.
- External repair and auxiliary retrofit of maturing foundation.
- For the capacity of harmful and radioactive squanders.
- Potential use in craftsmanship and enrichment.

2. PORTRAYAL OF MATERIALS

Materials which contain large silicon (Si) and aluminum (Al) in the vague edge are all possible source materials for the creation of geopolymer. Manufacture of geopolymer by several minerals and mechanical by-thing materials have been investigated in the past by various authorities. Numerous analysts have expressed that the calcined source materials, for example, fly powder, slag, exhibited a higher last compressive quality when contrasted with those made utilizing non-calcined materials like kaolin dirt, mine tailings, and normally happening minerals. The points of interest of materials utilized as a part of the arrangement of geopolymer composite examples are clarified beneath.

2. 1. Fly Ash Fly fiery debris is a standout amongst the most inexhaustible materials on the Earth. It is likewise a pivotal fixing in the formation of geopolymer concrete because of its part in the geo polymerization handle. A puzzolana is a material which displays cementitious properties when consolidated with calcium hydroxide. Fly slag is fundamental by item, made from the burning of coal in coal-let go control plants. There are two "classes" of fly ash, class F, and class C. Every class of fly ash has its own particular exceptional properties. The fly ash used in this exploration was class F, brought from the nearby NTPC of Vijayawada and it has a specific gravity of 2.78 with a consistency of 26%. The concoction structure of fly fiery is shown in Table 1.

2. 2. Ground Granulated Blast Furnace Slag Ground granulated impact heater slag includes most part of calcium oxide, silicon di-oxide, aluminum oxide, magnesium oxide. It has indistinguishable fundamental concoction constituents from standard Portland concrete in various extents. Furthermore, the expansion of GGBS in geopolymer Concrete expands the quality of the solid furthermore curing of geopolymer concrete at room temperature is conceivable. GGBS used in this exploration was taken from the Vizag steel industry and it has a specific gravity of 2.9 with a consistency of 34%. Concoction structure of GGBS is depicted in Table 2.

2. 3. Soluble Activators A blend of soluble silicate arrangement and basic hydroxide arrangement were picked as the antacid fluid. Sodium-based arrangements were picked on the grounds that they were less expensive than Potassium-based arrangements. It is seen that the geopolymer with sodium hydroxide arrangement display preferred zeolitic properties over potassium hydroxide actuated geopolymer. In the present study, the molarity of the arrangement is kept steady at 12M for all the trial examinations. Chemical analysis of NaOH flakes are shown in Table 3. The composition of aqueous solution of sodium silicate with SiO_2 / Na_2O ratio of 2.5 and pH 10.4 is indicated in Table 4.

2. 4. Quarry Dust Half of fine totals utilized as a part of this exploration was quarry clean. Quarry clean, a by-result of stone crusher industry was obtained from a nearby quarry. It confers workability, homogeneity, and consistency to the mortar/solid blend. Quarry clean is portrayed for the most part by rakish particles as opposed to adjusted/circular particles of regular sand. This was taken from nearby crushers of Guntur and it has a specific gravity of 2.55. Table 5 shows the physical properties of quarry dust.

2. 5. Aggregates The fine aggregate used was obtained from a nearby river source which conforming to zone III as per IS: 383-1970. The coarse aggregate used in this study was as per IS: 383-1970 [10]. 10mm and 20mm size aggregates are used in the ratio of 1:2 by practical experience. Test results of aggregates are indicated in Table 6 [11].

TABLE 1. Concoction structure of fly ash

S.NO	CONSTITUENTS	VALUE % BY WEIGHT
1.	SiO_2	52
2.	Al_2O_3	34
3.	Fe_2O_3	4
4.	CaO	1.2
5.	K_2O	0.83
6.	Na_2O	0.27
7.	MgO	0.81
8.	SO_3	0.28

TABLE 2. Concoction structure of GGBS

S.NO	Chemical Constitution	Value % by Weight
1.	CaO	40
2.	SiO_2	35
3.	Al_2O_3	10
4.	MgO	8

TABLE 3. Chemical analysis of NaOH flakes

Minimum Assay(Acidimetric)/ Maximum Limits of Impurities	96%
Carbonate	2%
Chloride	0.1%
Phosphate	0.001%
Silicate	0.02%
Sulphate	0.01%
Arsenic	0.0001%
Iron	0.005%
Lead	0.001%
Zinc	0.02%

TABLE 4. Composition of Na_2SiO_3

Sp. Gravity	Viscosity	Na_2O%	SiO_2 %	Water %
1.385	68 Seconds	8.35	28.12	63.53

TABLE 5. Physical properties of quarry dust

S. No	Description	Values
1	Specific Gravity	2.621
2	Bulk Density (Loosely compacted) kg/m^3	1644
3	Bulk Density (Heavily Compacted) kg/m^3	1756
4	Fineness Modulus	3.15
5	Grading Zone	I

TABLE 6. Test results for aggregates

S.No	Particulars	Fine Aggregate	Coarse aggregate
1	Source	River sand	Crushed
2	Zone	Zone III	-
3	Specific Gravity	2.60	2.76
4	Size of aggregate	-	20mm&10mm

3. METHODOLOGY

3. 1. Preparation of Soluble Activator In this exploration work, the quality of geopolymer cement is analyzed for the blends of sodium hydroxide 12 M. For preparing, 480 g of sodium hydroxide chips are weighted and broken down in refined water to frame 1-liter arrangement. Volumetric carafe of 1-liter limit is taken and sodium hydroxide chips are added gradually to refined water to get ready 1-liter arrangement.

3. 2. Mix Design Mix design process is illustrated for the concrete mix designed for the trial mix with chemical ratio 0.45 and 12 M [8].

1. Assume density of the concrete = 2400 kg/m^3
2. Take mass of combined aggregate
   77% mass concrete = 1848 kg/m^3
3. Mass of fly ash and alkaline liquid (2400-1848) = 552 kg
4. Take alkaline liquid to fly ash ratio = 0.45
5. Molarity of NaOH = 12 M
6. Mass of fly ash 554/(1+0.45) = 380.6 kg
7. Mass of alkaline liquid (552-380. 6) = 171.4 kg
8. Taking ratio of sodium silicate to NaOH=2.5
9. Mass of NaOH 171.4/ (1+2. 5) = 48097 kg
10. Mass of sodium silicate (171. 4-48. 97) = 122.43 kg
11. Water in the sodium silicate is 55. 90%
Therefore 122.43X0.559 = 68.43 kg
12. Solids in sodium silicate (122. 43-68. 43) = 54 kg
13. Solids in NaOH 26. 2% (48.97X0.226) = 11.06Kg
14. Water in the NaOH solution is (48. 97-11.06) = 37.91Kg
15. Total mass of water (68.43+37.91) = 106.3Kg
16. Mass of geopolymer solids (380.6+54+11. 06) = 445.66Kg

Abstract of Quantities (/m^3)
Coarse aggregate =1293.6 kg
Fine aggregates (50% sand + 50% quarry dust) =554.4 kg
Sodium silicate =122.43 kg
NaOH (36 kg wate+13 kg NaOH flakes) = 48.97 kg
Ratio of mix proportion 1:1.45:3.39

4. EXPERIMENTAL PROGRAM

The experimental program was done for determining the compressive strength, split tensile strength, flexural strength of concrete. According to the mix design, the mix proportion is related to M20. Details of cast specimens are indicated in Table 7.

Here, F80G20, F70G30, F60G40 indicate the percentages of fly ash GGBS used in the total amount. C.C. indicates conventional concrete of M20.

5. RESULTS AND DISCUSSION

5. 1. Compressive Strength The average compressive strength was calculated on 150 x 150 x 150mm size cubes by taking the average of 3 specimens for 3, 7 and 28 days. The formula for calculating compressive strength is given in Equation (1). Table 8, indicates the results of compressive strength [12].

$$\text{Compressive Strength} = \frac{P}{A} \quad (1)$$

where:
P is the applied load
A is the cross - sectional area (150 X150 X 150mm)

From Figure 2, it shows that geopolymer mixes have high compressive strength when compared to C.C M20 mix. F60G40 mix shows higher compressive strength regarding all four mixes and drastic increase in strength compared to F70G30 mix. This is due to the increased percentage of GGBS in fly ash quantity. From Figure 3, it was noticed that, at the age of 3 and 7 days the specimens failures are in a brittle nature and at the age of 28 days, its failures are in a ductile manner.

5. 2. Split Tensile Strength To find the split tensile strength of concrete, 150 X 300 mm cylinders were cast and it was tested for 3, 7 and 28 days.

TABLE 7. Details of specimens cast

S.No	Mix	No of Specimens Cast		
		Cubes	Cylinders	Prisms
1	C.C M20	9	9	9
2	F80G20	9	9	9
3	F70G30	9	9	9
4	F60G40	9	9	9

TABLE 8. Test results for compressive strength

Name of Mix	Average Compressive Strength Values (N/mm^2)		
	3 days	7 days	28 days
Conventional Concrete M20	23.180	25.160	32.086
F80G20	35.450	38.080	55.210
F70G30	37.060	43.420	59.586
F60G40	40.410	47.960	69.460

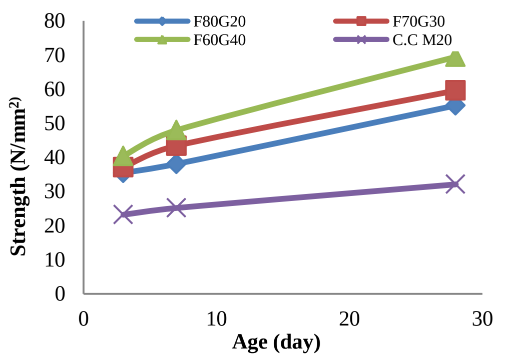

Figure 2. Compressive strength at different mixes

By using Equation (2), we can determine the split tensile strength of the concrete. Table 9 indicates the results of split tensile strength. Figure 4 shows the split tensile strength at different mixes.

$$\text{Tensile strength of Split} = \frac{2P}{\pi DL} \quad (2)$$

where:
P is the applied load
D is the diameter of cylinder (150 mm)
L is the height of cylinder (300 mm)

From Figure 4, it shows that F60G40 mix have high split tensile strength when compared to all other mixes. C.C M20 shows high strength regarding F80G20 and F70G30 mixes, but shows small decrease in strength when compared to F60G40 mix. From Figure 5, it was noticed that, at the age of 3 and 7 days the specimens failures are in a brittle nature and at the age of 28 days its failures are in a ductile manner.

5. 3. Flexural Strength

The average flexural strength was calculated on 100 x100 x 500 mm prisms. By taking the average of 3 specimens for 7 and 28 days, test results were tabulated and Formula for calculating the flexural strength is given in Equation (3).
Table 10 indicates the results of flexural strength [12].

$$\text{Flexural strength} = \frac{PL}{BD^2} \quad (3)$$

where:
P is the failure of load
L is the prism length (500 mm)
B is the breadth of prism (100 mm)

Figure 3. Testing of cubes at different ages.

TABLE 9. Test results for split tensile strength

Name of Mix	Average Split Tensile Strength Values (N/mm^2)		
	3 days	7 days	28 days
Conventional Concrete M20	1.8700	1.9000	2.2000
F80G20	1.6200	1.8041	1.9300
F70G30	1.8045	1.8700	2.0127
F60G40	2.0821	2.1510	2.2700

D is the Width of Prism (100 mm)

From Figure 6, it shows that F60G40 mixes have high split tensile strength with more variation in strength when compared to the other mixes. From Figure 7, it was noticed that geopolymer concrete with an increase in age shows ductile nature.

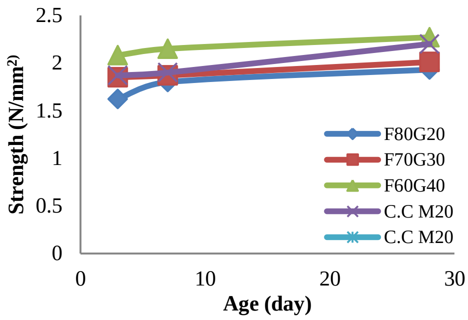

Figure 4. Split tensile strength at different mixes

Figure 5. Testing of cylinders at different ages

TABLE 10. Test results for flexural strength

Name of Mix	Average Flexural Strength Value (N/mm^2)	
	7 days	28 days
Conventional concrete M20	5.390	6.210
F80G20	4.820	5.540
F70G30	5.886	6.620
F60G40	7.602	9.560

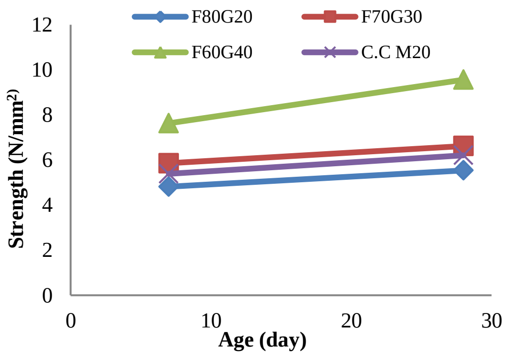

Figure 6. Flexural strength at different mixes

Figure 7. Testing of prisms at different ages

6. CONCLUSION

- The present study was to develop sustainable geopolymer concrete with the use of industrial wastes such as fly ash, GGBS and quarry dust.
- Compressive strength, split tensile strength and flexural strength were compared with conventional concrete of M20.
- Test specimens are kept in sunlight curing and ambient curing to know the strength difference.
- It was observed that specimens which were kept in sunlight curing show somewhat high strength values.
- It was also observed that addition of GGBS percentage in fly ash content shows better results and high compressive strength.
- There is a scarcity of water and sand subsequently by using soluble activators and quarry dust overcome this situation.

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چکیده

با وجود پیشرفت های گسترده در تکنولوژی ساخت و ساز، سیمان هنوز هم به عنوان اتصال مواد برای ساخت و ساز باقی مانده است. صنایع سیمان از منابع اصلی برای سهیم شدن دی اکسید کربن (CO_2) در داخل جو است .بنابراین نیاز به استفاده از مواد جدید را به عنوان binders (binders سبز) در جایگزینی برای سیمان وجود دارد که منجر به کاهش تولید سیمان می شود. در این مطالعه، خاکستر بادی و زمین سرباره کوره گرانول (GGBS) به عنوان منبع مواد استفاده می شود .از آنجا که خاکستر بادی و GGBS ضایعات صنعتی که غیر قابل تجدید در طبیعت هستند می باشند، گرد و غبار معدن به عنوان جایگزینی جزئی است که در ۵۰٪ در وزن با ریزدانه استفاده می شود. فعال کننده های محلول مانند هیدروکسید سدیم (سود) و سیلیکات سدیم (Na_2SiO_3) M ۱۲ به جای آب در نسبت ۱:۲:۵ استفاده می شود. نسبت های مختلف مخلوط در این مطالعه از قبیل F80G20 ، F70G30 و F60G40 در نظر گرفته شد. این نتایج نتاسب مخلوط با بتن معمولی M20 مقایسه شد .نتایج برای آزمایش های قدرت مختلف مانند آزمون مقاومت فشاری، آزمون استحکام کششی تقسیمی و آزمون استحکام خمشی انجام شد. از نتایج، این نتیجه به دست آمد که ترکیب F60G40 دارای مقاومت فشاری ، استحکام کششی تقسیمی و استحکام خمشی بالا در مقایسه با مخلوط های باقی مانده همراه با بتن معمولی دارد.

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