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Renewable Energy for Carbon Footprint Reduction of Production of Lightweight Geopolymer Concrete

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Abstract: - In the present world, researchers have been keenly interested in developing special concrete like Geo polymer concrete in recent years due to its lower global warming impact, better serviceability, higher durability, and overall economy compared to conventional concrete. Geo polymer is a comparatively new substitute binder for making concrete. The geopolymer binders are produced using industrial by-products such as fly ash and blast furnace slag instead of ordinary Portland cement. Using Geo polymer can reduce CO_2 emissions and lower the global warming impact. The major issue before the present community is to minimize the CO_2 emission, which is also the lead source of global warming. In the present research, an attempt has been made to predict that the CO_2 emission rate has either increased or declined in preparing the concrete by using Hand-mixing concrete. The calculations of CO_2 emission during manufacturing have been devised based on the collected data. It has also been proposed that how CO_2 emission can be reduced by varying the concrete mix proportions or by replacing the ingredients of concrete.

Keywords: Ordinary concrete, Inventory Data, lightweight geopolymer Concrete, CO_2 Emission

1. INTRODUCTION

Concrete is one of the most extensively utilized building materials in the world, producing more than 4 billion tons of it annually. However, the energy-intensive process of producing traditional Portland cement, a necessary component of concrete, greatly increases greenhouse gas emissions and the degradation of the environment. Cement production alone is a significant contributor to climate change, accounting for around 8% of worldwide carbon dioxide (CO_2) emissions[1], [2], [3]. Recently many researchers have been done on alkali-activated composite lightweight aggregate geopolymer concrete the sole reason is sustainability factors of reduced carbon footprints and better characteristics it also gains initial strength very quickly lightweight geopolymer concrete can be prepared using aluminous silicate along with sodium-based solutions of alkali. If we talk about aluminous silicate the best option available is widely used as fly ash ground granulated blast furnace slag (GGBFS) or silica fumes some of the geologically available materials are obtained from volcanoes, clay particles of matter red mud [4], [5], [6]. The preparation of aggregate to surface saturated dry condition was achieved by soaking the aggregate and water for 24 hours and letting it dry in the air until the SSD condition was reached. To avoid more absorption of alkaline activated solution in Geopolymer Concrete. It was necessary to prepare for SSD condition which affects the polymerization of the flash and GGBFS with alkaline activator an alkaline activator 24 hours before casting the concentration of sodium hydroxide and the SH/SS were 12M and 2.5 respectively which was prepared according to quality of casting. Another alteration is the ratio of alkaline solution with cement. In the current research, we are fixing this ratio to be 0.7 of alkaline solution to binder ratio. So, to achieve perfect design mix ratio various trial mixes have been done. We are preparing the design mix as per IS 10262 2019[7], [8], [9]. The reason behind all these efforts is to reduce the emissions of carbon dioxide arising due to the utilisation of OPC in the concrete. It has been estimated that the production of 1 metric ton of OPC will generate 1 metric ton of carbon dioxide in mother nature. So, the green concrete or Geo polymer concrete that do not contain Ordinary Portland Cement and therefore are better for the environment. Simultaneously green concrete reduces the quantity of waste generated by industries and carbon footprints. This Geo polymer concrete can be utilized in precast construction and in two construction activities for preparing green concrete replacement of cement completely

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with GGBFS and fly ash. In this research, we are concerned to check the parameters like compressive strength workability of geopolymer concrete[10], [11], [12], [13].

2. MATERIAL AND METHODS

2.1 Aggregates (Sintered fly ash lightweight aggregates (SFA))

Sintered fly ash lightweight aggregates (SFA), produced by sintering fly ash (IS Code 9142 Part 2), are utilized as coarse aggregate. Sintered aggregates are artificially produced round-shaped aggregates with hard interior honeycombed spongy structures by thermal processing. The fly ash particles are sintered, or partially melted and fused, using heat from the cured pellets in a rotary kiln or other similar furnace. The average range for the sintering temperature is 1100°C to 1300°C (2012°F to 2372°F), depending on the fly ash composition and the desired product qualities. Depending on the size of the pellets and the level of sintering that is desired, the heating time needed for sintering might range from 10 minutes to 2 hours[14], [15], [16], [17].

Table 1: Physical Properties of Aggregate [16]

Properties	Value
Aggregate size	4-8mm; 8-12mm
Aggregate strength	More than 40MPa
Bulk density	@ 850Kg/M^3
Bulk porosity	35-40%
Water absorption	17%
Aggregate shape	Rounded pallets
Specific Gravity	1.796

Litagg Industries Private Limited Ahmadabad, INDIA manufactures it. According to IS 2386-3, each combination's specific gravity and water absorption were calculated**.**

2.2 Fly ash: - If we are using only fly ash in geopolymer concrete then heat curing of 45-90ºC is required due to the low calcium amount in a binder (fly ash). The low initial setting is due to the low calcium content in fly ash so heat curing is necessary to gain early strength.

2.3

Table 2: Chemical characteristics of fly ash[17]

Properties	Value
SiO_2	55
Al_2O_3	26
Fe2O	7
CaO (Lime)	9
MgO	2
SO_3	1

2.4 GGBFS: - GGBFS-based Geopolymer concrete due to the good amount of calcium content in GGBFS based Geopolymer concrete gain good initial strength. So, it does not require heat curing for early strength gain. No heat curing is required only ambient curing is required[17], [18].

Table 3: Chemical characteristic

Properties	Value
SiO_2	33
Al_2O_3	13.46
Fe2O	0.31
CaO (Lime)	41.7

MgO	5.99
SO_3	2.74

3. MIX DESIGN OF GEOPOLYMER CONCRETE

3.1 Materials properties: - Mixing Composition Five series mixes were used in this research paper

1. Alkaline liquid-to-binder ratio is 0.7%
2. Sodium hydroxide to sodium silicate is 2.0.
3. Temperature curing is ambient.
4. The molarity of NaOH is 12.
5. GGBFS &Fly ash Combination (70:30)

3.2 Manufacturing process

At this stage, the mix design process of GPC mix as per Indian Standard code guidelines was carried out. On finalization of the mix design, the following laboratory tests were undertaken;

- Mix Design for GPC

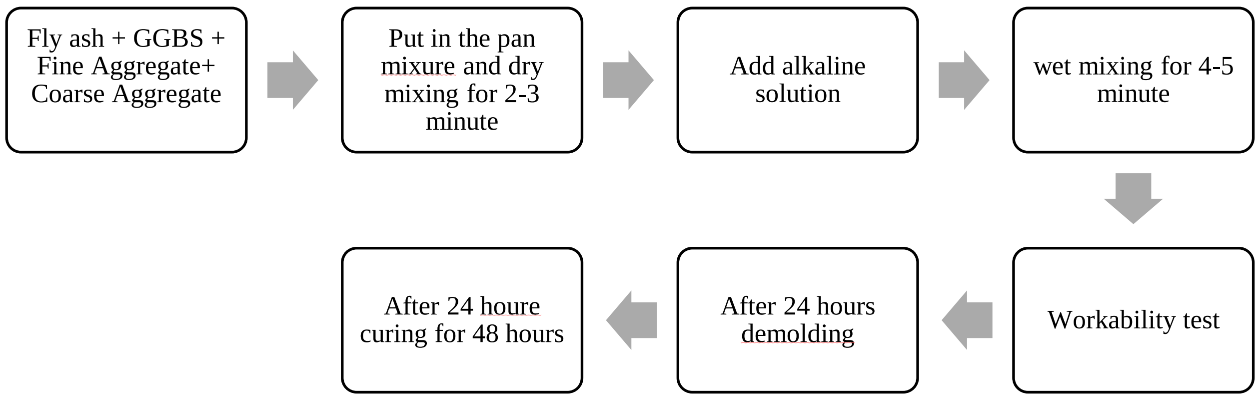


Figure 1: Geopolymer concrete manufacturing process flow chart

- Fresh state properties of GPC mix
- Hardened state properties of GPC mix
- Cube Compression Test

3.3 Manufacturing test specimen: -

Preparation of materials and alkaline Activator: - The binder as Fly ash GGBFS and OPC was prepared to be lump-free. The binders were several at moisture-free and placed above ground level. Both fine aggregate and coarse aggregate were sieved as per standard and stored. The preparation of aggregates to saturated surface dry conditions (SSD). The preparation of aggregate to surface saturated dry condition was achieved by soaking the aggregate and water for 24 hours and letting it dry in the air until the SSD condition was reached. To avoid more absorption of alkaline activated solution in Geopolymer Concrete[19], [20], [21], [22], [23], [24]. It was necessary to prepare for SSD condition which affects the polymerization of the flash and GGBFS with alkaline activator an alkaline activator 24 hours before casting the concentration of sodium hydroxide and the SH/SS were 12M and 2.5 respectively which was prepared according to quality of casting [25], [26]

Table 4: Material Requirement for Concrete Block

Designation of Mix	Aggregate		Cement	Water	Curing Condition
	C.A (kg)	Sand (kg)			
Fly ash aggregate	552	552	406.07	170.5	Water Curing

Table 5: Material Requirement for GPC Block

Designation of Mix	Aggregate		GGBFS (kg)	Fly ash (kg)	Alkaline solution	Sodium Hydroxide	Sodium hydroxide:	Curing Condition
	C.A (kg)	Sand (kg)				Molarity (M)	Sodium Silicate	
Fly ash aggregate	552	552	373.07	33	243.64	12.5 M	2	Ambient Temperature

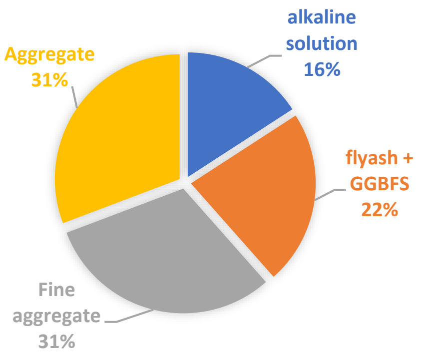


Figure 2. Lightweight geopolymer concrete

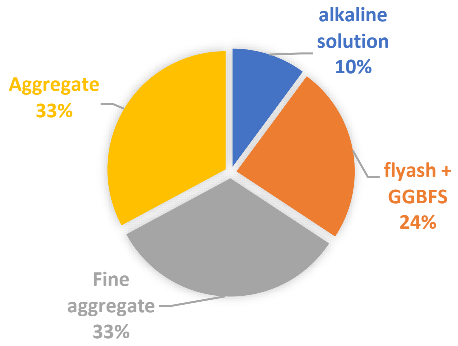


Figure 3. Lightweight concrete

5.2 Raw materials (concrete)

Concrete as known is the most widely consumed construction material. The basic disadvantage of using concrete is the emission of carbon dioxide which leads to worldwide problems like global warming.

The major source of this emission is the use of cement; this emission is divided into two types.

1) Direct emission

This emission is considered with time when cement linkers are produced like the calcination's reaction.

2) Indirect emission

This is the result of different activities like production and transportation.

5.2.1 Supplementary materials

The major supplementary materials used in the research works are fly ash and Ground Granulated Blast Furnace Slag (GGBFS) which are industrial waste products and mainly responsible for air pollution, hence to balance the carbon dioxide emission from the traditional concrete, we are utilizing these waste products. The entire cement has been replaced with a combination of fly ash and GGBFS[27]. The emission inventory data of the cement, natural aggregate, fly ash aggregate fly ash and GGBFS is shown below in the table: -

Table 6. Concrete containing fly ash and coarse aggregate combinations[5]

S.No.	Constituent	Mix kg per m^3 concrete	Embodied CO_2 (kg CO_2/t)	Embodied CO_2 (kg CO_2/m^3 concrete)	Emission Factor (t-CO_2/t)
1	Water	170	2	0.4	0.002
2	Cement	260	930	241.8	0.93
3	Fly ash	130	150	2.6	0.15
4	Sand	640	8	5.2	0.008
5	Granite Aggregate (6-20mm)	300	25	7.5	0.025
6	LWA (4-12mm)	300	220	66	0.22
7	Fresh Concrete Density	1800		298	

Table 7 Concrete containing fly ash and natural coarse aggregate[5]

S.No.	Constituent	Mix kg per m^3 concrete	Embodied CO_2 (kg CO_2/t)	Embodied CO_2 (kg CO_2/m^3 concrete)	Emission Factor (t-CO_2/t)
1	Water	170	2	0.4	0.002
2	Cement	260	930	241.8	0.93
3	Fly ash	120	150	2.6	0.15
4	Sand	650	8	5.2	0.008
5	Granite Aggregate (6-20mm)	1200	25	7.5	0.025
6	Fresh Concrete Density	2400		282	

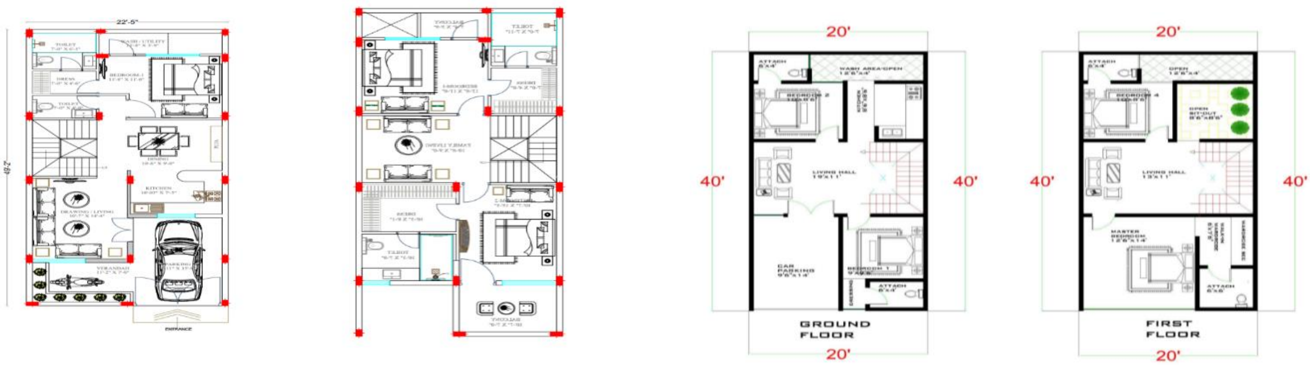
6.1 METHODOLOGY

In the present research work, we are trying to evaluate the carbon footprint of a residential campus in one of India's Tier -II City (Bhopal). The residential project chosen is “Sagar Spring” Ayodhya bypass road Bhopal, consisting of various types of duplexes and multi-story buildings whose details have been given below, along with the plan of the campus and the houses constructed. We are conducting the current research and making a comparative study about the fact that if the entire campus had been constructed using traditional concrete, then how much carbon emission would be done as compared to another type of concrete in which cement has been replaced 100% with fly ash and Ground Granulated Blast Furnace Slag.

The comparative study of the same residential campuses has been done by considering the traditional concrete in the first case and in the second case concrete which has been prepared with full replacement of cement has been considered. The mix design calculations have been chosen for the M-35 grades of concrete and lightweight geopolymer concrete.

6.2 Case study of a residential project

For the current research work, we are considering a residential project named “Sagar Spring” Ayodhya bypass road Bhopal, located in a Tier-II city Bhopal. It is a residential project having the following details



Design B_1 Design C_1

Figure 4. Project Layout and House Plan

Table 8 Type of House and Quantity of Concrete ingredient

Sr No	Material	Unit	Type of Houses			
			800 Sq Ft (B_1)	1000 Sq Ft (C_1)	1100 Sq Ft (C_2)	1200 Sq Ft (D_1)
1	Cement	Bags	640	800	880	960
2	Sand	Cu. Ft	2400	3000	3326	4000
3	Aggregate	Cu. Ft	1680	2100	2315	2470
4	Steel	Kg	6400	8000	8816	9600

Table 9 Number of House and Quantity of Concrete

Type	No. of Houses	Quantity of Concrete per house (m^3)	Total Quantity (m^3)
B1	45	41	1845
C1	53	36	1908
C2	61	39	2379
D1	58	44	2552
		Total	8684 Cu. Meter

The carbon dioxide emission of the concrete based on both cases will be evaluated as follows. Traditional concrete will be prepared in which the traditional cement has been used it will be evaluated and geopolymer concrete is also this project and CO_2 emission is also calculated by Hand mixing concrete

Table10 Total CO_2 emission in Concrete

Material	Quantity (kg/m^3)	Emission Factor ($t\text{-}CO_2/t$)	Total Emission ($t\text{-}CO_2$)
Cement	3526311.9	0.93	3279.470048
Fine	4793568	0.008	38.348544
Coarse (FAA)	4793568	0.025	119.8392
Lightweight Concrete		Total Emission of the Project	3437.66 ($t\text{-}CO_2$)/t

Table11 Total CO_2 emission in Concrete

Material	Quantity	Emission Factor	Total Emission
	(kg/m^3)	(t-CO_2/t)	(t-CO_2)/t
Fly ash + GGBFS	3526311.9	0.15	528.946782
Fine	4793568	0.008	38.348544
Coarse (FAA)	4793568	0.025	119.8392
Lightweight Geopolymer concrete		Total Emission of the Project	687.13 (t-CO_2)/t

8. CONCLUSIONS

- The major objective is to utilize sources based on renewable energy so that a minimum carbon footprint is obtained while preparing geopolymer concrete.
- The result can be easily compared while manufacturing traditional concrete. Also, the technical, and feasible aspects of using renewable energy sources shall be considered. The lightweight geopolymer concrete is leading to sustainable development.
- Also, future challenges to reduce carbon footprint shall be taken into consideration which will ultimately result in maximizing the environmental advantages and reducing the losses to nature.
- The total quantity of CO_2 produced during the manufacture of conventional concrete using cement, sand, and aggregates is 3437.66 (t-CO_2)/t.
- The total quantity of CO_2 produced during the manufacture of lightweight geopolymer concrete using Fly ash + GGBFS, sand, and aggregates is 687.13 (t-CO_2)/t.
- The CO_2 emission of ordinary concrete is found to be more as compared to geopolymer concrete.

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