International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 09 | September - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

AN INVESTIGATION ON THE PROPERTIES OF GEOPOLYMER LIGHT WEIGHT CONCRETE

Chetankumar B Vankihal[1], Sandeep Kulkarni[2], Dr. K B Prakash[3]

[1]Post Graduate Student, Department of Civil Engineering, S G Balekundri Institute of Technology, Belagavi, Karnataka, India. (Visvesvaraya Technological University, Belagavi)

[2]Assistant Professor, Department of Civil Engineering, S G Balekundri Institute of Technology, Belagavi, Karnataka, India. (Visvesvaraya Technological University, Belagavi)

[3]Professor & Head, Department of Civil Engineering, S G Balekundri Institute of Technology, Belagavi, Karnataka, India. (Visvesvaraya Technological University, Belagavi)

---***---

Abstract - The large-scale production of cement is posing environmental problems on one hand and unrestricted depletion of natural resources, on the other hand causing greenhouse effect and global warming. Each ton of Portland cement production results in loading about one ton of CO_2 in to the environment. Environmental and economic reasons require the vision of present concrete making materials. Fortunately in such scenario a new material has emerged that can help in mitigating the problem and the material is Geopolymer Concrete. Hence, the present research work is focused on the production of geopolymer concrete using pozzolans. Geopolymer concrete donot use cement in its productive. Materials like fly ash, ground granulated blast furnace slag (GGBS), silica fume, etc may be used as pozzolanes. The parameters influencing strength of GPC are total combined aggregate, alkaline to binder ratio, mass of sodium silicate to sodium hydroxide, molarity of sodium hydroxide and curing conditions.

The main objective of this experimental investigation is to produce geopolymer concrete using industrial wastes such as fly ash to reduce the global warming effect. The industrial waste foundry slag is used as partial replacement with coarse aggregate in various percentages such as 0%, 20%, 40%, 60%, 80% and 100% by weight. Specimens are prepared with 13 molarity, with alkaline to binder ratio as 0.35 and with mass of Na_2SiO_3 to NaOH as 2.0. The specimens are kept for ambient curing for required days. The workability tests such as slump test, vee-bee test and compaction factor test are conducted. The mechanical properties are studied by testing for compressive strength, tensile strength and flexural strength. Durability properties like water absorption, sorpitivity tests are carried out.

The test results showed the ability of producing light weight geopolymer concrete with acceptable performance of strength and durability properties.

Key Words: Geopolymer concrete, Light weight aggregate, waste foundry slag, alkaline solution, sorpitivity.

1. INTRODUCTION

One-ton of CO2 is emitted to the nature while the production of PC(Portland-cement). Among the greenhouse gases, CO2 contributes 65 % in global warming. The cement demand in India is expected to hike at 10% annually in the medium term buoyed by housing, infrastructure and corporate capital expenditures. In the view of increased cement production in construction industry which is causing global-warming effect, a fly-ash based geopolymer-concrete can be a better substitute for replacement of cement [1]. Geopolymers are inorganic materials that are created by reaction of an aluminosilicate source material, can be fly-ash or slag, with an alkaline activator, typically sodium or potassium hydroxide or sodium silicate [4]. Geopolymer-concrete is cost-effective, energy-efficient, thermally stable, simple to work with, environment-friendly, cementless & long-lasting. By employing industrial-solid wastes like slag, fly-ash, & rice husk ash, GPC lowers its carbon impact [2].

Waste foundry slag is a byproduct of industrial processes such as metal smelting or steel production. It's a liquid waste material that is generated when the impurities of metal or ore are separated and removed. The waste foundry slag is typically composed of various minerals, oxides, and other compounds.

The disposal of waste foundry slag has been significant environmental challenge, as it can release harmful substances into the air, soil, and water. Improper disposal of waste foundry slag can lead to pollution of nearby ecosystems and pose a risk to human health [3].

However, waste foundry slag can also have potential uses and benefits. It’s also used as construction material, for example, as aggregate in road and building construction. It may be used as a raw material while production of cement & concrete.

2. OBJECTIVE OF THE WORK

Geopolymer-concrete is a versatile type of concrete, which acts as a pivotal role in reduction of the emission of carbon dioxide to atmosphere and reducing the dead load of structure.

In this experimental investigation the main objective is to study, the issues of replacement of coarse aggregate by light weight aggregate (Waste Foundry Slag) in the production of geopolymer concrete. The percentage replacement of LWA planned are 0, 20, 40, 60, 80 and 100%. Following are the objectives:

1. To study and identify the suitability of waste foundry slag as a light weight aggregate in producing light weight geopolymer concrete.
2. To study the workability properties through slump, compaction factor and vee-bee degree of light weight geopolymer concrete.
3. Evaluating mechanical properties of geopolymer-lightweight-concrete, including compressive-strength, tensile-strength, & flexural-strength.
4. To study the durability properties such as water absorption and sorpitivity of light weight geopolymer concrete.

3. MATERIALS AND METHODOLOGY

This experimental investigation work involves materials collection and testing, mix proportioning of geopolymer concrete as per IS code, casting and testing of specimens (tests on fresh concrete and harden concrete), results and discussions and conclusion.

3.1 MATERIALS USED

Fly ash: The fly ash used in the experiment was obtained from Bellary**,** specific gravity of fly ash was obtained as 2.43

Fine aggregate: The sand used in the experiment is M sand obtained from local crusher, which has a fineness modulus of 2.50 and a specific gravity of 2.65

Coarse aggregate: In the experimental work coarse aggregate were obtained from local crusher, passing from 20mm sieve and retained on 4.75mm sieve with fineness modulus of 7.83, specific gravity of 2.79 and a bulk density of 1.689 kg/m^3

Waste foundry slag as light weight coarse aggregate: Waste foundry slag that is extracted from the foundry industry, passed from 20mm sieve and retained on 4.75mm sieve with fineness modulus of 8.23, specific gravity of 1.253 and bulk density of 1.06 kg/m^3 is used for the experimental work.

Alkaline solution:

a) NaOH: In this work **13M NaOH** solution is prepared and used as alkaline solution.

b) Na_2SiO_3: In this work **13M Na_2SiO_3** solution is prepared and used as alkaline solution.

3.2 MIX PROPORTION OF M30 GRADE GEOPOLYMER CONCRETE

Table 1 gives the details of mix proportion of geopolymer concrete.

Table 1 Materials required for M-30 grade geopolymer-concrete

Item of geopolymer concrete	Fly ash	NaOH	Na_2SiO_3	FA	CA	Total-water (W/GPB)	Extra water
Quantity (kg/m^3)	405	94.5	47.25	683.5	1269.346	110	28.41
Proportion	1	0.35		1.688	3.134	0.271	0.07

4. RESULTS AND DISCUSSSION

4.1 WORKABILITY TEST RESULTS

The workability tests such as slump test, compaction factor test and vee-bee consistometer test are conducted on the various fresh geopolymer-concrete and the results are as shown in table 2.

Table 2 Test results of workability of geopolymer-concrete

Replacement of CA by LWA in geopolymer-concrete(%)	Slump (mm)	Compaction factor	Vee-Bee degree (Sec)
0%	60	0.78	7
20%	50	0.74	6
40%	45	0.72	10
60%	42	0.70	13
80%	40	0.68	13
100%	35	0.65	15

Graphical representation of workability values are given in fig 1 2 & 3

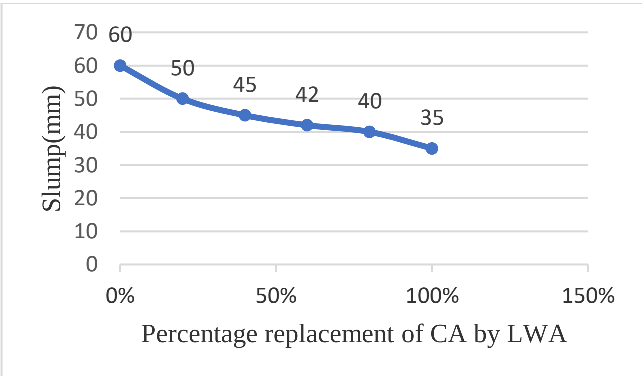

Fig 1. Variation of slump

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 09 | September - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

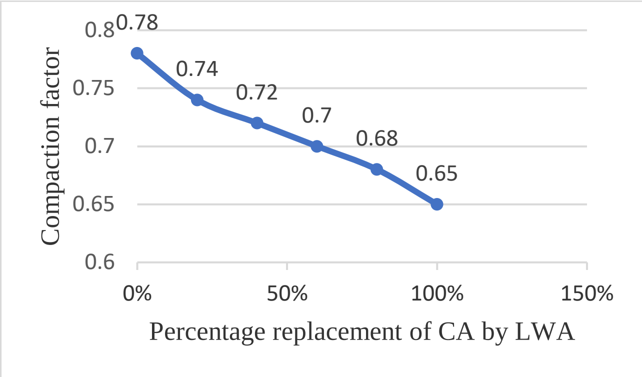

Fig 2. Variation of compaction factor

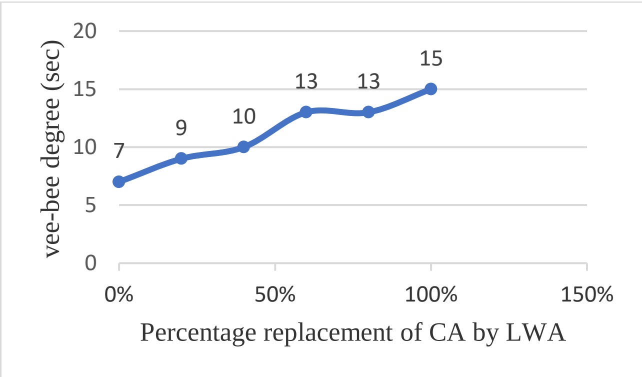

Fig 3. Variation of vee-bee degree

4.2 WATER ABSORPTION TEST

Table 3 gives the water absorption test results.

Table 3 Test results of water absorption

Replacement of CA by LWA in geopolymer-concrete(%)	Water-absorption (%)			Average water absorption (%)
	Trail 1	Trail 2	Trail 3	
0%	3.71	3.94	4.05	3.9
20%	3.44	3.62	3.74	3.6
40%	3.98	4	4.14	4.04
60%	4.22	4.53	4.9	4.55
80%	4.86	4.9	5.27	5.01
100%	5.29	5.5	5.56	5.4

Graphical representation of water-absorption values are given in fig 4

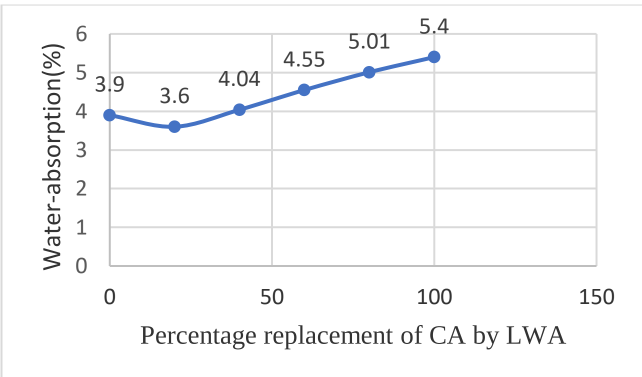

Fig 4. Variation of water-absorption

4.3 SORPITIVITY TEST RESULTS

Table 4 gives the sorpitivity test results.

Table 4 Test result of sorpitivity

Replacement of CA by LWA in geopolymer concrete (%)	Sorpitivity in mm/sec
0%	0.4
20%	0.36
40%	0.41
60%	0.48
80%	0.56
100%	0.63

Graphical representation of sorpitivity values are given in fig 5

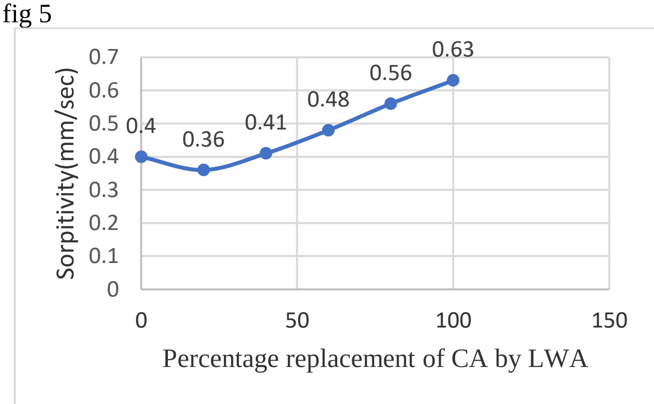

Fig 5. Variation of sorpitivity

4.4 COMPRESSIVE STRENGTH TEST RESULTS

Test results of compressive-strength of various specimens at 28-days are shown in table 5

Table 5 Test result of compressive strength

Replacement of CA by LWA in geopoly mer-concrete(%)	Failure load 'P' (kN)	Compressive strength in $F=\frac{P}{A}$ (N/mm²)	Average compressive-strength in (N/mm²)	Weight (in kgs)	Density (in kg/m³)	Percentage increase or decrease of compressive strength w.r.t. ref. mix
0% (Ref. mix)	720	32	31.26	7.59	2248.88	-
	690	30.67				
	700	31.11				
20%	740	32.88	33.18	7.83	2320	6.14
	750	33.33				
	750	33.33				
40%	670	29.78	29.63	7.48	2216.29	-5.50
	680	30.22				
	650	28.89				
60%	630	28	27.26	7.21	2316.29	-14.67
	600	26.67				
	610	27.11				
80%	590	26.22	26.07	7.14	2115.55	-19.09
	590	26.22				
	580	25.78				

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 09 | September - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

100%	560	24.88	24.44	7.04	208 5.93	-27.90
	550	24.44				
	540	24				

Graphical representation of compressive strength values are given in fig 6

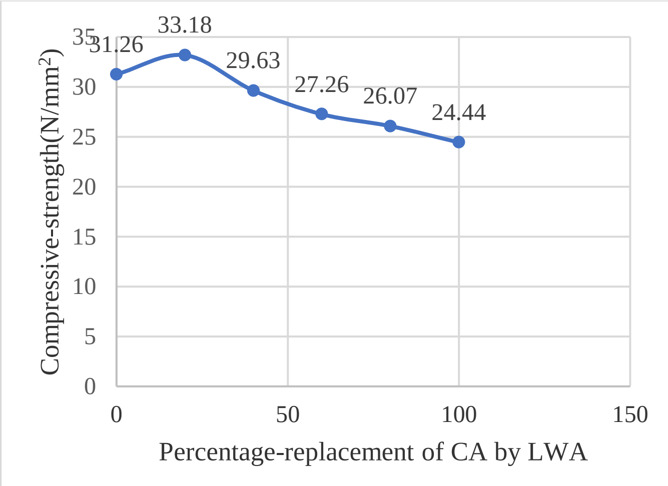

Fig 6. Variation of compressive-strength

Graphical representation of tensile-strength values are given in fig 7

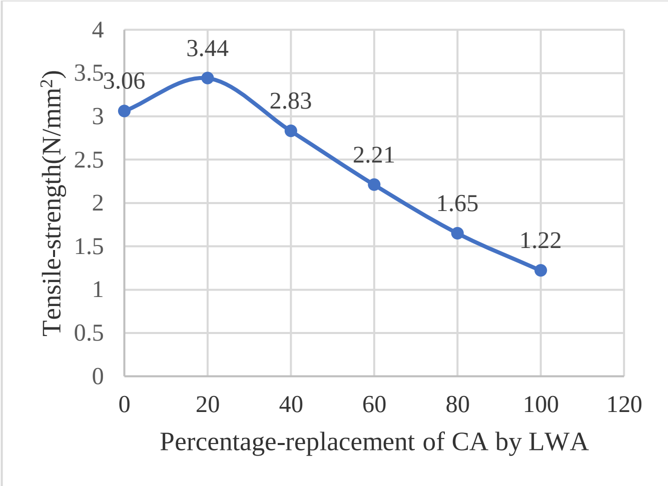

Fig 7. Variation of tensile-strength

4.5 TENSILE STRENGTH TEST RESULTS

Test results of tensile-strength of various specimens at 28-days re shown in table 6

Table 6 Test result of tensile-strength

Replacement of CA by LWA in geopolymer-concrete(%)	**Failure load 'P' (kN)**	**Tensile strength in F=$\frac{2P}{\pi DL}$ (N/mm²)**	**Average split tensile strength in (N/mm²)**	**Percentage increase or decrease of tensile strength w.r.t. Ref. mix**
0% (Ref. mix)	220	3.11	3.06	-
	210	2.97		
	220	3.11		
20%	240	3.39	3.44	12.41
	230	3.25		
	260	3.68		
40%	210	2.97	2.83	-8.12
	180	2.55		
	210	2.97		
60%	150	2.12	2.21	-38.4
	160	2.26		
	160	2.26		
80%	120	1.7	1.64	-84.2
	100	1.41		
	130	1.84		
100%	90	1.27	1.22	-145.1
	100	1.41		
	70	0.99		

4.6 FLEXURAL STRENGTH TEST RESULTS

Test results of flexural-strength of various specimens at 28-days are shown in table 7

Table 7 Test-result of flexural-strength

Replacement of CA by LWA in geopolymer-concrete(%)	**Failure load 'P' (kN)**	**Flexural strength in F=$\frac{PxL}{BxD^2}$ (N/mm²)**	**Average flexural-strength in (N/mm²)**	**Percentage increase or decrease of flexural-strength w.r.t. Ref. mix**
0% (Ref. mix)	8.0	4	4.10	-
	8.4	4.2		
	8.2	4.1		
20%	8.8	4.4	4.45	8.53
	8.9	4.45		
	9	4.5		
40%	7.8	3.9	3.80	-7.89
	7.6	3.8		
	7.4	3.7		
60%	6.9	3.45	3.316	-23.64
	6.7	3.35		
	6.3	3.15		
80%	5.5	2.75	2.76	-47.55
	5.3	2.65		
	5.8	2.9		
100%	3.4	1.7	1.65	-143.4
	3.5	1.75		
	3.0	1.5		

Graphical representation of flexural-strength values are given in fig 8

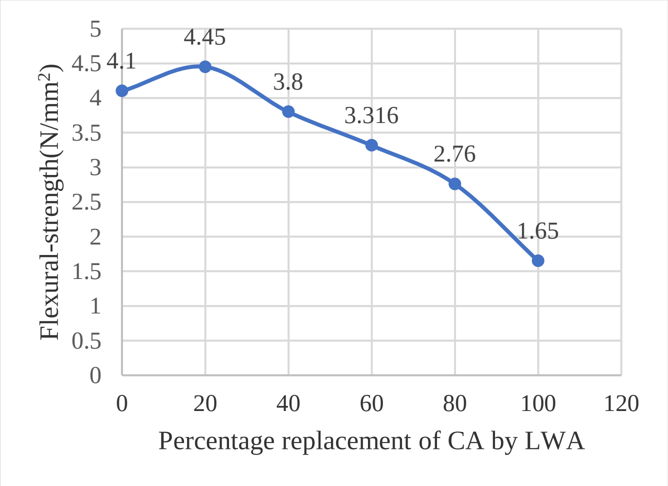

Fig 8. Variation of flexural-strength

5. OBSERVATIONS AND DISCUSSIONS

Based on the work carried out, the following observations are made:

1. It is seen that the workability of geopolymer concrete produced by replacing CA by LWA goes on decreasing as the percentage replacement of CA by LWA goes on increasing.
   This is probably due to the rough texture of LWA which will prevent the flow of geopolymer concrete.
   Thus it may be concluded that the workability of geopolymer concrete produced by replacing CA by LWA goes on decreasing as the percentage replacement of CA by LWA goes on increasing.
2. It is seen that the water absorption and sorpitivity of geopolymer concrete produced by replacing CA by LWA reaches the least value at 20% replacement level. After 20% replacement water absorption and sorpitivity goes on increasing.
   This is probably reasoned for the fact that at 20% replacement of CA by LWA may fill all the pores of concrete, thereby by lowering the transport of liquid through the concrete mass.
   Thus it may be concluded that the water absorption and sorpitivity of geopolymer concrete produced by replacing CA by LWA reaches the least value at 20% replacement level.
3. It is seen that the compressive strength of geopolymer concrete produced by replacing CA by LWA reaches the higher value at 20% replacement level. After 20% replacement level the compressive strength starts decreasing. At 20% replacement level the geopolymer concrete exhibits a compressive strength of 33.18 MPa which is 6.14% increase in the compressive strength as compared to the reference mix.
   This may be reasoned for the fact that at 20% replacement of CA by LWA may fill all the pores of concrete, thereby improving the micro structure of concrete.
   Thus it may be concluded that the compressive strength of geopolymer concrete produced by replacing CA by LWA reaches the higher value at 20% and the value is 33.18 MPa.
4. It is seen that the tensile strength of geopolymer concrete produced by replacing CA by LWA reaches the higher value at 20% replacement level. After 20% replacement level the tensile strength starts decreasing. At 20% replacement level the geopolymer concrete exhibits a tensile strength of 3.44 MPa which is 12.41% increase in the tensile strength as compared to the reference mix.
   This may be reasoned for the fact that at 20% replacement of CA by LWA may fill all the pores of concrete, thereby improving the micro structure of concrete.
   Thus it may be concluded that the tensile strength of geopolymer concrete produced by replacing CA by LWA reaches the higher value at 20% and the value is 3.44 MPa.
5. It is seen that the flexural strength of geopolymer concrete produced by replacing CA by LWA reaches the higher value at 20% replacement level. After 20% replacement level the flexural strength starts decreasing. At 20% replacement level the geopolymer concrete exhibits a flexural strength of 4.45 MPa which is 8.53% increase in the flexural strength as compared to the reference mix.
   This may be reasoned for the fact that at 20% replacement of CA by LWA may fill all the pores of concrete, thereby improving the micro structure of concrete.
   Thus it may be concluded that the flexural strength of geopolymer concrete produced by replacing CA by LWA reaches the higher value at 20% and the value is 4.45 MPa.

6. CONCLUSIONS

Following conclusions are drawn based on the study:

1. The workability of geopolymer concrete produced by replacing CA by LWA goes on decreasing as the percentage replacement of CA by LWA goes on increasing.
2. The water absorption and sorpitivity of geopolymer concrete produced by replacing CA by LWA reaches the least value at 20% replacement level.
3. The compressive strength of geopolymer concrete produced by replacing CA by LWA reaches the higher value at 20% and the value is 33.18 MPa.
4. The tensile strength of geopolymer concrete produced by replacing CA by LWA reaches the higher value at 20% and the value is 3.44 MPa.
5. The flexural strength of geopolymer concrete produced by replacing CA by LWA reaches the higher value at 20% and the value is 4.45 MPa.

ACKNOWLEDGEMENT

It gives me an immense pleasure in expressing my gratitude to all those people who have supported me and had their contributions in making this Project work possible.

REFERENCES

1. Pallavi Vivek Dongre, et.al., Fly Ash based Geopolymer Concrete (2020), International Journal of Engineering Research & Technology (IJERT)

2. Manvendra Verma, et.al., Geopolymer Concrete: A Material for Sustainable Development in Indian Construction Industries (2022), Crystals 2022, 12, 514. https://doi.org/10.3390/cryst12040514
3. Mohd Mustafa Al Bakri Abdullah, et.al., Fly Ash-based Geopolymer Lightweight Concrete Using Foaming Agent (2012), International Journal of Molecular Sciences, Int. J. Mol. Sci. 2012, 13, 7186-7198; doi:10.3390/ijms13067186
4. Ahmad L. Almutairi, et,al., "Potential applications of geopolymer concrete in construction". (2021), Published by Elsevier Ltd
5. Balamurali Kanagaraj, et.al., "Behavioural studies on binary blended high strength self compacting geopolymer concrete exposed to standard fire temperature". (2023), Ain Shams Engineering Journal, https://doi.org/10.1016/j.asej.2023.102394
6. "Abdulrahman Albidah, et.al., "Characteristics of metakaolin-based geopolymer concrete for different mix design parameters". (2020), journal of materials research and technology 2021;10:84-98
7. Elavarasan S, et.al., "Experimental Investigation on Hybrid Fiber Reinforced Geopolymer Concrete" (2017), International Journal of Innovative Research in Science, Engineering and Technology
8. Sourav Kr. Das, et.al., "Geo-polymer Concrete–Green Concrete for the Future" (2014), International Journal of Civil Engineering Research. ISSN 2278-3652 Volume 5, Number 1 (2014), pp. 21-28
9. Waleed Abbas, et.al., Production of lightweight Geopolymer concrete using artificial local lightweight aggregate, MATEC Web of Conferences 162, 02024 (2018)
10. Lan-Ping Qian, et.al., Concrete made with high-strength artificial geopolymer aggregates: Mechanical properties and failure mechanisms (2023), Construction and Building Materials 367 (2023) 130318
11. Yue Li, et.al., Optimization design for alkali-activated slag-fly ash geopolymer concrete based on artificial intelligence considering compressive strength, cost, and carbon emission (2023), Journal of Building Engineering 75 (2023) 106929
12. Davidovits, J. (2013). Geopolymer cement: A review. Journal of hazardous materials, 248-249, 1-9.
13. Awoyera, P. O., Olutoge, F. A., & Osuolale, O. O. (2018). Review of geopolymer lightweight concrete: Materials, properties, and applications. International Journal of Engineering Research and Applications, 8(4), 66-72.
14. Temuujin, J., Williams, R. P., van Riessen, A., & Rickard, W. D. (2009). Effect of calcium compounds on the mechanical properties of fly ash geopolymer pastes. Journal of hazardous materials, 167(1-3), 82-88.
15. Kearsley, E. P., & Wainwright, P. J. (2010). Geopolymer synthesis using zeolites as aluminosilicate precursors. Cement and Concrete Research, 40(6), 898-907.
16. Provis, J. L., & van Deventer, J. S. (2009). Geopolymers: structures, processing, properties and industrial applications. Woodhead Publishing.
17. Duxson, P., Fernández-Jiménez, A., Provis, J. L., Lukey, G. C., Palomo, A., & van Deventer, J. S. (2007). Geopolymer technology: the current state of the art. Journal of materials science, 42(9), 2917-2933.
18. Memon, S. A., Ibrahim, Z., & Ahmad, S. (2016). A review on geopolymer concrete as an alternative to ordinary Portland cement. ARPN Journal of Engineering and Applied Sciences, 11(14), 8877-8884.
19. Jones, M. R., & MacKenzie, K. J. (2012). Review of the durability of geopolymer concrete. Construction and Building Materials, 30, 210-221.
20. IS: 456-2000, Plain and reinforced concrete – code of practice (Fourth Revision)
21. IS: 1199-2018(part 1), Fresh concrete - Methods of sampling and analysis of concrete
22. IS: 516 (part 4) : 2018, Methods of tests for strength of concrete

BIOGRAPHIES

Mr. Chetankumar B Vankihal
M.tech in Structural Engineering
S G Balekundri Institute of Technology, Belagavi, Karnataka, India (Visvesvaraya Technological University, Belagavi)
email: chetanvankihal@gmail.com

Mr. Sandeep S. Kulkarni
Assistant Professor, Dept. of Civil Engg.
S G Balekundri Institute of Technology, Belagavi, Karnataka, India (Visvesvaraya Technological University, Belagavi)
Area of interest: Concrete Technology
email: sandeepk@sgbit.edu.in

Dr. K B Prakash
Professor & Head, Dept. of Civil Engg.
S G Balekundri Institute of Technology, Belagavi, Karnataka, India (Visvesvaraya Technological University, Belagavi)
email: kbprakash04@gmail.com