IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⨳ Peer-reviewed & Refereed journal ⨳ Vol. 13, Issue 7, July 2026

DOI: 10.17148/IARJSET.2026.13706

"Experimental Investigation On Strength Characteristics Of Concrete With GGBS And Metakaolin"

Darshana Chavan[1], Dr. Ansari Fatima Uz Zehra[2]

P. G. Student, Department of Civil Engineering, Deogiri College of Engineering and Management Studies, Ch.Sambhajinagar, 431001 Maharashtra, India[1]

Assistant Professor, Department of Civil Engineering Deogiri College of Engineering and Management Studies, Ch.Sambhajinagar, 431001 Maharashtra, India[2]

Abstract: This study looks at how to make M30 grade concrete in a sustainable way by using less Ordinary Portland Cement and adding Ground Granulated Blast-Furnace Slag and Metakaolin. The goal is to reduce the impact that making traditional cement has on the environment without making the concrete weaker.The researchers are comparing a mix that is 100 percent Ordinary Portland Cement to three other mixes. One mix has 25 percent less Ordinary Portland Cement. Is replaced with 20 percent Ground Granulated Blast-Furnace Slag and 5 percent Metakaolin. Another mix has 35 percent less Ordinary Portland Cement. Is replaced with 25 percent Ground Granulated Blast-Furnace Slag and 10 percent Metakaolin. The last mix has 45 percent less Ordinary Portland Cement. Is replaced with 35 percent Ground Granulated Blast-Furnace Slag and 15 percent Metakaolin. They are testing the strength of these M30 grade concrete mixes at 7 days, 14 days and 28 days to see how strong they are. They are also testing how well the concrete can bend and stretch. The study wants to find the mix of Ground Granulated Blast-Furnace Slag and Metakaolin that is good, for the environment and still makes strong M30 grade concrete that can be used to build things. This will help us build in a sustainable way.

Keywords: IS 456-2000, IS 10262-2019, OPC53, M30 Grade, Metakaolin, Ground Granulated Blast Furnace, High Strength, Mechanical and Durability Properties.

I. INTRODUCTION

The search for sustainable, low-carbon construction materials has driven extensive research into ternary concrete blends that combine Ordinary Portland Cement with supplementary cementitious materials like Ground Granulated Blast-Furnace Slag (GGBS) and Metakaolin. This experimental investigation evaluates the mechanical strength characteristics of M30 grade concrete by systematically replacing cement across three distinct trial combinations: the first trial utilizes a replacement of 20% GGBS and 5% Metakaolin, the second evaluates 25% GGBS and 10% Metakaolin, and the third examines 35% GGBS and 15% Metakaolin. While industrial by-products like GGBS enhance long-term durability, reduce hydration heat, and lower overall material costs, highly reactive engineered pozzolans like Metakaolin act as micro-fillers that accelerate early-age strength development and refine pore structures.

a) Ground Granulated Blast Furnace Slag

The Ground Granulated Blast Furnace Slag is a by-product of the iron manufacturing industry. Iron ore, coke, and limestone go into the furnace, and molten slag floats above the molten iron at temperatures of about 1500°C to 1600°C. The molten slag contains about 30% to 40% SiO_2 and about 40% CaO, which closely matches the chemical composition of Portland cement. After the molten iron is removed, This slag mostly consists of siliceous and aluminous residue. Producing GGBFS uses more energy than making Portland cement. Replacing Portland cement with GGBFS can cut carbon dioxide emissions GGBFS has better water permeability and improved resistance to corrosion and sulphate attack

Properties Of GGBS

Sr No	PHYSICAL PROPERTIES	Reference To Properties As Per IS 16714:2018	Test Result
1	Specific Gravity		2.91
2	Fineness, M2/Kg	320 (Min)	340
3	Slag Activity Index		

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁒ Peer-reviewed & Refereed journal ⁒ Vol. 13, Issue 7, July 2026

DOI: 10.17148/IARJSET.2026.13706

	a) 7 Days	60 % (Min)*	Awaited
	b) 28 Days	75 % (Min)**	Awaited

Table No 1: Physical Properties of GGBS

b) Metakaolin

Metakaolin is the dry, calcined version of the clay mineral kaolinite. Rocks that have a high content of kaolinite are referred to as china clay or kaolin, which has been traditionally utilized in porcelain production. The size of metakaolin particles is smaller than that of cement particles, yet not as fine as silica fume. Metakaolin is recognized as a premium pozzolanic material. These days, metakaolin is among the most commonly used mineral admixtures. It enhances both the performance and cost-effectiveness of concrete. Rather, it is specially manufactured from high-grade kaolin. Metakaolin is a material and the quality of metakaolin is crucial. The characteristics of the material used to make metakaolin play a big role in determining the quality of metakaolin. Metakaolin is made from kaolinite and kaolinite is a component of metakaolin.

Ph (10% SUSPENSION)	5.5 – 6.5
Bulk Density (Kg / Litre)	0.4 – 0.5
SPECIFIC SURFACE AREA M2/G (BET)	10 – 12
OIL ABSORPTION G/100g	45 – 55
S.G.	2.6
Ret. On 500 Mesh	0. 05%

Table No 2: Physical Properties of Metakaolin

a) Ground Granulated Blast Furnace Slag

b) Metakaolin

Fig No 1:- Used In Experimental Program

II. LITERATURE SURVEY

(Durai et al. 2025) investigated the partial replacement of cement in M40 grade concrete. They determined that a 30% replacement level of GGBFS, alongside 15% alccofine and 10% metakaolin, significantly enhanced the compressive, tensile, and flexural strengths. The improved performance was attributed to enhanced pozzolanic activities and denser particle packing.

(Annie T J and Bhuvana G 2020) The chemical composition is rich in reactive calcium and silicates; studies show that it generally contains 25.52% to 32.79% Calcium Oxide (CaO) and 30.34% to 35.26% Silica (SiO_2). This abundance of calcium promotes early-age strength development by forming additional calcium silicate hydrate (C-S-H) gels during the hydration process.

(Arjun Raj PK et al.) Conducted extensive testing on GGBS-dolomite geopolymer concrete. They found that replacing fine aggregates with 15% crumb rubber maximized fracture energy and ductility. In a subsequent study on thermal stability, it was revealed that while GGBS provides excellent ambient strength, the addition of fly ash (forming a GGBS-fly ash-dolomite ternary blend) is required to prevent severe strength degradation at elevated temperatures up to 700^C.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 7, July 2026

DOI: 10.17148/IARJSET.2026.13706

(P.Muralinathan, A. Joshua Daniel & S. Sivakamasundari **)** Metakaolin is a high-quality pozzolanic material. Metakaolin is one of the most widely used mineral admixtures these days. It helps concrete obtain both higher performance and economy. Unlike others, it is neither the by-product of an industrial process (like GGBS) nor entirely a natural product. It is specially produced from high quality Kaolin. According to the **(**Published in International Journal of Pure and Applied Mathematics), Metakaolin is produced by the calcinations of pure or refined kaolinite clay at a temperature between 650℃ to 850℃.

III. MATERIAL TESTING RESULT IN THIS INVESTIGATION

Properties	**Results**
Fineness Modulus	2.83
Water Absorption	3.33
Specific Gravity	2.70
Zone of Aggregates	Zone- II

Table No 3: Physical Properties Of Fine Aggregate

Properties	**Results**
Fineness Modulus	6.72
Water Absorption	1.02
Specific Gravity	2.9

Table No 4: Physical Properties Of Coarse Aggregate

Particulars	**Test Results**	**Requirements of IS:269-2015**	
Physical Requirement			
1. Fineness (m^2/kg)	301	225	Min
2.Standard Consistency (%)	28.0		
3.Setting Time (minutes)			
a. Initial	140	30	Min
b. Final	180	600	Max
4.Soundness			
c. Le-Chat Expansion (mm)	1.5	10.0	Max
d. Autoclave Expansion (%)	0.051	0.8	Max

Table No 5: Physical Properties of Cement

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 7, July 2026
DOI: 10.17148/IARJSET.2026.13706

IV. Mix Proportioning Protocal M30 GRADE

The mix design follows the guidelines of IS 10262:2019. The total cementitious content is held constant while OPC 53 is replaced by a ternary blend of GGBS and Metakaolin. Total binder volume remains unchanged strength and workability

Total Replacement	OPC 53 (%)	GGBS (%)	Metakaolin (%)
0%	100%	0%	0%
25%	75%	20%	5%
35%	65%	25%	10%
45%	55%	30%	15%

V. MIXING PROCEDURE

For M30 grade, consistency is essential. To guarantee homogeneity, the binder cement, GGBS, and metakaolin needs to be pre-mixed. In a mechanical mixer, dry mix all of the aggregates and binder ingredients for two minutes. Wet Mix: While the mixer is operating, gradually add water and the super plasticizer. Mixing Time until a homogenous, consistent paste is produced, keep mixing for a further three minutes. Slump Cone Test Perform a The test ensures that the concrete has enough fluidity to be placed in molds and compacted without honeycombing, but not so much that it causes segregation or bleeding. Slump Cone test immediately to verify workability target range for M30 is usually 100mm

VI.Experimental Methodology For Experimental Performance Casting And Compaction Of Cube, Beam, And Cylinder.

The casting process for the experimental program began with the thorough preparation of standard cast iron molds, specifically 150 mm cubes for compressive strength, 150 × 150 × 700 mm beams for flexural strength, and 150 × 300 mm cylinders for split tensile strength tests. The casting process began by preparing standard mold configurations for the cube, beam, and cylinder specimens by cleaning and lubricating their inner surfaces. The fresh M30 concrete mixtures comprising the designated combinations of OPC, GGBS, and Metakaolin binders were filled into the respective molds in uniform layers. Mechanical compaction was systematically performed using a vibrating to eliminate entrapped air voids. The top surfaces were neatly leveled and trowel-finished before being left to set under ambient laboratory conditions. After 24 hours, the concrete specimens fully submerged in a water curing tank to undergo standard hydration and pozzolanic development until being tested at 7, 14, or 28 days.

Fig No 2: Cube Casting Process

ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 7, July 2026

DOI: 10.17148/IARJSET.2026.13706

Fig No 3: Beam Casting

Fig No 4: Cylinder Casting

VII. Detailed Testing Procedures Compressive Strength (Mechanical Integrity) As Per Is: 516-1959

The cubes were tested after 7 days, 14 days and 28 days. The specimen was put in the Compression Testing Machine (CTM). It was not applied to the top and bottom. A steady load of 140 N/mm^2 per minute was applied. The load was kept on until the specimen failed. The maximum load, at failure was recorded. It could be explosive, shear or columnar.

Fig No 5: Cube Testing

Flexural Strength

The beams were tested to see how strong they are when they are bent in the middle. This is called Third-Point Loading. Sometimes it is also called Two-point loading. The beams were put on two rollers that were 400 mm apart. The load was applied using two rollers that were placed at the one marks of the span. When we did the math to figure out the strength of the beams we used a way of calculating.

Fig No 6: Beam Testing

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 13, Issue 7, July 2026

DOI: 10.17148/IARJSET.2026.13706

Split Tensile Strength

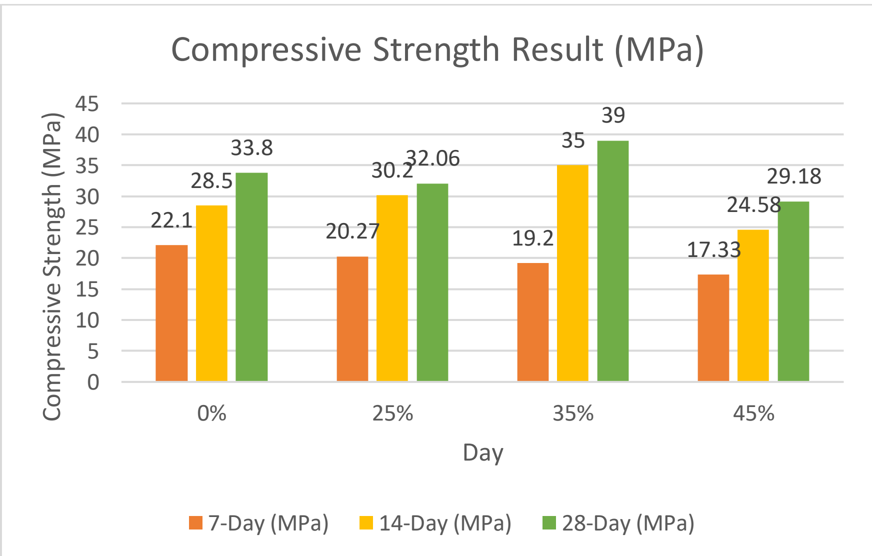
Cylinders (150*300 mm) were tested in the CTM using a specialized jig to hold the cylinder horizontally. Failure alalysis upon failure the split surface was eamined to see if the aggregate had sheared or if the failure occurred in the cement-paste, which indicates the strength of the Interfacial Transition Zone. Split Tensile Strength testing uses cylinders. Filling Three equal layers, each about 100 mm deep, are placed inside the cylinder. Compaction: The tamping rod is used to tamp each layer thirty times. Make sure the rod penetrates into the underlying layer due to the depth. Capping For cylinders, a high-strength mortar or sulphur capping is applied prior to testing in order to guarantee even load distribution if the top surface is not exactly plane.

Fig No 7: Cylinder Testing

VIII. RESULTS AND DISCUSSIONS RESULTS: COMPRESSIVE STRENGTH (CUBES: 150MM)

Percentage Replacement	7-Day (MPa)	14-Day (MPa)	28-Day (MPa)
0%	22.1	28.5	33.8
25%	20.27	30.2	32.06
35%	19.20	35	39
45%	17.33	24.58	29.18

Table No 7: Compressive Strength Results (M30 Grade)



Graph For Compressive Strength Result (M30 Grade)

The pozzolanic reactions of Metakaolin and GGBS speed up and make the matrix denser. By 14 days the 25% and 35%

International Advanced Research Journal in Science, Engineering and Technology
Impact Factor 8.066 ⪤ Peer-reviewed & Refereed journal ⪤ Vol. 13, Issue 7, July 2026
DOI: 10.17148/IARJSET.2026.13706

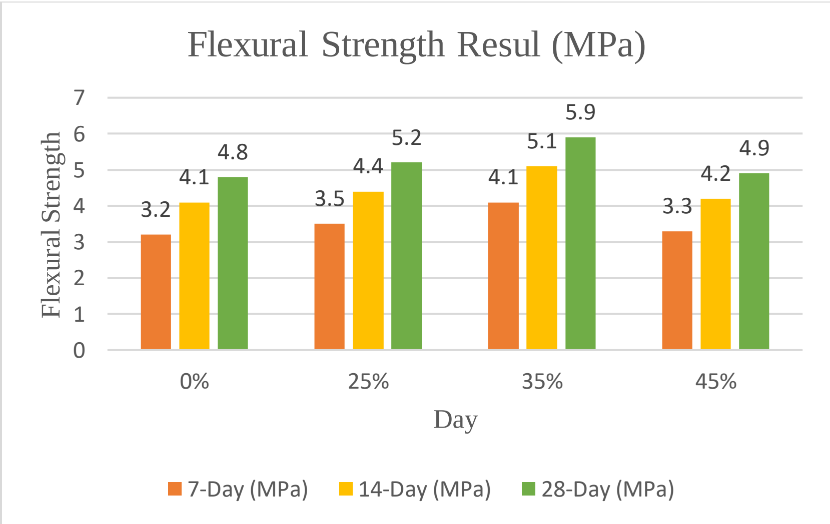
replacement mixes have 30.2 MPa and 35 MPa strength. These outperform the control mixs 28.5 MPa. At 28 days the 35% replacement mix is the best with a strength of 39 MPa. The M30 ternary concrete mix with 35% replacement has the performance. M30 ternary concrete mix results show that 35% replacement is optimal. The compressive strength of M30 ternary concrete mix increases, with 35% replacement.

Results: Flexural Strength (Beams: 100mm X 100mm X 500mm)

Flexural strength tests measure the Modulus of Rupture, demonstrating the bond efficiency between the

Percentage Replacement	7-Day (MPa)	14-Day (MPa)	28-Day (MPa)
0%	3.2	4.1	4.8
25%	3.5	4.4	5.2
35%	4.1	5.1	5.9
45%	3.3	4.2	4.9

Table No 8: Flexural Strength Results (M30 Grade)



Graph For Flexural Strength Result (M30 Grade)

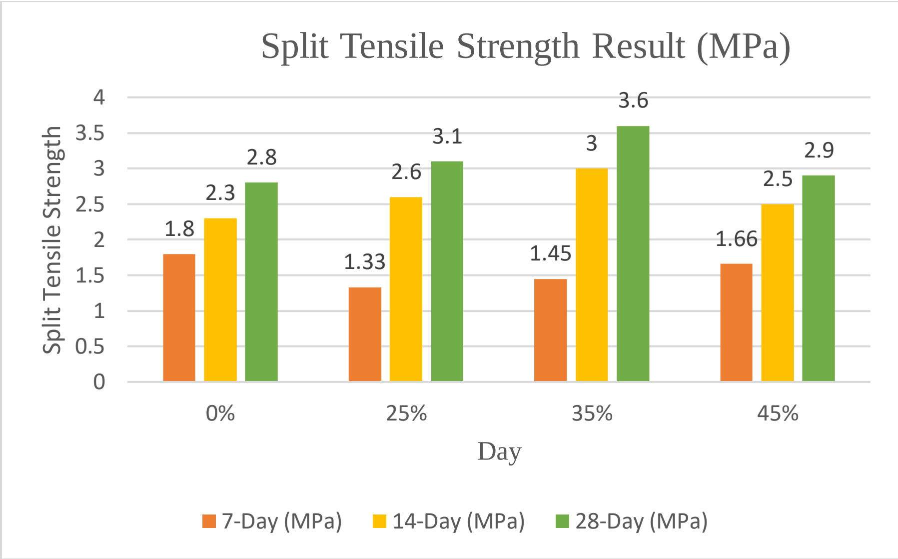
The experimental data for the flexural strength development of the M30 ternary concrete matrix demonstrates a highly favorable performance trend across all curing ages when utilizing GGBS and Metakaolin. Notably, both the 25% and 35% replacement configurations. As curing progresses to 14 and 28 days, the 35% replacement mix consistently maintains its superior performance, culminating in a peak 28-day flexural strength of 5.9 MPa, a substantial improvement over the control mix's 4.8 MPa. However, elevating the binder substitution level to 45% triggers a clear strength dilution effect, causing the values to drop sharply to 4.9 MPa at 28 days. This demonstrates that while a 35% blend achieves.

Results: Split Tensile Strength (Cylinders: 150mm X 300mm)

Percentage Replacement	7-Day (MPa)	14-Day (MPa)	28-Day (MPa)
0%	1.8	2.3	2.8
25%	1.33	2.6	3.1
35%	1.45	3.0	3.6
45%	1.66	2.5	2.9

Table No 9: Split Tensile Strength Results (M30 Grade)

DOI: 10.17148/IARJSET.2026.13706



Graph For Split Tensile Strength Result (M30 Grade)

The experimental results for the split tensile strength of the M30 ternary concrete matrix reveal a clear progression in tensile capacity and crack resistance across the designated curing ages. At the early age of 7 days, all replacement mixes experience an initial strength deficit compared to the, the 35% replacement mix establishes itself as the optimum design configuration, peaking at an impressive 3.6 MPa compared to the control's 2.8 MPa. Conversely, elevating the binder substitution level to 45% initiates a notable strength dilution effect, dropping the 28-day tensile capacity down to 2.9 MPa. This performance decline confirms that exceeding a 35% threshold starves the blended matrix of essential calcium silicate hydrate gel due to an inadequate primary clinker content.

Cumulative Table For M30 Grade Concrete

Strength	**7th day**				**14th day**				**28th day**			
	0%	**25%**	**35%**	**45%**	**0%**	**25%**	**35%**	**45%**	**0%**	**25%**	**35%**	**45%**
Compressive Strength	22.1	20.27	19.20	17.33	28.5	30.2	35	24.58	33.8	32.06	39	29.18
Flexural Strength	3.2	3.5	4.1	3.3	4.1	4.4	5.1	4.2	4.8	5.2	5.9	4.9
Split Tensile Strength	1.8	1.33	1.45	1.66	2.3	2.6	3.0	2.5	2.8	3.1	3.6	2.9

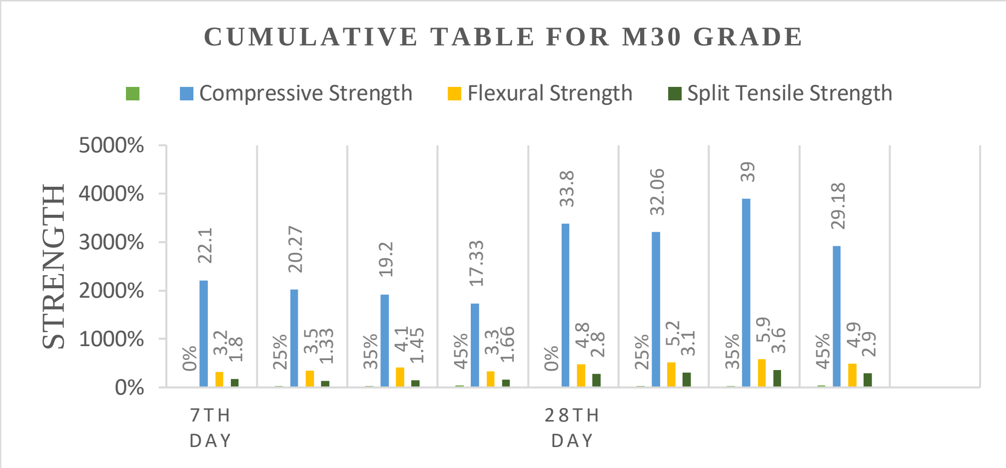
Table No 10: Cumulative Table For M30 Grade Concrete Average Value

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁘ Peer-reviewed & Refereed journal ⁘ Vol. 13, Issue 7, July 2026

DOI: 10.17148/IARJSET.2026.13706



Graph For Cumulative Table (M30 Grade)

IX. Conclusion

In comparison to pure OPC 53 concrete, the analysis verifies that the mechanical properties of M30 grade concrete are improved by the ternary blending of GGBS and Metakaolin. The Trial 2 mix's higher performance suggests an ideal chemical balance, producing a more robust and long-lasting structural material that may be used in harsh environments where dense concrete is needed.This study effectively demonstrates that using a 35% ternary blend for M30 concrete applications is both advantageous and physically possible. Future studies could expand on these results by examining the long-term durability properties for this particular 35% replacement ratio, such as acid resistance and chloride ion permeability.The Over replacement threshold Mix M3 is a problem. We saw a drop in performance with Trial Mix M3. This mix has 35% GGBS and 15% Metakaolin. After 28 days it was 29.18 MPa, which is not enough to meet the M30 grade criteria. This drop is because of a "dilution effect". When we replace much cement with other things there is not enough calcium hydroxide from the cement reaction. This means a lot of the materials like the SCMs are not working properly. The good thing about Mix M3 is that it is better for the environment. We can replace up to 35% of the cement with GGBS and calcined clay which are waste products from industry. This means we use energy to make concrete and we do not need as many natural resources. Mix M3 is a choice, for building things because it is a green alternative.

REFERENCES

[1]. W. Cardoso, R. di Felice, R.C. Baptista, T.A.P. Machado, A.G. de S. Galdino, Evaluation of the use of blast furnace slag as an additive in mortars, REM, Int. Eng. J. 75 (Jul. 2022) 215–224, https://doi.org/10.1590/0370-44672021750075.

[2]. Ansari, F. U. Z., & Sohoni, V. S. (2025). Optimization of bagasse ash and recycled aggregates in M40 concrete for sustainable pavement construction: A fuzzy Logic-Based Approach. *Engineering Technology & Applied Science Research*, *15*(4), 24623–24629. https://doi.org/10.48084/etasr.11669

[3]. T. Pavlů, V. Koˇ cí, P. Hajek, Environmental assessment of two use cycles of recycled aggregate concrete, Sustainability 11 (2019) 6185, https://doi.org/ 10.3390/su11216185.

[4]. K. Mahendra, M.C. Narasimhan, G.B. Prakash, A.K. Das, Experimental investigation and optimization of one-part alkali-activated self-compacting concrete mixes, Case Stud. Constr. Mater. 21 (2024) e04062, https://doi.org/ 10.1016/j.cscm.2024.e04062.

[5]. Abiodun, Y.O., Orisaleye, J.I., Adeosun, S.O., 2023. Effect of calcination temperatures of kaolin on compressive and flexural strengths of metakaolin-concrete. Nigerian J. Technol. Develop. 20, 33–43.

[6]. 5) Ahmed, H.U., Mohammed, A.A., Mohammed, A., 2022. Soft computing models to predict the compressive strength of GGBS/FA- geopolymer concrete. PLoS One 17, 1–28. https://doi.org/10.1371/journal.pone.0265846.

[7]. A. Albidah, A.S. Alqarni, H. Abbas, T. Almusallam, Y. Al-Salloum, Behavior of Metakaolin-Based geopolymer concrete at ambient and elevated temperatures, Constr. Build. Mater. 317 (2022) 125910, https://doi.org/10.1016/j.conbuildmat.2021.125910.

[8]. M.A. Faris, et al., Review the mechanical properties of Metakaolin geopolymer concrete by the inclusion of steel fibers, Arch. Metall. Mater. 67 (1) (2022) 261267, https://doi.org/10.24425/amm.2022.137500.

[9]. L.Y. Yang, Z.J. Jia, Y.M. Zhang, J.G. Dai, Effects of nano-TiO 2 on strength, shrinkage and microstructure of alkali activated slag pastes, Cement Concrete Compos. 57 (2015) 1–7.

DOI: 10.17148/IARJSET.2026.13706

[10]. X. Weng, N. Karmali, Housing Demand in Urban India: through the (Kitchen) Roof, Worldbank.Org, 2022. https://blogs.worldbank.org/en/developmenttalk/ housing-demand-urban-india-through-kitchen-roof. (Accessed 22 March 2024).

[11]. References [1] T. Wang, X.Q. Fan, C.S. Gao, Development of high-strength geopolymer mortar based on fly ash-slag: correlational analysis of microstructural and mechanical properties and environmental assessment, Constr. Build. Mater. 441 (2024) 137515.

[12]. Abbas, R., Khereby, M.A., Ghorab, H.Y., Elkhoshkhany, N., 2020. Preparation of geopolymer concrete using Egyptian kaolin clay and the study of its environmental effects and economic cost. Clean Technol. Environ. Policy 22, 669–687.

[13]. A.M. Zeyad, B.A. Tayeh, M.O. Yusuf, Strength and transport characteristics of volcanic pumice powder based high strength concrete, Constr. Build. Mater. 216 (2019) 314–324, https://doi.org/10.1016/j.conbuildmat.2019.05.026.

[14]. W. Tangchirapat, R. Buranasing, C. Jaturapitakkul, Use of high fineness of fly ash to improve properties of recycled aggregate concrete, J. Mater. Civ. Eng. 22 (2010) 565–571, https://doi.org/10.1061/(asce)mt.1943-5533.0000054.

[15]. N. Roux, C. Andrade, M. Sanjuan, Experimental study of durability of reactive powder concretes, J. Mater. Civ. Eng. 8 (1) (1996) 1–6.

[16]. Mehta PK. Pozzolanic and cementitious by-products in concrete- another look. In: ACI spec publ 114. 1989, Published online.

[17]. M. Aliofkhazraei, Corrosion Inhibitors, Principles and Recent Applications, BoD – Books on Demand, 2018.

[18]. Adel, H., Palizban, S.M.M., Sharifi, S.S., Ghazaan, M.I., Korayem, A.H., 2022. Predicting mechanical properties of carbon nanotube-reinforced cementitious Nano composites using interpretable ensemble learning models. Construct. Build. Mater. 354, 129209.

[19]. M.S. Imbabi, C. Carrigan, S. McKenna, Trends and developments in green cement and concrete technology, Int. J. Sustain. Built Environ. 1 (2) (2012) 194–216.

[20]. A. Rao, K.N. Jha, S. Misra, Use of aggregates from recycled construction and demolition waste in concrete, Resour. Conserv. Recycl. 50 (2007) 71–81, https:// doi.org/10.1016/j.resconrec.2006.05.010.

[21]. J. Correia, Y. Bai, T. Keller, A review of the fire behaviour of pultruded GFRP structural profiles for civil engineering applications, Compos. Struct. 127 (2015) 267–287. https://doi: 10.1016/j.compstruct.2015.03.006.

[22]. Etxeberria M, V´azquez E, Marí A, Barra M. Influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete. Cem Concr Res 2007;37(5):735–42.

[23]. M.-F. Kai, J.-G. Dai, Understanding geopolymer binder-aggregate interfacial characteristics at molecular level, Cem. Concert. Res. 149 (2021), 106582, https:// doi.org/10.1016/j.cemconres.2021.106582.

[24]. Y. Dong, Performance assessment and design of ultra-high-performance concrete (UHPC) structures incorporating life-cycle cost and environmental impacts, Constr. Build. Mater. 167 (2018), https://doi.org/10.1016/j.conbuildmat.2018.02.037.

[25]. Karikalan A T1, Prabaghar A2 and Saravanan J3 "Flexural behaviour of GGBS concrete beam with steel, hybrid FRP and GFRP bars" Turkish Journal of Computer and Mathematics Education Volume.12 No.11 (2021)

[26]. 25) Girija Vidnyan Gaikwad1, Dr.Y.M.Ghugal2, "Experimental Investigation on Metakaolin Modified fiber Reinforced Concrete" International Research Journal of Engineering and Technology Volume: 06 Issue: 08, Aug 2019.

[27]. Egwuonwu, William C1, Iboroma Z.S Akobo2 Barisua E Ngekpe3, "Effect of Metakaolin as a Partial Replacement for Cement on the Compressive Strength of High Strength Concrete at Varying Water/Binder Ratios" SSRG International Journal of Civil Engineering, Volume 6, Issue 1, January 2019.

[28]. Venu Malagavelli1, Srinivas Angadi2 and J S R Prasad3 "influence of metakaolin in concrete as partial replacement of cement", International Journal of Civil Engineering and Technology, Volume 9, Issue 7, July 2018.

[29]. S. Mallikarjuna1, M. Mujahid Ahmed2, "Compressive Strength of Concrete using GGBS", International Journal of Scientific Engineering and Technology Research, Volume.05, IssueNo.34, October-2016.

[30]. Dr. B. Vidivelli1, M. Gopinath2, T. Subbulakshmi3 "Study on flexural behaviour of reinforce concrete beam with GGBS and steel fibre" International Journal of Scientific & Engineering Research, Volume 7, Issue 6, June-2016.

[31]. 30) Deepthi Dennison1,Jean molly simon2 "effect of metakaolin on the structural behaviour of normal and steel fibre reinforced concrete beams", International Journal of Scientific & Engineering Research, Volume 5, Issue 7, July-2014.

[32]. Dr.K.Srinivasu1, M.L.N.Krishna Sai2, Venkata Sairam Kumar.N3 "A Review on Use of Metakaolin in Cement Mortar and Concrete", International Journal of Innovative Research in Science, Engineering and Technology Vol. 3, Issue 7, July 2014.

[33]. Ansari, F. U. Z., & Sohoni, Dr. (2023). DEVELOPMENT OF MODIFIED CONCRETE INCORPORATING RECYCLED AGGREGATE AND BAGASSE ASH: A SUSTAINABLE APPROACH. European Chemical Bulliten, 12(4), 194–200.