Numerical Investigation on Geopolymer Concrete Beam with Partial Replacement of M- Sand Using Iron Ore Tailings

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***Abstract* - This research work aims to study further sustainability to the cement - less geopolymer concrete by partially replacing M-Sand by Iron ore tailings. Geopolymer RC beam of with 40% iron ore tailings as a replacement to M-Sand was studied for its flexural behaviour and compared with Geopolymer reinforced concrete beam. The analysis was also carried out using ANSYS software. The study derived that in all stages, the performance of the geopolymer beam with iron ore tailings was marginally better than the Geopolymer RC beam. From this numerical investigation, it is concluded that deflection of the beam with 40% iron ore tailings geopolymer concrete beam was lower than the 0% iron ore tailings geopolymer beam. The study demonstrates the potential of Iron ore tailing as a viable sand substitute in structural applications and promotes the circular use of waste materials.**

***Index Terms* - GPC, Iron ore tailings, Von misses stress , Von misses strain, Deformation, ANSYS.**

I.INTRODUCTION

The construction industry faces a dual challenge: the depletion of natural resources and the need for sustainable materials. Cement production alone accounts for 8% of global CO_2 emissions. As an alternative, geopolymer concrete (GPC) has emerged as a promising solution due to its low-carbon footprint and superior chemical durability. GPC is synthesized by activating alumino-silicate materials such as fly ash and GGBS with alkaline solutions, eliminating the need for conventional Portland cement. This study explores the structural feasibility of using IOT as a partial sand replacement in GPC beams. A finite element model is developed and analysed to simulate the flexural behaviour under loading conditions. This numerical approach offers valuable insight into the load-bearing characteristics, enabling the prediction of performance without extensive experimental testing.

II. OBJECTIVE

- To analyse the flexural behaviour and deflection of Geopolymer Iron ore tailing reinforced beam using ANSYS software
- To compare the numerical analysis of Geopolymer beam with Geopolymer Iron ore tailing reinforced beam
- Numerical stress-strain relations and the load-deformation relations in ANSYS are discussed.

III. METHODOLOGY

1. To carry out a literature survey on geopolymer concrete and iron ore tailings properties that can be feasible to use in concrete.
2. To compare the result of the ANSYS model with 0% iron ore tailings model with 40% iron ore tailings model.

IV. LITERATURE REVIEW

Raghunandan Kumar et.al (2020): This study investigates the utilization of iron ore tailings (IOT), slag sand, ground granulated blast furnace slag (GGBS), and fly ash as primary constituents in the production of geopolymer bricks. The methodology involves replacing traditional clay or natural sand with IOT and slag sand, and using geopolymer binders instead of conventional cement. Alkaline activators, specifically sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH), are employed to initiate the geopolymerization process. Bricks are cast and cured at ambient temperatures, and their mechanical properties are evaluated at 7, 14, and 28 days. The study examined various mix proportions, particularly focusing on the molarity of the NaOH solution (8M and 10M) and the ratios of IOT and slag sand. Bricks with 70% slag sand and 30% IOT achieved compressive strengths of 8.91 MPa and 10.21 MPa for 8M and 10M NaOH solutions, respectively. The optimal mix, comprising 70% slag sand and 30% IOT with a 10M NaOH solution, resulted in bricks with satisfactory compressive strength and durability.

S.R. Mahesh et.al (2021):The study investigates the flexural behaviour of geopolymer reinforced concrete beams through both finite element analysis (FEA) using ANSYS 18.1 and experimental testing. The primary objective was to analyse crack propagation, failure mechanisms, and stress distribution under applied loading conditions. The geopolymer concrete attained a maximum compressive strength of 37.27 MPa after 28 days of curing. Initial cracks were observed at the bottom tension zone and expanded progressively as the load increased, leading to the development of both flexural and shear cracks. The failure patterns and stress distribution observed in FEA closely correlated with experimental results, demonstrating the reliability of the simulation model. The failure load recorded experimentally was 47.3 kN with a corresponding deflection of 7.72 mm, which closely matched the FEA predictions of 48 kN and 7 mm deflection. Maximum compressive stress in the concrete was found to be 7.93 MPa, while the maximum tensile stress in the tension zone reached 18.9 MPa.

Mahmud Abubakar (2023): The study explores the use of iron ore tailings (IOT) as a sustainable alternative to natural sand in reinforced concrete beams. Utilizing three-dimensional non-linear finite element analysis (FEA) through ABAQUS/CAE, the research simulates the behaviour of beams with a 20% replacement of sand by IOT. The simulation effectively predicts the damage behaviour of the modified concrete, indicating that this modelling approach can accurately forecast the performance of waste-based concrete mixtures in various designs. This approach offers a cost-effective and time-saving method to assess the viability of incorporating industrial by-products into construction materials, promoting environmental sustainability in the construction industry.

Nan Zhang et.al (2023): This study explores the viability of utilizing mine tailings to produce geopolymers as sustainable alternatives to conventional construction materials. The methodology involved conducting uniaxial compression tests on geopolymer specimens with varying sodium hydroxide (NaOH) molarities to assess their mechanical behaviour, complemented by Discrete Element Method (DEM) simulations to analyse microscale cracking and damage mechanisms. Findings indicated that the Uniaxial Compressive Strength (UCS) of the geopolymers increased with NaOH molarity up to 10 M, beyond which it declined, Uniaxial compressive strength increases from 0.15 Mpa of 0M NaOH to 29.2 Mpa of 10M NaOH, suggesting an optimal molarity for mechanical performance. X-ray diffraction (XRD) analysis revealed that quartz was the dominant crystalline phase, with its formation closely linked to the alkaline molarity. The DEM simulations corroborated the experimental results, effectively illustrating crack propagation and damage patterns within the geopolymer matrix. The study concludes that mine tailings-based geopolymers exhibit promising mechanical properties and damage resistance, positioning them as viable, eco-friendly alternatives for construction applications.

V.TEST RESULTS AND DISCUSSION

The specimen is fabricated in the size of 1000*150*150 mm and imported on ANSYS software with simply support.

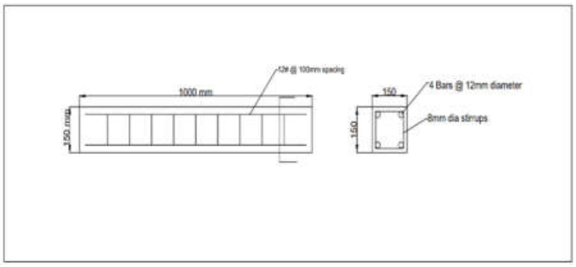

Fig -1: Dimensions of beam

A. REINFORCED GPC BEAM WITH 0% IRON ORE TAILINGS

Table – 1: Properties of steel

S.no	Property	Value
1	Young's modulus	2E-07 GPa
2	Poisson's ratio	0.3
3	Bulk Modulus	166.67 Pa
4	Shear modulus	76.923 Pa
5	Density	7850 kg/m^3
6	Yield strength	415 Mpa
7	Tangent modulus	4E-09 Gpa

Table – 2: Properties of geopolymer concrete

S.no	Property	Value
1	Youngs modulus	25 GPa
2	Poisson's ratio	0.23
3	Bulk modulus	1.5432E+10Pa
4	Shear modulus	1.0163E+10Pa
5	Density	2400 kg/m^3

Table – 3: Result of reinforced geo polymer concrete beam with 0% iron ore tailings

S. No	Load (KN)	Deformation (mm)	Stress (MPa)	Strain
1	0	0	0	0
2	10	0.044548	1.9882	0.000079
3	20	0.089098	3.9763	0.000159
4	30	0.13365	5.9642	0.000238
5	40	0.1782	7.952	0.000318
6	50	0.22276	9.9398	0.000397
7	60	0.26732	11.927	0.000477
8	70	0.31188	13.815	0.000556
9	80	0.35644	13.987	0.000636
10	90	0.40101	14.010	0.000715
11	100	0.4458	14.577	0.000795

The beam is design and analysis of specified dimension (1000*150*150mm) with geo polymer. The analysis based on gradually load acting on the beam. Load applied on the beam is 0 to 100 KN and deflection value is 0.044548 mm to 0.4458 mm respectively. As well as the von misses stress and von misses strain values are increased gradually.

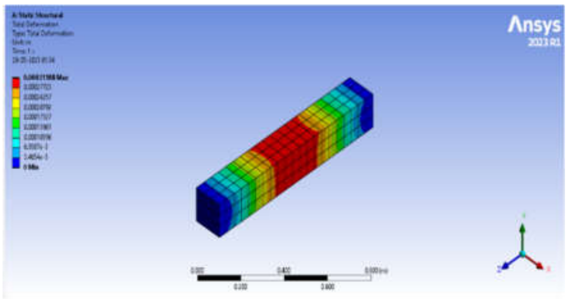

Fig -2: Total deformation of reinforced GPC beam with 0% iron ore tailings

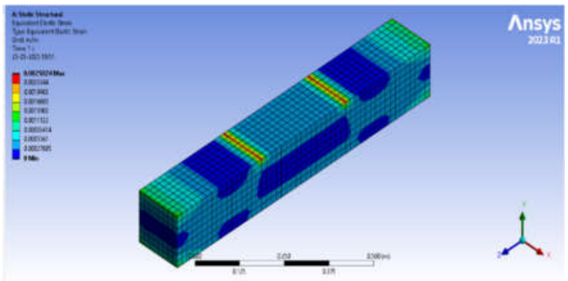

Fig -3: Von mises stress of reinforced GPC beam with 0% iron ore tailings

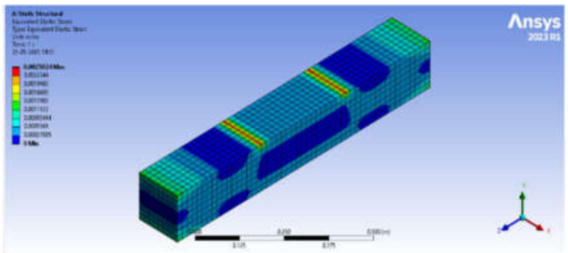

Fig -4: Von mises strain of reinforced GPC beam with 0% iron ore tailings

B. REINFORCED GPC BEAM WITH 40% IRON ORE TAILINGS

Table – 4: Properties of geopolymer concrete

S.no	Property	Value
1	Youngs modulus	30 GPa
2	Poisson's ratio	0.21
3	Bulk modulus	1.7241E+10Pa
4	Shear modulus	1.2397E+10Pa
5	Density	2750 kg/m^3
6	Compressive strength	30 Mpa
7	Tensile strength	12 Mpa

Table – 5: Result of reinforced geo polymer concrete beam with 40% iron ore tailings

S. No	Load (kN)	Deformation (mm)	Stress (MPa)	Strain
1	0	0	0	0
2	10	0.037207	2.6126	0.00007
3	20	0.074416	5.2251	0.000161
4	30	0.11163	7.8375	0.000227
5	40	0.14884	10.450	0.000308
6	50	0.18605	14.062	0.000379
7	60	0.22370	18.674	0.000463
8	70	0.26048	20.287	0.000576
9	80	0.2777	24.599	0.000617
10	90	0.3492	24.511	0.000658
11	100	0.39215	25.123	0.000771

The beam is designed and analysed with specified dimension (1000*150*150mm) with 40% iron ore tailings. The analysis based on gradually load acting on the beam. Load applied on the beam is 0 to 100KN and deflection value is 0.037207 mm to 0.39215 mm respectively. Also, the von misses stress and von misses strain values are found to increase gradually.

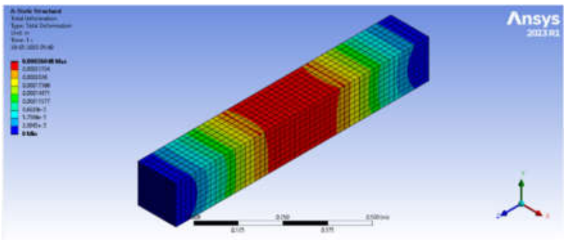

Fig -5: Total deformation of reinforced GPC beam with 40% iron ore tailings

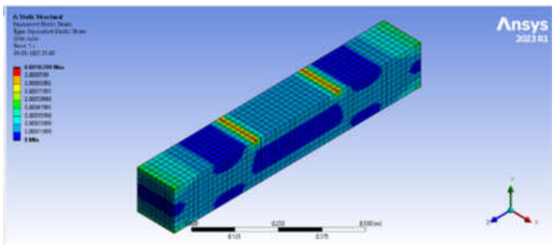

Fig -6: Von mises stress of reinforced GPC beam with 40% iron ore tailings

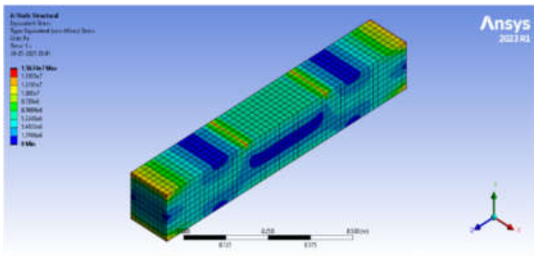

Fig -7: Von mises strain of reinforced GPC beam with 40% iron ore tailings

VI.CONCLUSIONS

1. From this numerical investigation it is concluded that the partial replacement of M-Sand by Iron ore tailings, the deformation values are found to decrease.
2. The stress and strain values of GPC beam with 40% iron ore tailings is higher than that of GPC beam with 0% iron ore tailings.
3. Thus,compared to of GPC beam with 0% iron ore tailings, of GPC beam with 40% iron ore tailings withstands more stress,less deformation and improved strength.

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