International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Evaluation of Strength Properties of Geopolymer Concrete Incorporating with GGBS and Rice Husk Ash (RHA)

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ABSTRACT - Geopolymer concrete is also known as Alkali activated concrete. It is one of the innovative construction materials, which addresses global issues like CO_2 emission and energy reduction. In current research proposes use of GGBS and RHA materials, both are sustainable materials and used as substitute for binders. Alkaline solution of Sodium Hydroxide (NaOH) and Sodium silicate (Na_2 SiO_2) are used. Various concentration of NaOH like 8N,10N,12N are used for mix proportions of 10%, 20%, 30% of RHA along with 90%. 80%, 70% of GGBS as substitute binder for geopolymer concrete. The study shows that for a range 10-20% GPC gains good compressive strength Beyond that compressive strength reduces. For 30% of RHA compressive strength is Very Low. For a mix combination GPT at 10% RHA with 10N NaOH GPC achieved highest compression strength of 52.87 N/mm^2 at 28 days. Microstructural analysis with SEM and EDAX shows better bonding is created b/w the particle with minor cracks and voids.

Key words: Sodium Silicate (NS), Sodium Hydroxide (NH), Normality-N, GGBS, RHA, Geopolymer Concrete (GPC)

1. INTRODUCTION

Geopolymer concrete (GPC) is having resistant to acid and sulphate and salt attack. It allows the utilization of waste materials effectively and gives a long life for the structure with the use of residue materials**.** Conventional Cement is major responsible for emission of the greenhouse gases, contributing approximately about 0.5-0.9 tonne of carbon dioxide for the production of 1 tonne of Cement. By the Census Worldwide in CO_2 emission India is holding 2nd rank in the year 2024 for the production of cement**.** By using GPC, it is possible to reduce 50-94% Carbon dioxide emission, since it is made with recycled and residual waste materials. It also not requires any fuels for its manufacturing process of GPC. The usage of residue and waste material make it ecofriendly material and low energy consumption material. In present study GGBS and RHA are used as Supplementary binders, GGBS is a residue from iron manufacturing industry where as RHA is an agricultural residue it is rich in Silica.

Joseph Davidoits first developed the Geopolymer concrete in 1978 using Activated alkaline solution. Davidoit's the founder of Geopolymer Concrete. He also developed geopolymer cement upto 90% less CO2 emission than the traditional Portland cement which is sustainable development [3]. GPC Specimens prepared for 8, 10, 12 molarity of achieved the compressive strength ranges from 33.6 to 46.5 MPa. it was found that the Compressive strength is proportional to density of the LWGPC and also, they found that the compressive strength increases with increase in the morality and GGBS content [1]. When RHA increases from 0 to 20% the compressive strength increases to 43.4 to 47.5 MPa. Effect of substituting RHA for fly ash is partially were studied on the compressive strength. It revealed that RHA combined with 15% and 20% were showed better compressive strength of 46.7 MPa and 47.5 MPa [2]. For the GPC with RHA the Na_2SiO_2 and NaOH combination were used as liquid alkaline with ratio at 70:30, the concentration of NaOH were maintained at 8M molarity. The liquid alkaline activator by Binder ratio of 1.2 was used. The mix proportion with different percentages of RHA ranging from 0 to 30% analysed. The compressive strength of 7 and 14 days after testing shows high compressive strength compared to 28 days [4]. A study found that increasing the RHA content from 0 to 30% led to 120% improvement in the compared compressive strength with control mix. The binder content decreases from 400 kg /m3 to 280 kg /m3 as a fine aggregate as RHA increases from 0 kg /m3 to 120 kg /m3. Sodium hydroxide and sodium silicates are kept constant 60 kg /m3 and 120 kg /m3 respectively with super plasticizers added at 2 kg /m3. Sand and coarse aggregates are consistently used as 600 kg /m3, 400 kg /m3 and 800 kg /m3 for all mixes respectively. The study demonstrates that increase of RHA concentration results in decrease in the workability while compressive strength increases from 16 MPa to 35 MPa [5,6]. Considered the minimum maximum binder content were 340 kg /m3 and 440 kg /m3 respectively by IS10262. The coarse aggregate,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

fine aggregate referred from table 2 of IS10262-2019. The concrete analysed for various volume of fly ash, GGBS and for the ratios of activator to binder, aggregate to binder. Combination of Class F fly ash and GGBS were taken for binder the specific gravity of GGBS and fly ash was 2.87 and 2.19 respectively. Increasing the GGBS in the mixture results in high GPC compressive strength. When GGBS exceeds 50% GPC workability is reduced for WG/B -0.55. WG/B increase after 0.5 results in high earlier strength development. It accelerates polymerization reaction leads to rapid formation of polymeric gel, results in gain of strength at a faster rate. When WG/ B increases up to 0.6 GPC becomes excessively fluid negatively affect workability and causing issues like segregation and bleeding by increasing AG/ B leads to decreasing in strength of GPC higher the aggregate reduces the bonding strength between the particles make weak bonding. [7,8]

2.MATERIALS AND METHODOLGY

2.1 Materials

The following materials are used in this study

1. Ground granulated blast furnace Slag (GGBS): Low calcium class F grade satisfying IS standards of GGBS is used, supplied by local supplier. Rich in SiO_2 used as a primary binder for the GPC.
2. Rice Husk Ash (RHA): It is Rich in Amorphous silica about 90% is used as substitute binder. It supplied by the Local supplier satisfying IS standards is used.
3. Sodium hydroxide (NaOH): NaOH flakes are dissolved to prepare required Normality of Solution. NaOH with 8N,10N,12N is used with NS/NH ratio of 2:1 by mass. It enhances polymerisation and imparts strength and workability.
4. Sodium silicate ($Na_2 SiO_2$): It is a primary alkaline activator colourless viscous liquid is used, supplied by local supplier.it boosts compressive strength and accelerates setting action.
5. Fine Aggregate (M sand): M sand of particle size less than 4.75mm, well graded free from lumps and inherit material used satisfying IS standards.
6. Coarse aggregate: 20mm and down size well graded flaky elongated granite jelly is used satisfying IS standards.

2.2 Mix design

Mix design of GPC is done with reference to IS 10262 and IS 456. As per the IS 456 The minimum binder content given as 340 - 440 Kg/m^3 taken 400 Kg/m^3 for all the mixes. The volume of Coarse aggregate is taken as 65% to the total aggregate volume and fine aggregate volume is taken as 35% to the total aggregate volume with reference to the table -2 and table -3 of the IS 10262. On this basis volume of coarse aggregate and fine aggregate is calculated and tabulated as 633 Kg/m^3, 1176 Kg/m^3 for fine aggregate and coarse aggregate respectively. W/B ratio taken as 0.5, mixes are prepared using 10%, 20%, 30% RHA as Binder with sodium hydroxide normality of 8N,10N,12N. Alkaline solution prepared with Activator to binder (a/b) ratio of 0.5, for NS/NH ratio -2.0, mass of NaOH flakes and sodium silicate volume is calculated to prepare the alkaline solution. NaOH flakes are dissolved in calculated volume of water and liquid solution is prepared and mixed thoroughly with sodium silicate of calculated volume, alkaline solution of required normality is now ready which is kept in jar to mix with the ingredients. Three mixes been prepared with 8N,10N,12N normality to find the optimum strength with the varied proportion of RHA as a substitute binder. Nominal mix proportions were (GGBS & RHA: fine aggregate: Coarse aggregate) 1:1.58:2.94 with alkaline solution.

Table -1 Mix proportions for GPC as per Mix Design

NaOH		**Mix**	**GGBS in Kg/m^3**	**RHA in Kg/m^3**	**NaOH in Kg/m^3**	**Na_2SiO_2 in Kg/m^3**	**CA in Kg/m^3**	**FA in Kg/m^3**
8N	90% GGBS, 10% RHA	GPM1	360	40	60	120	1176	633
10N		GPT1						
12N		GPX1						
8N	80% GGBS,	GPM2	320	80	60	120	1176	633
10N		GPT2						

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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12N	20% RHA	GPX2						
8N	70% GGBS, 30% RHA	GPM3	280	120	60	120	1176	633
10N		GPT3						
12N		GPX3						

3. RESULTS AND CONCLUSION

3.1 Compression Strength

Compressive strength results are given in the graphs in Fig 1,2,3 showing 7 days strength Vs 28days strength. Among all the mixes GPT mix at 10% RHA mix taking High compressive strength of 52.87 N/mm^2 at 28 days and also 50.58 N/mm^2 at 7 days.

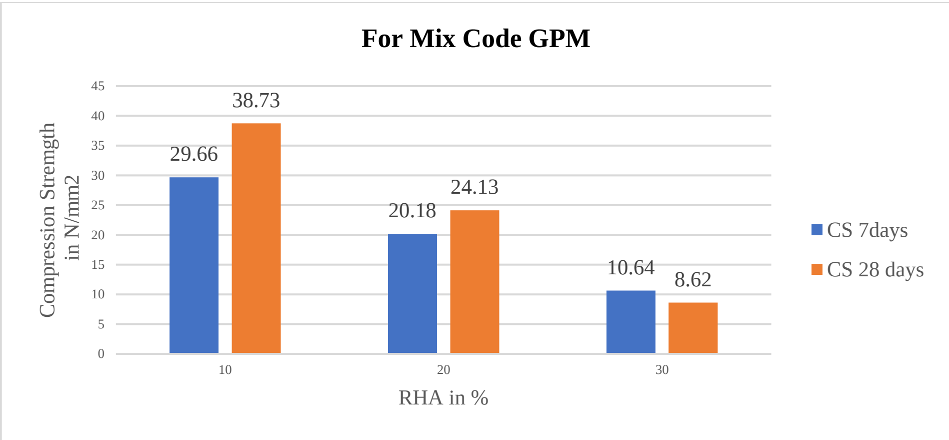

Fig:1 Compressive strength of Geopolymer Mix GPM

The above bar chart indicating that the mix GPM 1 is having a 30.57% strength gain for 28 days compare to 7 days. Similarly, GPM 2 is having19.57% strength gain at 28 days compare to 7 days. For GPM 3, 18.98 % strength gain at 7 days with 28 days.

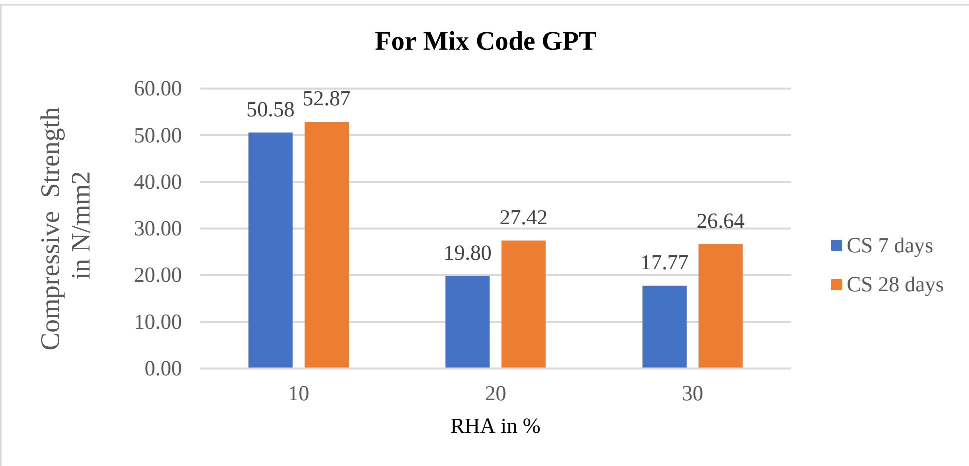

Fig:2 Compressive strength of Geopolymer Mix GPT

The above bar chart indicating that the mix GPT 1 is having a 4.53% strength gain at 28 days compare to 7 days. Similarly, GPT 2 is having 38.48% strength gain at 28 days compare to 7 days for GPT-3 49.91% strength gain at 28 days with 7days.

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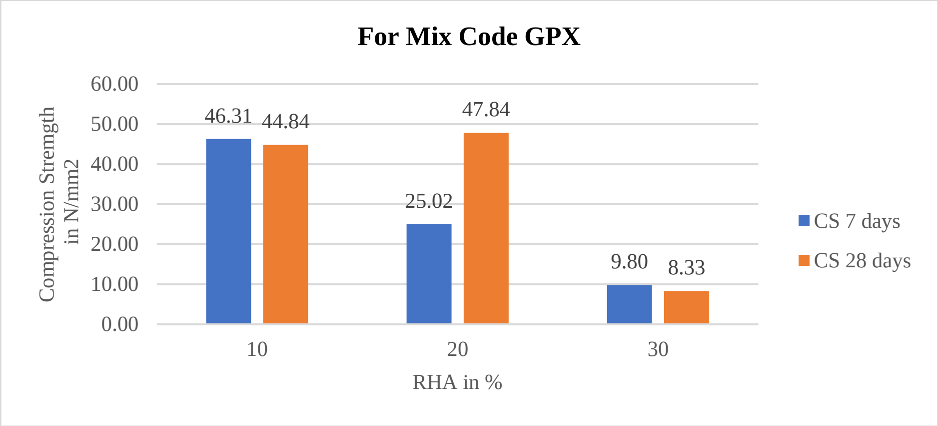
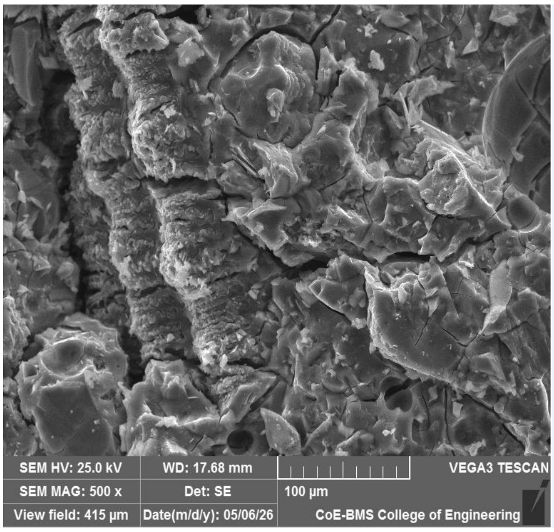


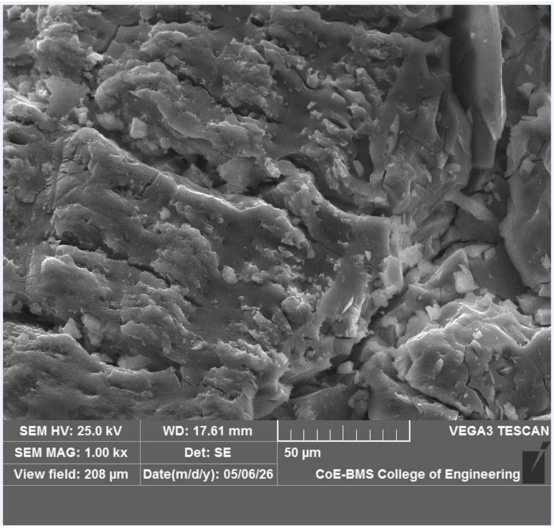
Fig: 3 Compressive Strength of Geopolymer Mix -GPX

The above bar chart indicating that the mix GPX 1 is having a 3.27% strength gain for 7 days compare to 28 days. Similarly, GPX 2 is having 47.70 % strength gain at 28 days compare to 7 days for GPX-3, 15 % strength gain at 7 days than with 28 days.

3.2 Micro Structural Analysis with SEM images of mix GPT at RHA 10%

Sem analysis is done with high-definition images with resolution of 0.5kx, 1kx, 2kx, 3.5Kx 5kx,10 Kx,13 Kx. Images are provided with various resolution showing that dense, compact bonding is formed by gel formation. With some pores and cracks. It indicating calcium-based reaction components which enhance early high strength and Dense structure. In 3.5kx image revealed small pores and micro voids. 5kx image showing irregularly shaped dispersed matrix and uneven surface indicating the unreacted matrix like GGBS, RHA.





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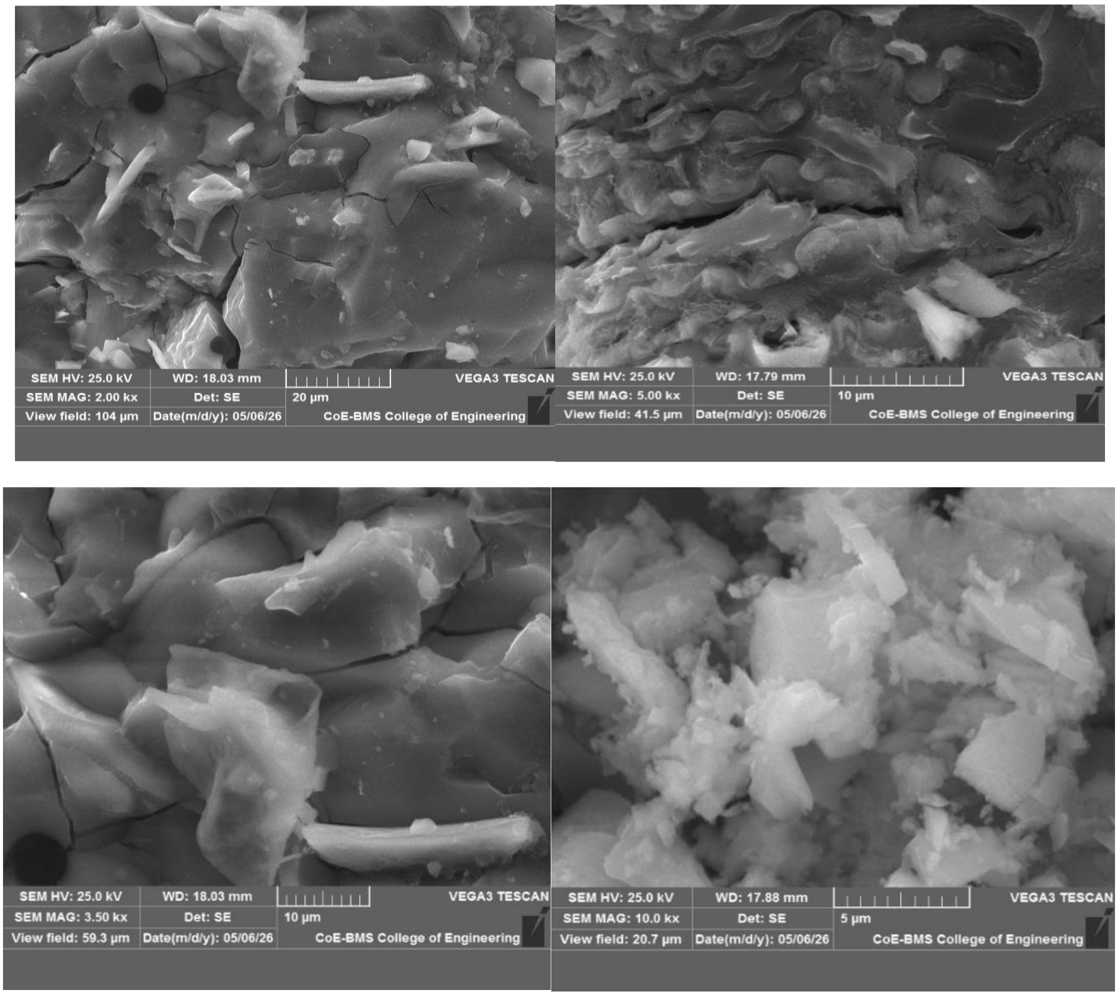

Fig:4 SEM Image of mix GPT

3.3 EDAX - Energy dispersive X-ray analysis

Table-2 Quantitative data showing Element Composition by EDAX

Element	Weight %	Atomic %
Na_2O	13.99	14.03
MgO	4.32	6.66
Al_2O_3	11.11	6.77
SiO_2	43.46	44.95
SO_3	0.83	0.65
K_2O	1.00	0.66
CaO	22.26	24.67
TiO_2	1.11	0.86
Fe_2O_3	1.91	0.74

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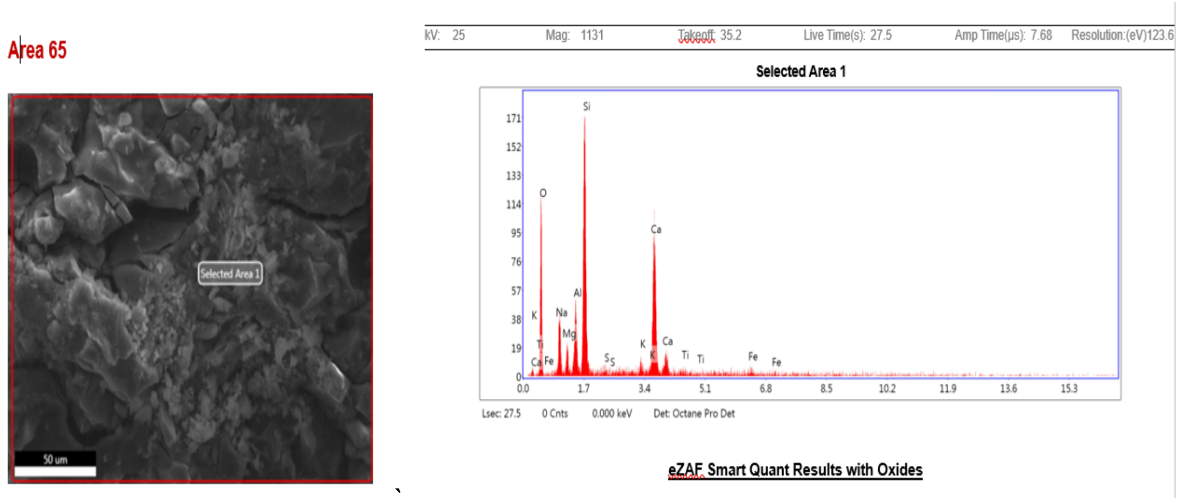

Fig:5 EDAX Image of mix GPT

The images showing the heterogeneous and flaky microstructural topology. it also indicating the coexistence of CASH and NASH Geopolymer Gels which is the backbone of the structure. It is also isolated with particles of unreacted raw precursors. The image is taken at 50 µm resolution which showing the internal crack. Quantitative data given in graph and Table, it gives that the matrix is having high Percentage of Silicon dioxide -SiO2, Alumina- Al, Calcium and other minor components in the matrix responsible for formation of bonding b/w the particles. Both the SEM and EDX images are Collectively indicating that the material is having a dense and compact structure. Bonding created by calcium-based gel with NASH and CASH gel formation indicating that reduce the pores, micro voids and improved strength. However, it also showing that some unreacted particles are there in the matrix. The bonding and the microstructure indicating that the structure will contribute the durability properties to the structure.

4.CONCLUSION

- It was observed that there was no specific code of practice is available for GPC as per research papers followed IS 10262 and IS 456.
- Geopolymer Mortar cubes are casted to finalize the optimum NS/NH ratio.
- The compressive strength of geopolymer concrete with varying percentage of GGBS and RHA is studied for 3 different concentrations of NaOH ie,8N,10N &12N
- Using RHA in GPC, high strength is obtained for 10-20% of binder, for 30% RHA compressive strength is decreased.
- It was observed that for 20-30% RHA as a binder, workability is low and difficult to handle requires more liquid content to mix properly.
- At the end of 7 days optimum compressive strength is 50.58 KN/m2 for mix of GPT with 10% RHA, same mix is having optimum compressive strength 52.87 KN/m2 at the end of 28 days.
- GPT mix with 10% RHA is tested for SEM analysis with high-definition images which showing dense, compact, well bonded structure with minor pores and cracks.
- EDAX quantitative data given for the matrix showing 43% of SiO_2 and 22%-CaO 11%-Al indicating the better formation of CASH gel and bonding formation of particles.
- Ambient curing is made for the cubes at normal temperature which save time and energy.

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