Application of Burnt Glass Powder as Partial Replacement of Cement in Concrete

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ABSTRACT

Waste glass creates broad environmental difficulties, because of unpredictability of waste glass streams. With growing environmental trauma to reduce waste glass and to recycle to the minimal, the construction industry had embraced number of procedures to achieve this goal. To achieve study objectives, waste glass was pulverized into powder form and burnt at a temperature of 200, 400, and 600^0C respectively. The burn waste glass powder was used to replace cement at 0%, 5%, 10%, 15%, and 20% by weight of the cement. Compressive strength assessments were carried out on 156 concrete cubes (150mm x 150mm x 150mm) with cement replaced burnt waste glass powder. The cubes were cured for 7, 14, 21 and 28-day age and examined in the laboratory for compressive strength. Results showed that the best replacement dosage of burnt glass powder at 200^0C, 400^0C and 600^0C are 5%, 15% and 5%. Replacement dosage 5% at 600^0C showed about 11% increase in strength than the 0%. Base on the results, it is recommended that the Burnt glass powder can be used to replace cement in concrete production from 5% -15% for 200^0C, 400^0C and 400^0C burnt temperature respectively. Other by-products constituting higher SiO_2 and CaO could be used to enhance the used of waste glass powder as cement replacement.

Key Words: Waste Glass Powder, Admixture, Concrete Strength, Calcination. Replacement

1.0 Introduction

The attention of the construction industry in utilizing solid waste materials in concrete is growing because of the importance placed on sustainable development, the waste glass from Bayelsa state is gathered as a waste and disposed as landfill. Glass is a material that does not react chemically which could be reprocessed and used several times without altering its chemical property (Aimin and Shayam, [1]. Apart from using waste glass as cullet in glass production, waste glass is crushed into required sizes for use as fine and coarse aggregate in different applications, (Carpenter and Cramer [2]. Using waste glass in concrete reduces the quantity of glass in landfills and replaces for expensive constituents in the concrete mix. A glass powder is utilized as a binder with partial replacement of cement which part takes in the reaction at the time of hydration and also acts as a filler material (Nathan *et al.*, [3]. Partial replacement of cement with pulverized glass profits the microstructure and stability of cementitious materials (Narayanan, [4]). A denser structure is produced when pulverized glass is employed as partial replacement for cement, which benefits the long-term permanence of cementitious materials. Major cost and energy savings can be achieved by partial replacement of cement with pulverized waste glass. Broad studies were carried out to explain the alkali silica reaction problems. Substituting cement by pulverized waste glass powder in concrete, not only improves the compressive strength and reduces cost but also increases the durability (Craig *et al*., [5]).

Shao *et al*. [6] revealed that milled waste glass having a particle size finer than 38µm did demonstrate a pozzolanic behavior.

Shayan and Xu ([7] studied the use of waste glass in concrete and revealed that both fine glass powder of < 10µm particle size, and crushed glass aggregate could be utilized in concrete together without harmful effects on concrete durability. Kou and Poon, [8]) examined the effects of reused glass cullet on fresh and hardened properties of self-compacting concrete. Recycled glass was used to replace river sand (in proportions of 10%, 20% and 30%), and 10 mm granite (5%, 10% and 15%) in making the self-compacting concrete mixes. The study showed that the slump flow and air content of the recycled glass self-compacting concrete mixes increased with increasing recycled glass content. Milling of glass to powder form, for improving the reactions amongst glass and cement hydrates brings environmental and economic benefits when cement is replaced partially with waste glass powder for production of concrete (Rashed, [9]).

Arthanari *et al.* [10] defined Pozzolans as siliceous material, which by itself possesses no cementitous properties but in processed form and finely divided form, react in the presence of water with lime, to form compounds of low solubility having cementitious properties.

Glass is a translucent substance formed by melting a mixture of substances for instance silica, soda ash, and CaCO3 at high temperature subsequently cooling through which solidification takes place without crystallization. The quantity of waste glass is steadily increased over the recent time because of an ever-growing usage of glass products. Mainly waste glasses have been discarded into landfill locations. The Land filling of waste glasses is objectionable since they are not biodegradable, which presents waste glasses environmentally less friendly. Thus, we utilize waste glass in concrete to achieve economical construction. Chemical compositions of Glass Powder and cement are shown in Table 1.0. The aim of this investigation is to examine the strength of concrete when burnt waste glass powder is use as partial replacement of cement in concrete.

Table 1.0: Chemical Composition of Glass Powder and Cement (Dhanaraj and Keshav[11])

S/N	Compositions (%)	Waste Glass Powder	Cement
1	SiO_2	70.22	23.71
2	CaO	11.13	57.27
3	MgO	-	3.85
4	Al_2O_3	1.64	4.51
5	Fe_2O_3	0.52	4.83
6	SO_3	-	2.73
7	Na_2O	15.29	-
8	K_2O	-	0.37
9	Cl	-	0.0068
10	Loss on ignition	0.8	7.24

2.0 MATERIALS AND METHODS

2.1 Materials

The constituents of concrete comprise of Cement, fine aggregate and coarse aggregates, water. When water reactions with cement hydration process takes place and a rigid substance is formed.

2.2 Cement

Portland limestone cement grade 42.5 is the common type of cement in usage. It is the basic constituent of concrete.

2.3 Aggregates

Fine and coarse aggregate make up the greater part of concrete mixture. Sand and crushed stone are mostly utilized for this purpose. Natural sand was used as fine aggregates with minimum size of 0.2 mm. Coarse aggregates used are with size between 12mm -14mm.

2.4 Waste Glass

Waste glass was milled to powder form and burnt in a furnace under a controlled temperature of 200, 400 and 600^{o}C. Milled glass powder burnt at 200, 400 and 600^{o}C are shown in Figure 1.0. After burning, it was noticed that the green particle of the burnt samples at 400 and 600^{0}C were

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bonded together, so further milling was carried out to attain the needed finest. The burnt waste glass powder was sieved through 75µmm British Standard (BS). The burn waste glass powder was used to replace cement at 0%, 5%, 10%, 15%, and 20% by weight of the cement.

(a) (b) (c)

Figure 1.0: Burnt milled waste glass powder; (a) 200^{0}C (b) 400^{0}C, (b) 600^{0}C

2.5 Experimental Work

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Samples were prepared in accordance with the mix proportion 1:2:4 with cement-water ratio 0.5 and by replacing cement with burnt waste glass powder in 0%, 5%, 10%, 15%, and 20% proportion by weight. To study the Compressive strength, samples of sizes 150 x 150 x 150mm were cast, cured and tested using a compressive testing machine for 7, 14, 21, 28 days mean compressive strength respectively. A total of 156 concrete samples were produced for this study, twelve for control and twelve for each percentage replacement of 0%, 5%, 10%, 15% and 20% by weight of the cement for each burnt temperature of 200^0C, 400^0C and 600^0C respectively.

2.6 Fresh Concrete Test

Slump was examined to verify the workability of fresh concrete both control and replaced concrete sample.

3.0 Results and Discussion

Compressive strengths with the cement replaced by 200^0C, 400^0C and 600^0C burnt waste glass power in concretes at various curing ages are given in Figure 1.0 – 6.0 and Table 1.0 - 4.0. Mean compressive strengths of 5% 10%, 15% and 20% replacement for 200^0C, 400^0C and 600^0C burnt temperatures are little Lower compared to the 0% mean compressive strengths at 28-days age except 5% of 600^0C burnt waste glass replacement. Higher compressive strengths of 5% 10% and 15% replacement for 600^0C, compared to the 0% were obtained at 7, 14, and 21-days age. The current research at 28 days, 5% of 600^0C burnt waste glass cement replacement level produced the highest compressive strength in concrete. Targeted mean strength of 20N/mm^2 at 28 days was met for all specimens of 0% – 15% replacement level for 600^0C calcination temperature.

Table 1.0: Compressive Strength of 200^0C Waste Glass Powder as Replacement for 7, 14, 21 and 28 days

Percentage Replacement	7 Days (N/mm^2)	14 Days (N/mm^2)	21 Days (N/mm^2)	28 Days (N/mm^2)
Control (0%)	**16.00**	**18.89**	**20.44**	**23.85**
5%	20.90	19.30	22.20	21.30
10%	18.00	17.50	20.60	20.60
15%	21.30	20.90	18.90	19.50
20%	22.74	21.78	21.93	21.04

Table 2.0: Compressive Strength of 400^{0}C Waste Glass Powder as Replacement for 7, 14, 21 and 28 days

Percentage Replacement	7 Days (N/mm^2)	14 Days (N/mm^2)	21 Days (N/mm^2)	28 Days (N/mm^2)
Control (0%)	**16.00**	**18.89**	**20.44**	**23.85**
5%	27.11	25.78	20.58	20.59
10%	19.17	22.96	19.33	20.74
15%	19.04	17.26	16.96	22.30
20%	19.04	14.67	17.48	17.33

Table 3.0: Compressive Strength of 600^{0}C Waste Glass Powder as Replacement for 7, 14, 21 and 28 days

Percentage Replacement	7 Days (N/mm^2)	14 Days (N/mm^2)	21 Days (N/mm^2)	28 Days (N/mm^2)
Control (0%)	**16.00**	**18.89**	**20.44**	**23.85**
5%	22.22	23.70	21.78	26.82
10%	22.22	21.20	21.73	22.0
15%	20.30	22.96	21.63	20.44
20%	13.41	15.10	14.30	14.78

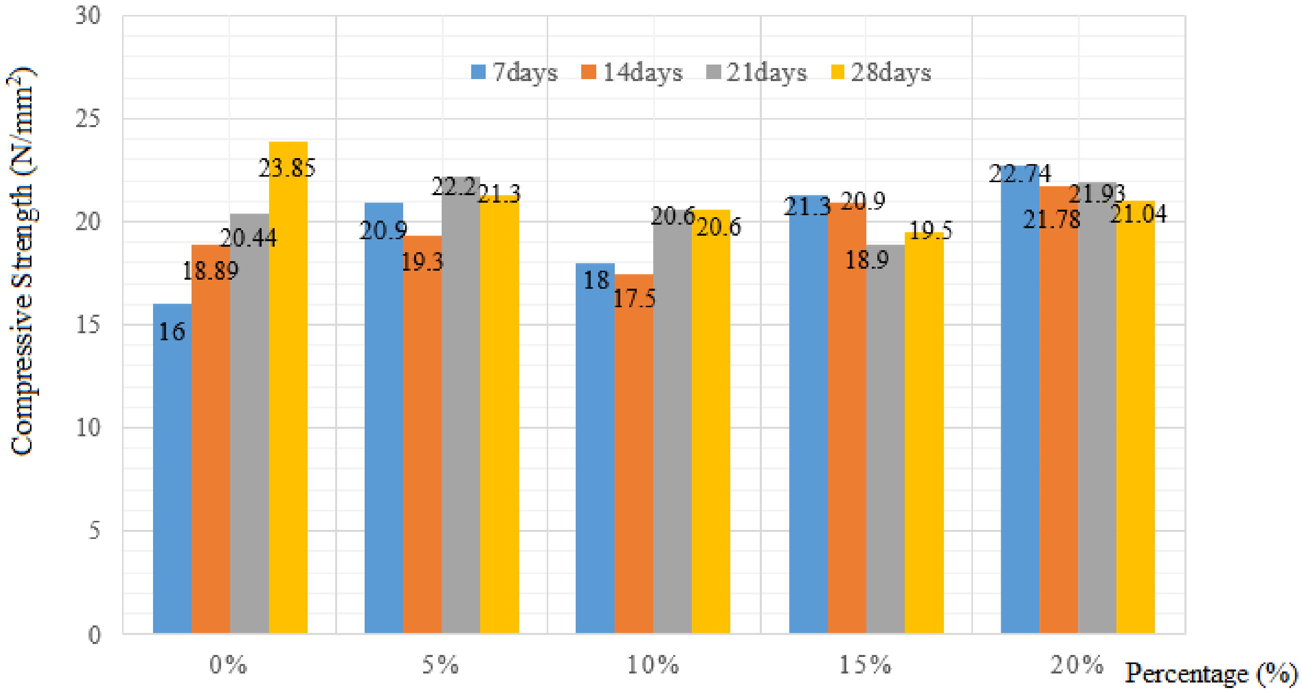

Fig 1.0: Compressive Strength against percentage replacement of 200^{0}C burnt waste glass powder at 7, 14, 21 and 28 days.

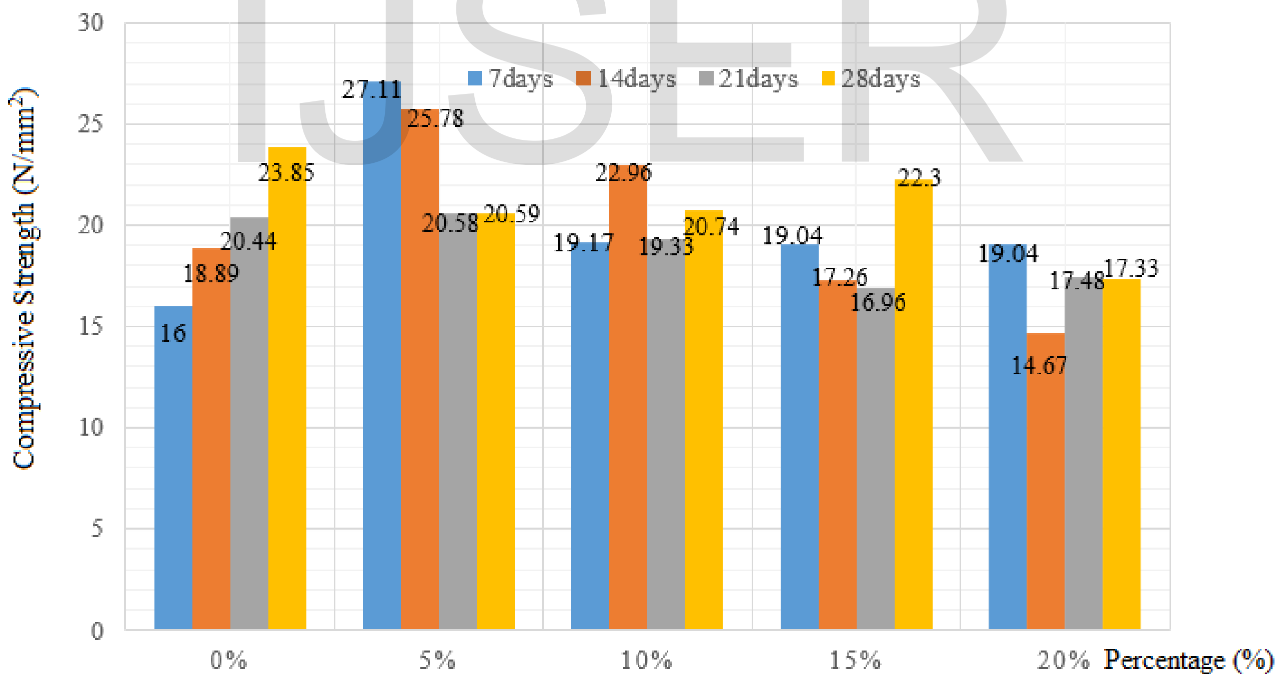

Fig 2.0: Compressive Strength against percentage replacement of 400^{0}C burnt waste glass powder at 7, 14, 21 and 28 days.

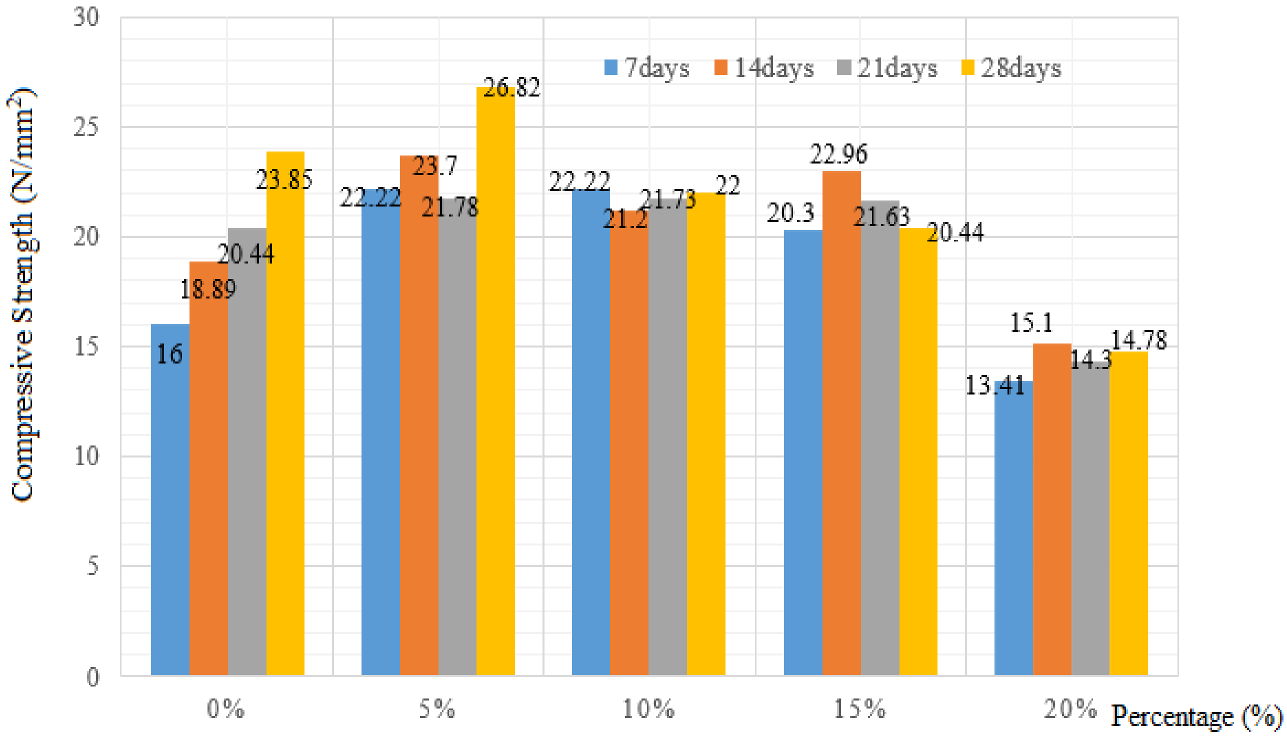

Fig 3.0: Compressive Strength against percentage replacement of 400^{0}C burnt waste glass powder at 7, 14, 21 and 28 days.

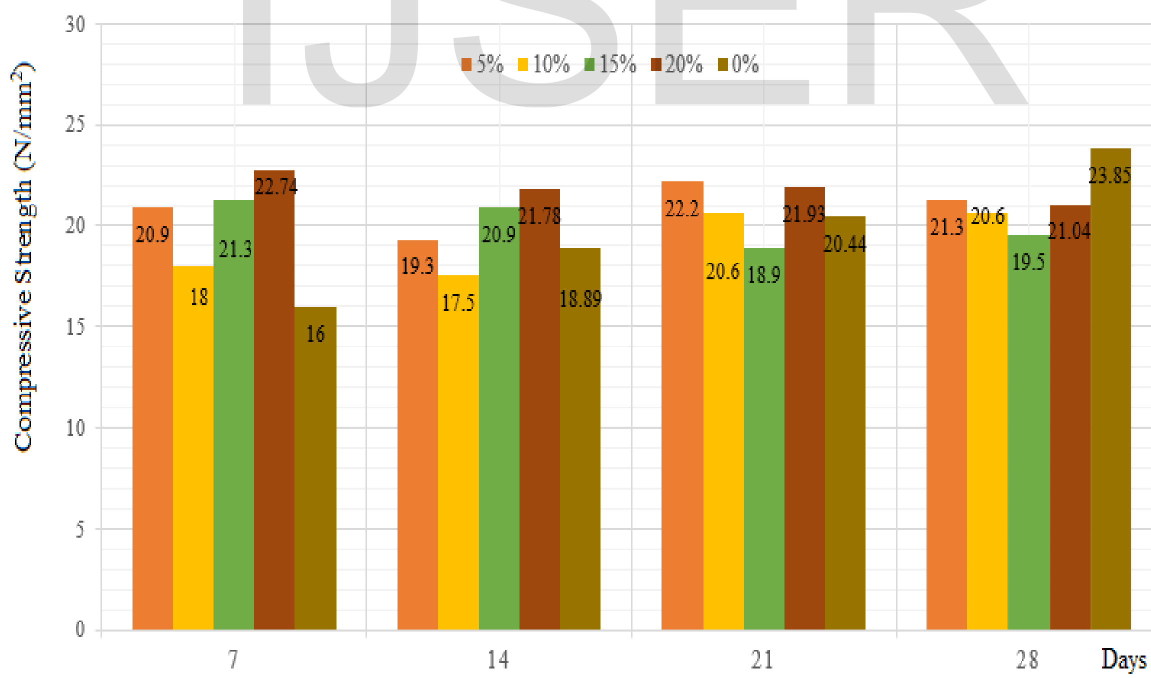

Fig 4.0: Compressive Strength against Days for 0%, 5%, 10%, 15% and 20% replacement of 200^{0}C burnt waste glass powder.

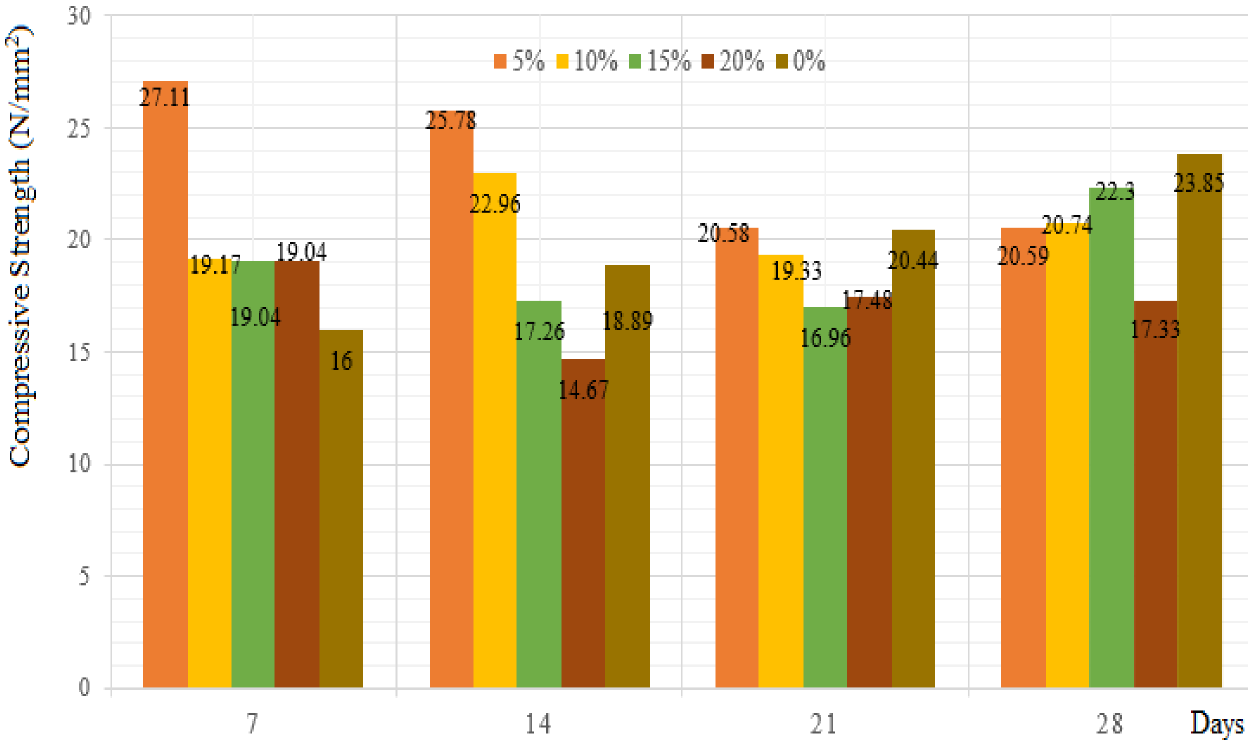

Fig 5.0: Compressive Strength against Days for 0%, 5%, 10%, 15% and 20% replacement of 400^{0}C burnt waste glass powder.

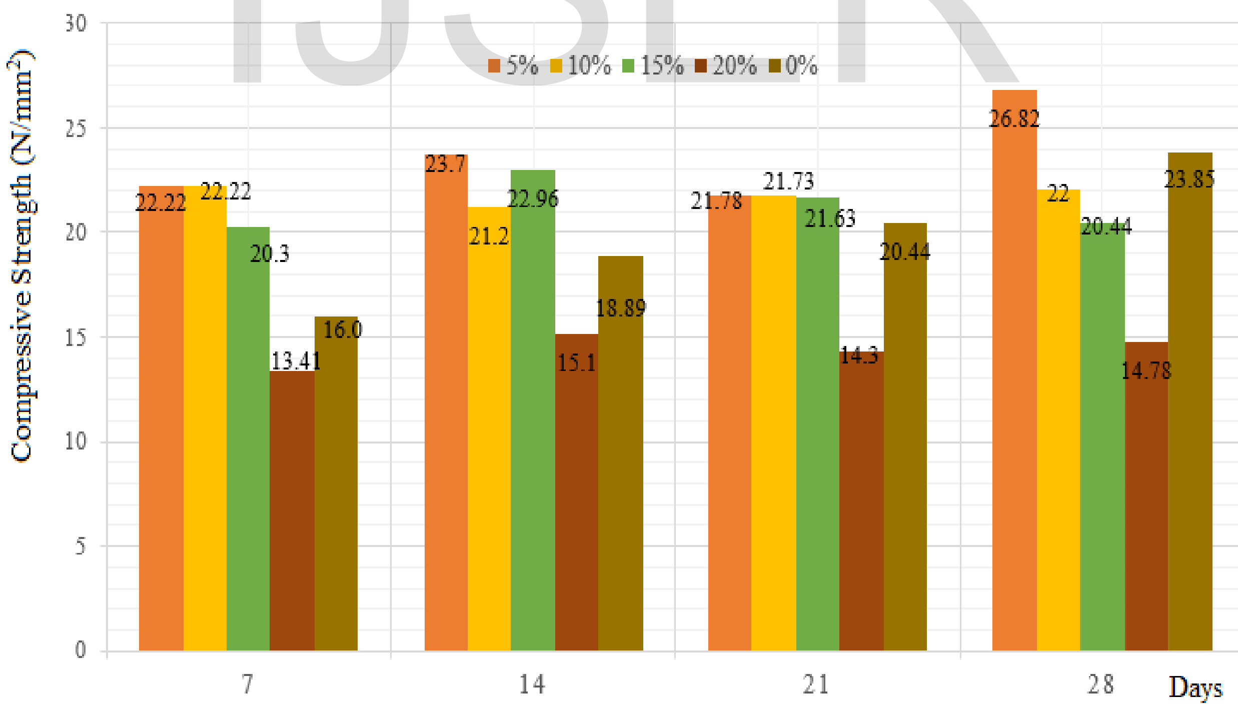

Fig 6.0: Compressive Strength against Days for 0%, 5%, 10%, 15% and 20% replacement of 600^{0}C burnt waste glass powder.

4.0 Conclusion

The following conclusions drawn:

i. Waste glass powder which has silica, as in cement, is substantial as a minor cement replacement.

ii. Burnt waste glass powder can efficiently use to replace cement in concrete

iii. 5% replacement of burnt waste glass powder at 600^0C gave about 11% increase in concrete strength.

iv. The best replacement dosage of burnt glass powder at 600^0C is 5%

v. The best replacement dosage of burnt glass powder at 400^0C is 15%

vi. The best replacement dosage of burnt glass powder at 200^0C is 5%

Recommendation

The following recommendations are drawn:

i. Burnt glass powder can be used to replace cement in concrete production of 5% -15% for 200^0C, 400^0C and 400^0C burnt temperature respectively.

ii. Other by-products constituting higher SiO_2 and CaO could be used to enhance the used of waste glass powder as cement replacement.

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