Behaviour of Slag Concrete under Heat and Water Curing Regimes

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Abstract: Because of the enormous demand for concrete and cement in developing nations such as India, it is critical to replace cement with an alternative material to limit emissions into the atmosphere. In the current study, GGBS is in place of cement to manufacture M20-grade concrete. Due to the numerous benefits connected with ggbs, such as energy, carbon dioxide emissions, cost, and mechanical qualities, two mixes are created with an alkaline solution and compared to standard concrete and slag mixes. The cure regimes of underwater and heating compared. The material is prepared and baked for a day at 60 degrees Celsius before being brought to room temperature for testing. In addition to embodied energy, and CO_2 emissions, cost analysis is also calculated. The slag mixtures with and without fiber outperform the other blends. This mix's cheap cost and better strength make it suitable for rural rigid pavement. Even from the analysis it is found that slag mixes are reducing energy and carbon emissions by nearly 50%.

Keywords: Embodied Energy, Embodied CO_2, Flexural Strength, Compressive Strength, Fiber.

Introduction:

Because of its low cost, concrete is the utmost used building material. The principal binder in concrete has been ordinary Portland cement. Single ton of ordinary cement produce releases around one ton of CO_2 into the environment. The release of carbon dioxide from cement plants is one of the contributors to ecological imbalance. Attempts have been undertaken to mitigate the effects of global warming. Alkali-activated binders, are created from industrial leftovers such as GGBS, can be acquired by slaking liquefied ferrous slag from a flash kiln in liquid or vapor to generate a glossy, grainy product, which is then dried up and crushed into a fine ash. In the manufacture of AASC, GGBS is the sole binder. Studies on alkali-activated slag concrete revealed that it has various benefits to OPC concrete, including strong resistance to chemical assault, freeze-thaw cycles, and chloride ion penetration. [1] According to the findings, AASC qualities are comparable to or slightly superior to those of traditional OPCC and satisfy the minimum strength criteria for pavement structures. [2] When compared to Conventional concrete, geopolymer concrete reduces greenhouse gas emissions by 80–90%. The key benefits of geopolymer concrete include its long lifespan, quick strength gain, low toxicity, low cost, and lack of need for water curing. [3] Changes in one of the alkaline activator's components don't significantly alter the GP density. [4] In comparison to other techniques, steam curing samples at 60°C for three days produces the samples with the best compressive strength. The compressive strength was enhanced by increasing the slag replacement ratio with OPC. [5] Stated that when carefully prepared, GPC created with K_2SiO_3/KOH performs better than GPC made with Na_2SiO_3/NaOH. Otherwise, the desired strengths were achieved by both alkaline activator solutions. [6] According to the findings, geopolymers based on potassium that are more alkaline exhibit greater reactivity. [7] The results have demonstrated that a geopolymer mix with the required strength may be made using fly ash and Blast furnace slag mixture outdoors without the necessity of an oven. [8] Alkali-activated slag concrete has greater compressive strength than regular concrete. In comparison to ambient-cured antacid-actuated slag concrete, heat-cured antacid-actuated slag concrete demonstrated greater compressive strength for all experimental mixes in this investigation. [9] It finds that geopolymers inclosing potassium catalysts ensure lower fluid requirements. This study's objective is to evaluate the compressive strength of alkali-activated slag mix at 28, 56, and 91 days under heat curing and ambient curing to that of ordinary concrete.

Materials:

Binder: BS: 6699:1900 blast furnace slag that has been ground up (GGBS). Based on its chemical composition, the GGBS has all properties as per limits. Regular Portland cement (PC) of 53 mark following IS: 12269-1987 was utilized.

Sand: Zone-3 sand is used in the mix design and has a relative density of 2.5 and a modulus of 2.03.

Coarse aggregates: A combination of 20 and 10 mm aggregates with a relative density of 2.7 and a modulus of 7.16 are employed as coarse aggregates.

Alkaline solution: In general, potassium hydroxides with a virtue of 97% accessible in a stable organization by employing drops have been investigated for a successful evaluation. An important factor is the amount of water put into KOH beds. . KOH pallets are purchased from a nearby retailer. Since it comes in a fluid (gel) form, potassium silicate is unique for being a potash glass that dissolves. With varying volumes of water, premium grades of the potassium silicate solution are available and are effective. 14 moles of KOH with a 5% oxide content and a 1.25 modulus ratio were used in the mix formulation.

Polypropylene fiber: These fibers, which have a hydrophobic characteristic, are used to replace 1% of the cement.

Water: Locally available potable drinking water is used.

Nomenclature:

OPC= Control concrete

SC= Slag concrete

OPCF= Control concrete inclusion of polypropylene fiber

SCF= Slag concrete inclusion of polypropylene fiber

PPF= Polypropylene fiber

Results and Discussions:

Material	EE (MJ/Kg)	OPC	SC	OPCF	SCF
Cement	4.8	1536	-	1520.6	-
GGBS	0.31	-	99.2	-	98.2
Potassium Hydroxide	19.2	-	101.56	-	101.56
Potassium Silicate	4.3	-	319.6	-	316.48
Sand	0.081	56.31	56.09	56.295	56.09
Coarse Aggregate	0.083	101.6	101.56	101.56	101.56
Polypropylene Fiber	64	-	-	204.8	204.8
Water	0.2	32	22.9	31.68	22.91
Total EE per m^3		1725.91	700.91	1914.97	901.6

Table.1: Detailed calculation for total Embodied Energy per cubic metre of concrete

From Table.1, it may be noticed that the EE for SC and SCF mixes are less when compared to OPC and OPCF mixes. Nearly 53% reduction in EE is observed for slag mixes than OPC mixes. SC mix is of low EE but when compared to SCF mix but strength of SCF is more than SC mix.

Material	ECO_2 PER kg	OPC	SC	OPCF	SCF
Cement	0.93	297.6	-	294.6	-
GGBS	0.083	-	26.56	-	26.3
Potassium Hydroxide	2.2	-	11.6	-	11.6
Potassium Silicate	1.3	-	96.64	-	95.68
Sand	0.0051	3.54	3.54	3.54	3.54
Coarse Aggregate	0.0048	5.87	5.87	5.86	5.86
Polypropylene Fiber	2.5	-	-	8	8
Water	0.0008	0.128	0.092	0.12	0.09
Total ECO_2 per m^3		307.13	144.3	312.2	151.07

Table.2: Detailed calculation for total Embodied CO_2 per cubic metre of concrete

From Table.2, it may be noticed that the ECO_2 for SC and SCF mixes are less when compared to OPC and OPCF mixes. Nearly 51% reduction in ECO_2 is observed for slag mixes than OPC mixes. SC mix is of low ECO_2 but when compared to SCF mix but strength of SCF is more than SC mix.

Material	Price per Kg	OPC	SC	OPCF	SCF
Cement	8.5	2720	-	2692.8	-
GGBS	2	-	640	-	633.6
Potassium Hydroxide	40	-	212	-	211.6
Potassium Silicate	18	-	1338.12	-	1324.8
Sand	1	695.28	694.34	695	693
Coarse Aggregate	1.3	1590.8	1588.6	1588	1588
Polypropylene Fiber	100	-	-	320	320
Water	0.5	80	57.87	80	57
Total Price(₹) per m^3		5086	4530.93	5375.8	4828

Table.3: Complete calculation of the cost per cubic meter of concrete

Referring to Table.3, slag mixes SC and SCF mixes exhibits less cost than OPC mixes. On an average 11% reduction in the cost of slag mixes is noticed. Since concrete mixes are air-cured, there is no need for water for curing, and this may be an advantage in places with acute shortages of water resources. Even the labour cost for curing also reduces the overall cost of the pavements.

Since salt enacted substantial combinations are air-restored, no water is expected for relieving, thus such a type of cement might be of extraordinary use in regions where water assets are scant. The utilization of modern waste materials like GGBS, etc. in salt-actuated substantial blends will bring about decreased natural issues related to the removal of such modern squander, as well as diminished creation of OPC, which will bring about lower ozone-depleting substance emanations from the development of OPC. Successful reusing of such modern garbage would assist with reducing removal expenses while moderating regular assets for people in the future.

Water Absorption (%)			
OPC	SC	OPCF	SCF
3.54	3.07	3.57	3.08

Table.4: Percentage of Water Absorption of concrete mixes

Table.4 shows that the water absorption capabilities of slag mixes are lower than those of concrete mixes. It is due to the excessive alkaline solution in slag mixtures, which does not allow through them, increasing density and strength.

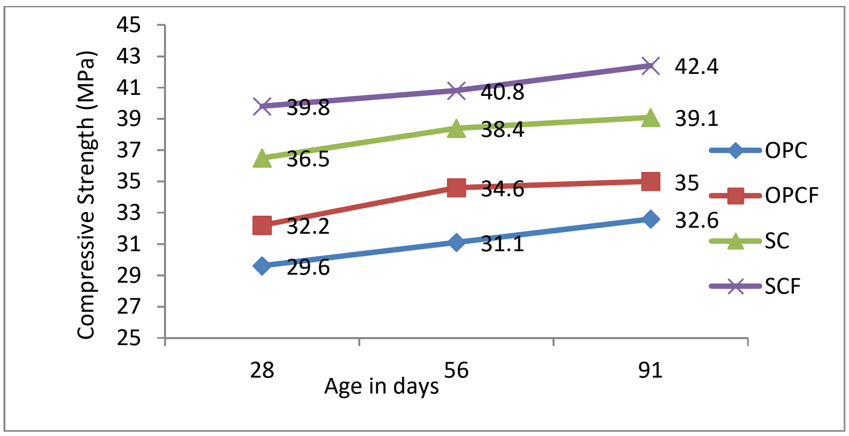

Figure.1 Variant of compressive strength for different mixes under water curing

The compressive strength of all the mixes rises with rise in age. The strength for conventional concrete and alkali-activated slag mixes are subjected to water and heat curing at 28, 56, and 91 days are shown in Fig.1-2.

Referring to Fig.1, slag mixes with and without the inclusion of PPF are having high strength than conventional mixes at all ages. The peak compressive strength was detected for the SCF mix at 91 days and is found to be 42.4. SCF mix exhibits a 34.45% increment of strength when compared to OPC at 28 days of drying. It is noticed that up to 56 days strength of all mixes increases but from then the graph is flat with minimal increment.

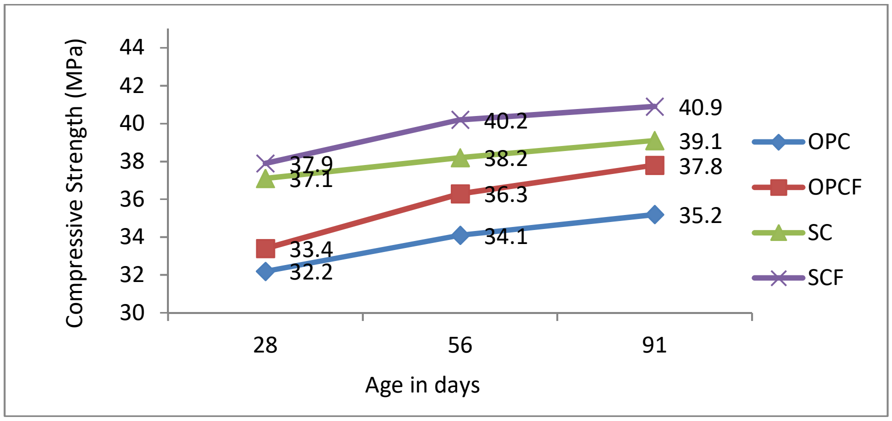

Figure.2 Variation of compressive strength for different mixes under heat curing

Referring to Fig.2, slag mixes with and without the inclusion of PPF are having high strength than conventional mixes at all ages. The peak compressive strength was witnessed for the SCF mix at 91 days and is found to be 40.9. SCF mix exhibits a 17.7% increment of strength when compared to OPC at 28 days of curing. It is observed that up to 56 days strength of all mixes increases but from then the slag mixes strength is not altered.

It is noticed from the above figures that the compressive strength of slag mixes is better than conventional mixes and also the inclusion of PPF increases the strength of specimens. Initially, the strengths are high under heat curing but as time progresses the value starts decreasing when compared to slag mixes under curing. So, higher values of strength were noted under water curing.

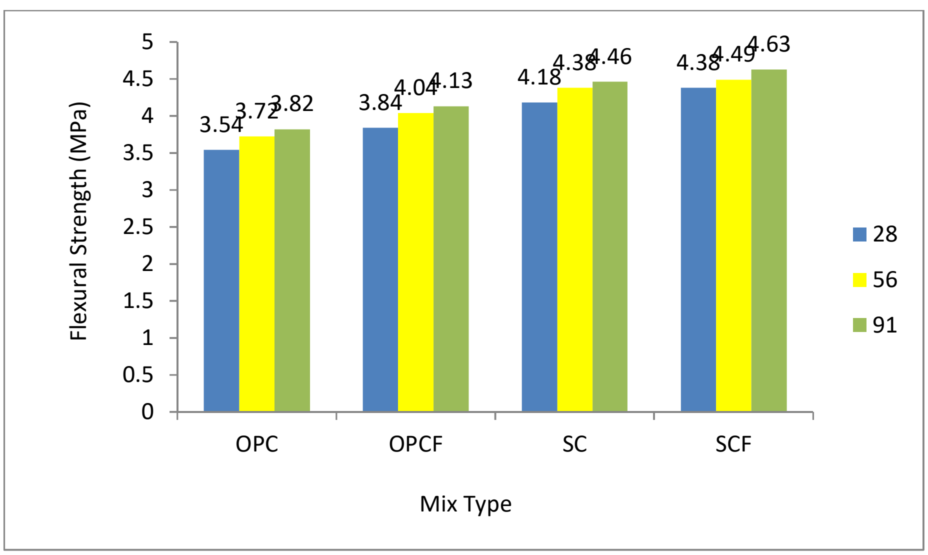

Figure.3 Deviation of flexural strength for diverse mixes under water curing

The flexural strength of all the mixes surges with a rise in age. The strength for conventional concrete and alkali-activated slag mixes are subjected to water and heat curing at 28, 56, and 91 days are shown in Fig.3-4.

Referring to Fig.3, slag mixes with and without the inclusion of PPF are having high strength than conventional mixes at all ages. The highest flexural strength was observed for the SCF mix at 91 days and is found to be 4.63. SCF mix exhibits a 23.72% increment of strength when compared to OPC at 28 days of curing. It is detected that up to 56 days strength of all mixes increases but from then the graph is flat with minimal increment.

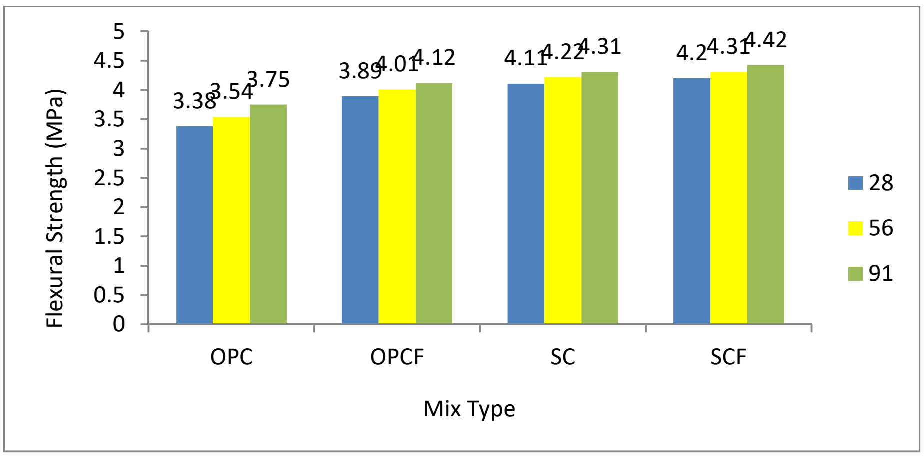

Figure.4 Variation of flexural strength for different mixes under heat curing

Referring to Fig.4, slag mixes with and without the inclusion of PPF are having high strength than conventional mixes at all ages. The highest flexural strength was observed for the SCF mix at 91 days and is found to be 4.42. SCF mix exhibits a 24.2% increment of strength when compared to OPC at 28 days of drying. It is seen that up to 56 days strength of all mixes increases but from then the slag mixes strength is not altered to a higher extent.

It is noticed from the above figures that the flexural strength of slag mixes is better than conventional mixes and also the inclusion of PPF increases the strength of specimens. Initially, the strengths are high under heat curing but as time progresses the value starts decreasing when compared to slag mixes under curing. So, higher values of strength were noted under water curing.

Conclusions:

Based on the above results, below conclusions are drawn

- The compressive strength of slag concrete mixes is better than conventional mixes. A higher value of compressive strength is found for specimens under water curing than heat curing.

- A Rise in the early strength of slag mixes is due to the presence of alkaline solutions consisting of potassium hydroxide and potassium silicate solutions. Slag mixes have high strengths in both types of curing regimes.
- The bending strength of slag mixes is high than control mixes.
- The EE, ECO_2, and cost of the slag mixes are best when compared to OPC. Because of their high strengths, high possibility to use in various fields of application.

Because of all the above results, slag mixes with a 1% addition of polypropylene and slag mixes are suggestible for rural rigid pavements, which also helps in reducing the thickness of pavements or by reducing reinforcement by using panel or interlocking pavement design. No fatigue is considered as the pavement is suggestible to low traffic rural areas.

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