An Investigation of Combined Replacement of Cement with Fly ash and Sand with Granulated Blast Furnace Slag Sand

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Abstract **The utilization of waste materials from the industries has been continuously gaining emphasis in the construction work recently. The present work is to use Processed Granulated Blast Furnace Slag Sand and Fly ash as combined replacement for river sand and ordinary Portland cement respectively. M35 grade of concrete with W/C 0.4 will be adopted with two percentages of cement replacement by Fly Ash i.e, 30% and 40%, along with this the slag sand is varied from 0% to 100% in step of 20%. In first variation, 30% Fly Ash is replaced by cement and slag sand is varied as 0%, 20%, 40%, 60%, 80% and 100%. In second variation, 40% GGBS is replaced with cement and slag sand is varied as 0%, 20%, 40%, 60%, 80%, and 100%. For all mixes compressive strength, split tensile and flexural strength will be determined at different days of curing. The strength of cube specimens, cylinders and beams will be determined and compared with conventional concrete specimens. The beams are tested for flexure, under two point loading condition. Different parameters will be investigated in detail. In this paper literature is reviewed in detail to understand the experimental analysis.**

Keywords* — *GGBS, Slag Sand, Fly ash, Compressive Strength, Split Tensile strength, Flexural Strength of Beams

I. INTRODUCTION

Concrete is the largest man made material on earth. It contains cement, fine aggregate, coarse aggregate & water. Among these 70% to 75% volume of concrete is occupied by coarse and fine aggregate, rest of about 25% to 30% is cement and water in form of cement paste. Beside these elements, chemical and mineral admixtures are added to enhance the properties of concrete. The large production of cement causes destruction of environment (Global Warming) and the continues use of Natural Sand leads to the depletion of river beds results into the ecological imbalance. Therefore the replacement of cement and natural sand by the industrial waste by-products (Mineral admixtures) has been continuously emphasized during recent years. In this study, the cement is partially replaced by Fly ash and natural sand is partially replaced by slag sand in various percentages. Fly ash and blast furnance slag sand are waste product obtained from Iron and steel manufacturing industry. Therefore the disposal problem of waste material is solved side by side the saving of cement and natural sand can be done.

II. PROBLEM STATEMENT

Worldwide, the cement industry is facing growing challenges in conserving material and energy resources, as well as reducing CO2 emissions.At the same time, the cement industry is facing challenges such as cost increases in energy supply, requirements to reduce CO 2 emissions, and the supply of raw materials in sufficient qualities and amounts so the partial replacement of materials like mineral admixture are used. M Sand is manufactured by crushing hard rocks and quarry stones into pieces. Special Knowledge and Technology is required for production of M – Sand and it is non – renewable resources.

III. AIM AND OBJECTIVES

The main aim of this project is to highlight the performance of concrete with the use of ground granular blast furnace slag sand and fly ash as Supplementary cementitious material in construction industries and to increase its application in concrete.

- To study the effect on physical properties concrete combined with fly ash and slag sand by conducting workability tests
- To compare the mechanical properties of fly ash and slag sand concrete, with conventional concrete.
- To check durability Parameters of Concrete with partial replacement of Cement with fly ash and aggregates with slag sand.

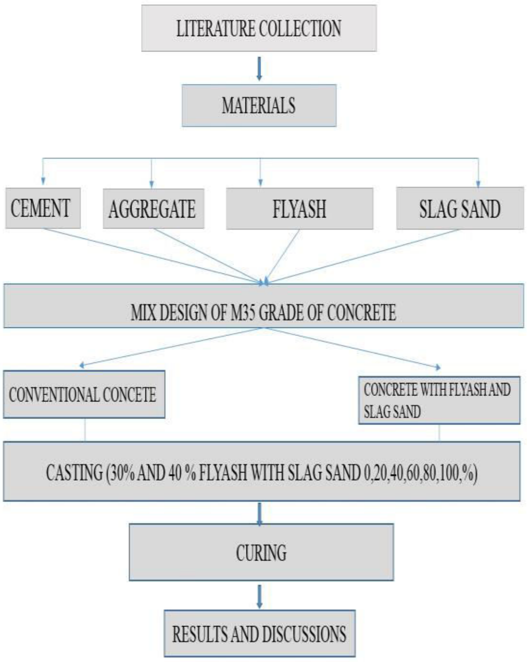
- To carry out Economic Feasibility comparing conventional concrete and and partial replacement of flyash ,slag sand concrete.

IV. LITERATURE REVIEW

Sr.No.	Author Name/Research Paper	Finding/Outcomes
1	V.R. Prasath Kumar et.al - Characterization study on coconut shell concrete with partial replacement of cement by GGBS	• The coarse aggregate is completely replaced with coconut shell. • To enhance the coconut shell concrete property, cement is partially replaced with GGBS. • The micro-structural characterization has proved that incorporating GGBS has improved the hydration process. • The IMM study has clearly shown improvisation in the interfacial transition zone (ITZ) of coconut shell concrete.
2	Meriem Senani et.al - Substitution of the natural sand by crystallized slag of blast furnace in the composition of concrete - Alexandria Engineering Journal (2016)	• The author investigates on the Substitution of the natural sand by crystallized slag of blast furnace in the totally or partially composition of concrete. • On adding Crystallized sand slag in proportions improves the compressive and tensile strength. • Interest in reducing the cost of Concrete.
3	Gaurav Singha et.al - Study of Granulated Blast Furnace Slag as Fine Aggregates in Concrete for Sustainable Infrastructure - Procedia - Social and Behavioral Sciences 195 (2015) 2272 – 2279	• The compressive strength of concrete increases with increase in GBFS percentage up to a certain percentage and after that it decrease following a Gaussian Model. • The most optimum percentage of GBFS to be used in normal conditions considering both strength and economy factor is from 40% to 50% and for marine conditions its from 50% to 60%. • The long term strength development of GBFS concrete is almost double of normal concrete in both normal and marine conditions.
4	ZemeiWu, et.al - Comparative study on flexural properties of ultra-high performance concrete with supplementary cementitious materials under different curing regimes - Construction and Building Materials 136 (2017) 307–313	• The compressive and flexural properties of UHPC with different GGBS or fly ash contents • The optimal GGBS and fly ash contents for flexural behavior of UHPC were 40% and 20%, respectively • Standard curing under standard, hot water, and steam curing were systematically studied.
5	Aliakbar Gholampour, et.al - Performance of sustainable concretes containing very high	• The Fly Ash and GGBS is partially replaced by weight of high volume of cement by different

	volume Class-F fly ash and ground granulated blast furnace slag - Journal of Cleaner Production 162 (2017) 1407e1417	percentages. • High volume use of FA and GGBS in concrete with the possibility of significantly reducing its environmental impact.

V. METHDOLOGY



VI. EXPERIMENTAL INVESTIGATION

A. *Cement*

OPC 53 Grade cement is required to conform to BIS specification IS:12269-1987 with a designed strength for 28 days being a minimum of 53 MPa or 530 kg/cm^2. 53 Grade OPC provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure.

Table No. 1 - Physical Properties of Cement

Sr. No.	Name of Test	Units	Test Results	Specified Limit (IS 12269-2013) 53 Grade
1	Standard Consistency	(%) Temperature	42 27+/-2	---
2	Density of cement	(g/cc)	3.2	---
3	Initial Setting Time	(min)	195	30 Min
4	Final Setting Time	(min)	280	600 Max
5	Soundness by Le- Chateliers Method	(mm)	1	10 mm Max
6	Fineness by Dry Sieving	(%)	3.4	10 % Max
7	3 Days Compressive Strength	(N/mm^2)	42	27 Min
	7 Days Compressive Strength		52	37 Min
	28 Days Compressive Strength		65	53 Min

B. *Fly Ash*

Fly ash from pulverized coal combustion is categorized as such a pozzolan. Fly ash or flue ash, also known as pulverised fuel ash is a coal combustion product that is composed of the particulates that are driven out of coal-fired boilers together with the flue gases.

Table No. 2 - Physical Properties of Fly Ash

Sr. No.	Name of Test	Units	Test Results	Specified Limits
1	Standard Consistency	%	25	-
2	Fineness (Reside on 45 micron sieve)	%	30	50 Max
3	Initial Setting Time	Minutes	160	-
4	Final Setting Time	Minutes	280	-
5	7 Days CS	N/mm^2	30	-
6	28 Days CS	N/mm^2	47	-

C. *Coarse Aggregate*

Coarse-grained aggregates will not pass through a sieve with 4.75 mm openings (No. 4). Those particles that are predominantly retained on the 4.75 mm (No. 4) sieve and will pass through 3-inch screen, are called coarse aggregate. The coarser the aggregate, the more economical the mix. Larger pieces offer less surface area of the particles than an equivalent volume of small pieces. Use of the largest permissible maximum size of coarse aggregate permits a reduction in cement and water requirements. Using aggregates larger than the maximum size of coarse aggregates permitted can result in interlock and form arches or obstructions within a concrete form. That allows the area below to become a void, or at best, to become filled with finer particles of sand and cement only and results in a weakened area.

Table No.3 - Sieve analysis for Coarse Aggregate

Fineness Modulus

Details	Result (20 mm)
Fineness Modulus	8

Table No.4 - Specific Gravity & Water Absorption of 20mm Coarse Aggregate IS: 2386 (Part 3)

Sr. No.	Details	CA (20 mm)
1	Specific Gravity	2.64
2	Apparent Specific Gravity	2.76
3	Water Absorption	1.765

Table No.5 - Aggregate Impact Value IS: 2386 (Part-4)

Sr. No.	Details	CA (20 mm)
1	Aggregate Impact Value	18.6 %

Table No.6 - Flakiness and Elongation Test (IS) 2386 Part 1 (For 20mm Aggregate)

Sr. No.	Details	CA (20 mm)
1	Flakiness Index%	35.17
2	Elongation% Index	45.2
3	Combined (EI+FI) %	80.37

D. *Fine Aggregate*

Quality of sand is as much of importance as other materials for concrete. Aggregate most of which pass through 4.75 mm IS sieve is known as fine aggregate. Fine aggregate shall consists of natural sand, crushed stone sand, crushed gravel sand stone dust or arable dust, fly ash and broken brick (burnt clay). Fine aggregate is the essential ingredient in concrete that consists of natural sand or crushed stone. The quality and fine aggregate density strongly influence the hardened properties of the concrete.

Table No.7- Sieve Analysis for Fine Aggregate

Details	Crushed Sand
Fineness Modulus	2.8

Table No.8 - Specific Gravity & Water Absorption Fine Aggregate

Sr. No.	Details	Fine Aggregate
1	Specific Gravity	2.7
2	Apparent Specific Gravity	2.84
3	Water Absorption	2.24

E. *Slag Sand*

Slag sand obtained from JSW, Bellary District is used. Locally available natural sand is also used in the work. Slag sand and natural sand confirming to Zone II asper (IS 383-1970) are used The use of granulated slag as sand in the composition of concrete can meet two objectives that have a direct relationship with the cost of concrete: minimizing the amount of cement in the concrete composition and increasing the mechanical characteristic of concrete.

Table No.9- Sieve Analysis for Slag Sand

Details	Slag Sand
Fineness Modulus	3.357

Table No. 10 - Specific Gravity & Water Absorption Slag Sand

Sr. No.	Details	Slag Sand
1	Specific Gravity	2.65
2	Apparent Specific Gravity	2.85
3	Water Absorption	2.86

VII. CONCRETE MIXES

Table No. 11 - M 35 Conventional Concrete

Sr. No.	Ingredients	Batch	Batch $0.04m^3$
1	Cement	394	15.76
2	Coarse Aggregate 20mm	1071.64 6	42.86
3	Crushed Sand	803.019	32.120
4	Water	195.114	7.804
5	Admicture	3.94	0.1576
	Total		98.70

VIII. SPECIMENS,CASTING AND CURING

An electric operated manual laboratory mixer of capacity 0.04 m3 was used for the concrete mixing. Initially, fly ash , Slag Sand, Aggregate and half of the mixing water were mixed in the mixer for two min. After that remaining portion of water mixed with the mixture for two minutes. The workability was measured for each batch in terms of slump. After completion of mixing. process, the obtained fresh concrete was put into the various types of designated moulds like cube, cylinders, beams and kept for a duration of 24 h and Demoulding was done after 24 h and the specimens were

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cured under water at 7,14 and 28 days specified period of curing. Concrete specimens such as 150x150x150 mm cubes, 150x300 mm sized cylinders and 150x150x700 mm Beams.

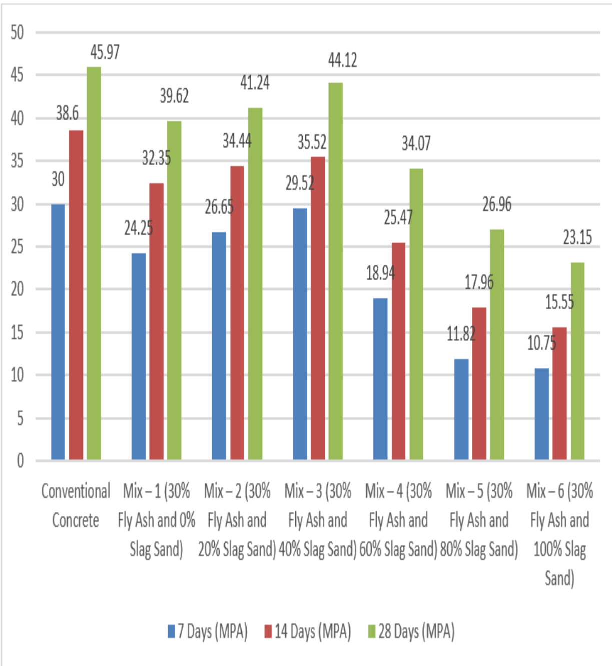
IX. RESULTS AND DISCUSSION

Table No. 11 - Workability Test

Sr. No.	Details of Replacement	Slump
1	Conventional Concrete	125mm
2	Mix – 1 (30% Fly Ash and 0% Slag Sand)	125mm
3	Mix – 2 (30% Fly Ash and 20% Slag Sand)	120mm
4	Mix – 3 (30% Fly Ash and 40% Slag Sand)	120mm
5	Mix – 4 (30% Fly Ash and 60% Slag Sand)	110mm
6	Mix – 5 (30% Fly Ash and 80% Slag Sand)	100mm
7	Mix – 6 (30% Fly Ash and 100% Slag Sand)	95mm
8	Mix – 7 (40% Fly Ash and 0% Slag Sand)	120mm
9	Mix – 8 (40% Fly Ash and 20% Slag Sand)	110mm
10	Mix – 9 (40% Fly Ash and 40% Slag Sand)	100mm
11	Mix – 10 (40% Fly Ash and 60% Slag Sand)	100mm
12	Mix – 11 (40% Fly Ash and 80% Slag Sand)	95mm
13	Mix – 12 (40% Fly Ash and 100% Slag Sand)	90mm

Table No. 12 - Compressive Strength Test

Details of Replacement	7 Days (MPA)	14 Days (MPA)	28 Days (MPA)
Conventional Concrete	30	38.6	45.97
Mix – 1 (30% Fly Ash and 0% Slag Sand)	24.25	32.35	39.62
Mix – 2 (30% Fly Ash and 20% Slag Sand)	26.65	34.44	41.24
Mix – 3 (30% Fly Ash and 40% Slag Sand)	29.52	35.52	44.12
Mix – 4 (30% Fly Ash and 60% Slag Sand)	18.94	25.47	34.07
Mix – 5 (30% Fly Ash and 80% Slag Sand)	11.82	17.96	26.96
Mix – 6 (30% Fly Ash and 100% Slag Sand)	10.75	15.55	23.15
Mix – 7 (40% Fly Ash and 0% Slag Sand)	26.2	28.1	37
Mix – 8 (40% Fly Ash and 20% Slag Sand)	28.55	33.28	40.4
Mix – 9 (40% Fly Ash and 40% Slag Sand)	31.75	36.15	44.61
Mix – 10 (40% Fly Ash and 60% Slag Sand)	14.7	23.72	31.2
Mix – 11 (40% Fly Ash and 80% Slag Sand)	10.75	16.71	24.2
Mix – 12 (40% Fly Ash and 100% Slag Sand)	11.93	13.06	20.2



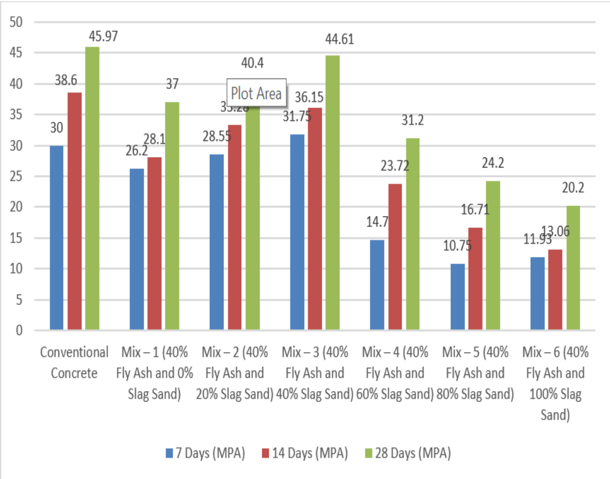
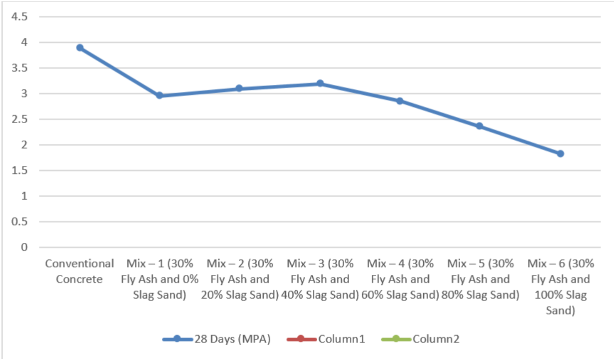


Table No. 13 - Split Tensile Test

Details of Replacement	28 Days (MPA)
Conventional Concrete	3.89
Mix – 1 (30% Fly Ash and 0% Slag Sand)	2.95
Mix – 2 (30% Fly Ash and 20% Slag Sand)	3.09
Mix – 3 (30% Fly Ash and 40% Slag Sand)	3.19
Mix – 4 (30% Fly Ash and 60% Slag Sand)	2.85
Mix – 5 (30% Fly Ash and 80% Slag Sand)	2.35
Mix – 6 (30% Fly Ash and 100% Slag Sand)	1.82
Mix – 7 (40% Fly Ash and 0% Slag Sand)	2.97
Mix – 8 (40% Fly Ash and 20% Slag Sand)	3
Mix – 9 (40% Fly Ash and 40% Slag Sand)	3.25
Mix – 10 (40% Fly Ash and 60% Slag Sand)	2.66
Mix – 11 (40% Fly Ash and 80% Slag Sand)	2.16
Mix – 12 (40% Fly Ash and 100% Slag Sand)	1.63



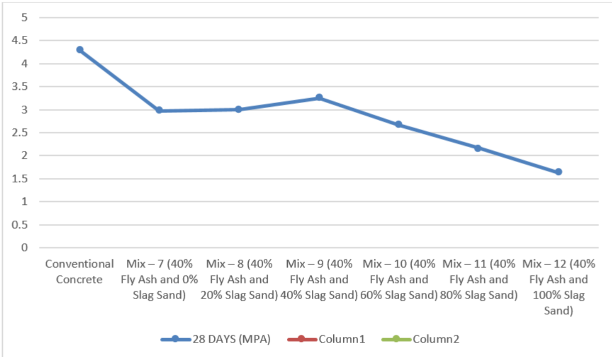
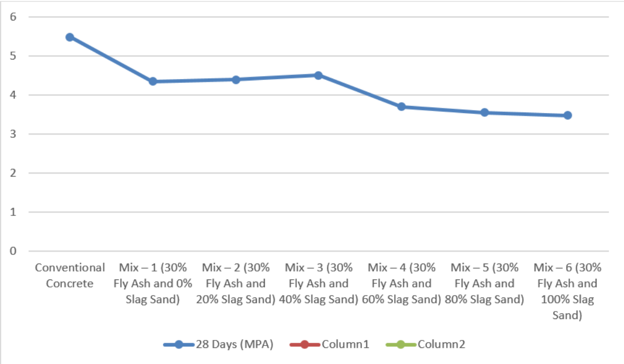
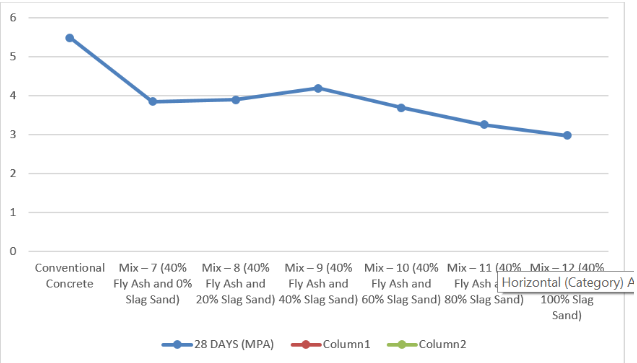


Table No. 14 - Flexural Test

Details of Replacement	28 Days (MPA)
Conventional Concrete	5.49
Mix – 1 (30% Fly Ash and 0% Slag Sand)	4.35
Mix – 2 (30% Fly Ash and 20% Slag Sand)	4.39
Mix – 3 (30% Fly Ash and 40% Slag Sand)	4.5
Mix – 4 (30% Fly Ash and 60% Slag Sand)	3.7
Mix – 5 (30% Fly Ash and 80% Slag Sand)	3.55
Mix – 6 (30% Fly Ash and 100% Slag Sand)	3.48
Mix – 7 (40% Fly Ash and 0% Slag Sand)	3.85
Mix – 8 (40% Fly Ash and 20% Slag Sand)	3.89
Mix – 9 (40% Fly Ash and 40% Slag Sand)	4.19
Mix – 10 (40% Fly Ash and 60% Slag Sand)	3.69
Mix – 11 (40% Fly Ash and 80% Slag Sand)	3.25
Mix – 12 (40% Fly Ash and 100% Slag Sand)	2.98





X. COST ANALYSIS

Table No. 14 - Cost for Conventional Concrete

Elements	Quantity	Price/kg	Total price
Cement	394	4.35	1713.9
Coarse Aggregate 20mm	1071.646	0.4	428.65
Crushed Sand	803.019	1.96	1573.91
Water	195.114	1	195.11
Admixture	3.94	41	161.54
Total			**4073.11**

Table No. 14 - Cost per m^3 (30% Fly Ash and 40% Slag Sand)

Elements	Quantity	Price/kg	Total price
Cement	275.8	4.35	1199.73
Fly Ash	118.2	2.08	245.85
Coarse Aggregate 20mm	1071.646	0.40	428.65
Crushed Sand	481.73	1.96	944.19
Slag Sand	329.116	1.5	493.67
Water	197.268	1	197.26
Admixture	2.758	41	113.078
Total			**3622.428**

Table No. 14 - Cost per m^3 (40% Fly Ash and 40% Slag Sand)

Elements	Quantity	Price/kg	Total price
Cement	236.4	4.35	1028.34
Fly Ash	157.6	2.08	327.808
Coarse Aggregate 20mm	1071.646	0.40	428.658
Crushed Sand	481.73	1.96	944.19
Slag Sand	319.116	1.5	478.67
Water	197.286	1	197.28
Admixture	2.364	41	96.92
Total			**3501.866**

XI. COCNCLUSION

The compressive, flexural performance, Split tensile strength with Fly Ash and Slag Sand will be investigated in detail in phase 2 of this report. The mass content of Fly Ash considered will be 30% and 40% by weight of total cement. The Slag Sand will be partly replaced by 0%, 20%, 40%, 60%, 80%, 100%. This experimental investigation is carried out under mix proportion i.e. M35 and the test results are compared with the same mix proportionated concrete cubes –

1. The Workability property of concrete property decreases as the percentage of replacement of slag sand increases. The slump varies from 90 mm to 125 mm for different mixes. By addition of GGBS, the slump is improved and all the concrete mixes were homogenous and cohesive in nature.
2. The compressive strength of cubes are increased with addition of Fly Ash and Slag Sand. The Optimum

percentages of replacements obtained are – 30% Fly Ash replaced by cement and 40 % slag sand replaced withNatural sand. Similarly for 40% Fly Ash and 40% slag sand replacement the compressive strength is higher than all other mixes.

3. Split tensile strength of Mix 3 (30% Fly Ash +40%SS) and Mix 8 (40%Fly Ash+40%SS) has highest strength as compared to conventional concrete.
4. The Flexural strength of concrete is also maximum for 30% replaced by cement and 40% slag sand replaced by natural sand. However 40% Fly Ash and 40% slag sand shows highest flexural strength values.
5. The cubes, cylinder and beam, the conclusion is that the optimum replacement can be done in two combinations: Mix 3- 30% Fly Ash can be replaced by cement along with 40% slag sand by natural sand. Mix 9- 40% Fly Ash can be replaced by cement along with 40% slag sand by natural sand.
6. Due to high glass content slag sand the higher replacements show decrease in strength of concrete(Mix 4,5,6,10,11,12).
7. Hence, it can be recommended that the GGBS and Slag Sand can satisfactorily utilize as Combined partial replacement for Cement and Natural sand respectively in concrete.

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