Mechanical properties of self-compacting concrete in M80 grade of concrete

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***Abstract*— In the world, concrete is the most often utilized civil engineering material used to build different kinds of structures. In order to enhance concrete's quality and adapt it to a variety of uses, concrete technology research has been conducted continuously. Numerous varieties of concrete, including fiber-reinforced concrete, self-compacting concrete (SCC), high strength concrete, and high-performance concrete, have been created as a result. One of the most notable developments in concrete technology over the past ten years is self-compacting concrete (SCC). Concrete that flows easily and can solidify on its own weight is known as self-compacting concrete The aim of the study is to make use of Ground Granulated Blast Furnace Slag and Metakaolin as replacements of cement and understand its effect on the fresh properties and hardened properties of concrete. The investigation includes the concept of double blending of Ground Granulated Blast Furnace Slag and Metakaoloin, this double blend exploits the beneficial characteristics of Pozzolanic materials in producing a better concrete. The mix design obtained for the M80 grade of self-compacting concrete. the quantities of cubes of dimensions 150mmx150mmx150mm and cylinders of the size 150mm diameter x 300 mm and beam sizes are 150mmx150mmx700mm length are casted and tested for the compressive strength, split tensile strength and flexural strength for 7days, and 28 days. The cement is replaced by weight as 10 % and 20% in order to find the optimum replacement for the metakaolin and ground granulated blast furnace slag is derived from the compressive strength results of the concrete blended by metakaolin and ground granulated blast furnace slag individually. The individual blends the double blend mix is obtained by replacing the cement by metakaolin and ground granulated blast furnace slag. the results obtained the metakaolin mix has increased compressive strength at 20 %replacement and it is more at 10% replacement of ground granulated blast furnace slag. a total replacement of cement by weight is 30 % i.e 20 % metakaolin and 10% ground granulated blast furnace slag.**

Key words :- SCC – Self Compacting Concrete, GGBS – Ground Granulated Blast Furnace Slag, Metakaolin, Mechanical Properties.

I. INTRODUCTION

Self-Compacting Concrete (SCC) is a type of concrete that can flow under its own weight and fill formwork without vibration, even with dense reinforcement. Developed in Japan to address issues with vibrators, Double blended cement is a type of concrete that is enhanced by mineral admixtures like metakaolin and ground granulated blast furnace slag, enhancing its physical, chemical, and mechanical properties.

Concrete is modified with admixture to suit various conditions, with pozzolonic materials like industrial waste by-products, fly ash, silica fume, stone dust, blast furnace slag, rice husk ash, and metakaolin being used in developing countries.

GGBS, produced by quenching iron slag, replaces cement in concrete, increasing durability, temperature resistance, workability, and resistance to chemical attack, while reducing water content, preventing early cracking, and reducing corrosion. Metakaolin is a pozzolan, a highly effective pozzolanic material for concrete, formed from heated china clay. Its quality is controlled during manufacture, making it less variable than industrial pozzolans. First used in Brazil in the 1960s, metakaolin suppresses alkali-silica reaction. Faster construction times. Easier placing and better surface finish. Greater freedom in design. Improved durability and reliability of concrete structures. Ease of placement results in cost savings through reduced equipment and labour requirement. Improved quality of concrete and reduction of onsite repairs and overall cost. Possibilities for utilization of dusts which are currently waste products and which are costly to dispose of.

II. MATERIALS AND METHODOLOGY

Cement is a material which is used to bind solid bodies together by hardening from a fresh or plastic state. In this research work locally available ordinary Portland cement was used.The coarse aggregate was air dried to obtain saturated surface dry condition to ensure that water cement ratio was not affect. Fine aggregate; Fine aggregate is commonly known as sand and should comply with coarse, medium, or fine grading needs. The fine aggregate was saturated under surface dry conditions to ensure the water cement ratio is not affected. Coarse aggregates are those particles that are predominantly retained on the 4.75 mm 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.

TABLE I. Physical properties of cement

Test	Result	Limits
Fineness	8%	not exceed 10%
Specific gravity	3.15 g/cc	3.15 g/cc
consistency	30%	30%
Intial setting time	30 min	3o min
Final setting time	600 min	600 min
Soundness	1.5 mm	not exceed 10mm

TABLE II. Physical properties of fine aggregate

Test	Result	Limits
Sieve analysis	2.65	2.0 to 3.5
Bulking	25%	Increase sand vol. 25%

TABLE III. Physical properties of coarse aggregate

Test	Result	Limits
Specific gravity	2.6	2.5 to 3.0
Impact test	17.3%	Exceptionally strong: <10%

TABLE IV. Chemical composition of cement

Composition	Percentage of content
SiO_2	55.3
Fe_2O	4.6
Al_2O_3	37.2
CaO	0.3
MgO	0.9
K_2O	1.35
LiO	3.39

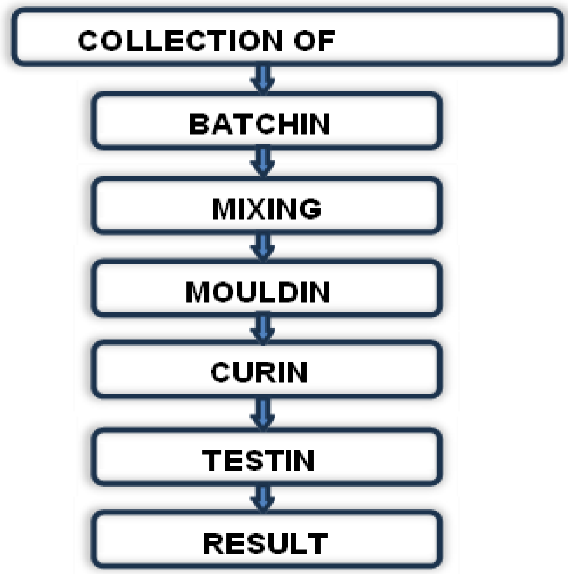


TABLE V. Physical properties of metakaolin

Properties	Range
Appearance	OFF White powder
Bulk density	355 gm/lit
Specific gravity	2.66

TABLE VI. Chemical properties of ground granulated blast furance slag

Properties	Range
Specific gravity	2.67
Bulk density	Dry-1536 kg/cu.m Loose-1339 kg/cu.m
Water absorption	6.75

TABLE VII. Physical properties of ground granulated blast furance slag

Composition	Percentage content
SiO_2	28 – 39
Al_2O_3	8 – 22
CaO	30 – 52
MgO	1 – 17

TABLE VII. Properties of super plasticizer

Properties	Range
Specific gravity	1.18
Appearance	Brown liquid
Chloride content	Nil
Air entrainment	Less than 2% additional air is entrained at normal dosage

The self-compacting concrete mix design follows the NANSU method, which requires verifying the volume ratio between fine aggregate and aggregate total (S/t) between 50% and 57%. A 53% S/t ratio was established, and the mixture's efficacy for self-compactibility was analyzed in fresh state tests, demonstrating its effectiveness in achieving self-compactibility.

Step 1 :- Determination of quantity of Cement

Step 2 :- Determination of quantity of Coarse and Fine aggregate

Step 3 :- Consumption of water

Materials	Quantity
Cement	668 kg / cu.m
Fine aggregate	710 kg / cu.m
Coarse aggregate	806 kg / cu.m

Step 4 :- Consumption of Super plasticizer

The quantity of coarse aggregate is determined

Wg = PF*WgL*(1- S/t)

Where:

Wg - amount of coarse aggregate in kg/m³

WgL - density of coarse aggregate, in loose state in kg/m³

PF - loose state aggregate and compacted state aggregate ratio in mass

S/t - volume ratio between fine aggregate and aggregate total

The quantity of Fine aggregate is determined by

Ws = PF*WsL*S/t

Where:

Ws - amount of fine aggregate in kg/m³;

WsL - density of fine aggregate, loose state, in kg/m³

PF - loose state aggregate and compacted state aggregate ratio, in mass

Materials	Mix 1	Mix 2	Mix 3
Cement	668 kg/cu.m	668 kg/cu.m	668 kg/cu.m
Fine aggregate	710 kg/cu.m	710 kg/cu.m	710 kg/cu.m
Coarse aggregate	806 kg/cu.m	806 kg/cu.m	806 kg/cu.m
W/C ratio	0.2	0.25	0.3

S/t - volume ratio between fine aggregate and aggregate total.The quantity of Cement is determined by

$$C = 1.26 * f_C / 0.14$$

Where

C - cement consumption in kg/m³;

fc - required compressive strength in MPa. Determination of cement content Target strength at 28 days is 80 Mpa

C = 1.17*80 / 0.14

= 668 kg/cum

Determination of coarse aggregate

Wg = PF*WgL*(1 – S/t

= 0.981*1602*(1 – 0.52)

=806 kg/ cum

Determination of fine aggregate

Ws = PF*WsL*(S/t)

= 1520*0.908*0.52

= 710 kg/ cum

TABLE VIII. Mix design proportions for m80 self compacting concrete obtained are as follows

Materials	Quantity
Cement	668 kg / cu.m
Fine aggregate	710 kg / cu.m
Coarse aggregate	806 kg / cu.m
W/C ratio	0.3
SP dosage	6 %

TABLE IX. The below are the trial mixes tested for the determination of w/c ratio and super plasticizer content

Materials	Mix 1	Mix 2
Cement	595.7 kg / cu.m	538.4 kg/cu.m
Metakaolin	65.3 kg	134.6 kg/cu.m
Fine aggregate	710 kg / cu.m	710 kg / cu.m
Coarse aggregate	806 kg / cu.m	806 kg / cu.m
W/C ratio	0.3	0.3
SP dosage	6 %	6 %

TABLE X. Mix design of self compacting concrete

Materials	Mix 1	Mix 2
Cement	595.7 kg / cu.m	538.4 kg/cu.m
GGBS	65.3 kg	134.6 kg/cu.m
Fine aggregate	710 kg / cu.m	710 kg / cu.m
Coarse aggregate	806 kg / cu.m	806 kg / cu.m
W/C ratio	0.3	0.3
SP dosage	6 %	6 %

TABLE XI. Mix proportion for metakaolin

Materials	Quantity
Cement	465.1 kg/cu.m
Metakaolin	133.6 kg/cu.m
GGBS	67.3 kg/cu.m
Fine aggregate	710 kg / cu.m
Coarse aggregate	806 kg / cu.m
W/C ratio	0.3
SP dosage	6 %

TABLE XII. Mix proportion for GGBS

TABLE XII. Mix proportion for double blended SCC

Mixes	Flow Test- T50 (Sec)	J Ring- J50(Sec)	L-Box (H2/H1)	U-Box (h1-h2)
Trial Mix – 1	10	14	0.59	20
Trial Mix – 2	7	10	0.77	22
Trial Mix – 3	5	5	0.90	23
Blend Mix – 1	4	5	0.92	20
Blend Mix – 2	3	6	0.93	25
Blend Mix – 3	4	6	0.95	24
Blend Mix – 4	4	6	0.96	24
Double Blend Mix	3	5	0.95	23

TABLE XIV. Workbility test on self compacting concrete

Mixes	Compressive Strength		Split Tensile Strength	Flexural Strength
	7 Days	28 Days	28 Days	28 Days
Self Compacting Concrete	57.5	79.87	5.92	5.97
Blend Mix – 1	60.735	80.98	5.94	5.98
Blend Mix – 2	61.02	81.37	6.15	6.20
Blend Mix – 3	59.37	80.23	5.96	6.02
Blend Mix – 4	58.87	79.71	5.92	5.96
Double Blend Mix	61.34	81.79	6.23	6.30

Fig 1. J ring

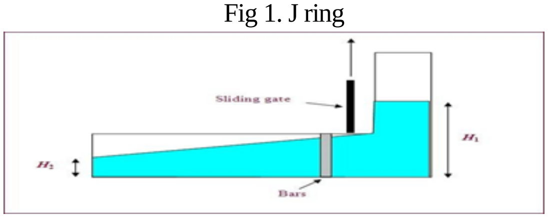


Fig 2. L Box

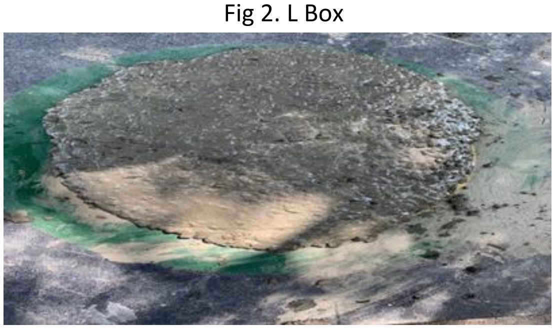


Fig 3. Flow test

Fig 4. U Box

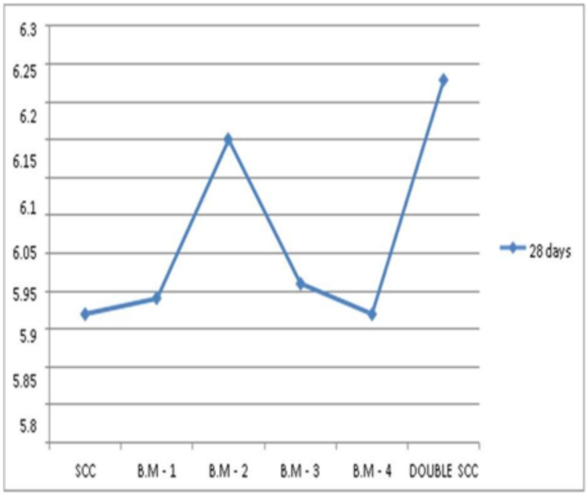
III. RESULT AND DISCUSSION

TABLE XV. Compressive test and split tensile test and flexural strength test

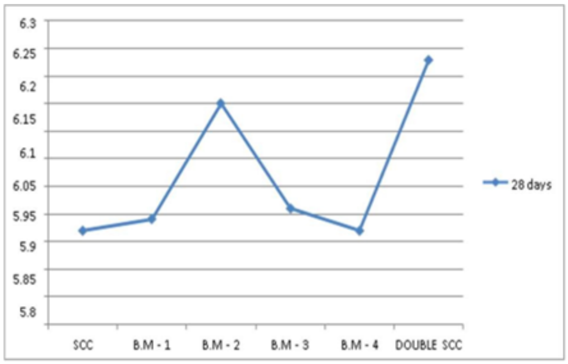
Fig 5. Compression test

Fig 6. Cubes and cylinders

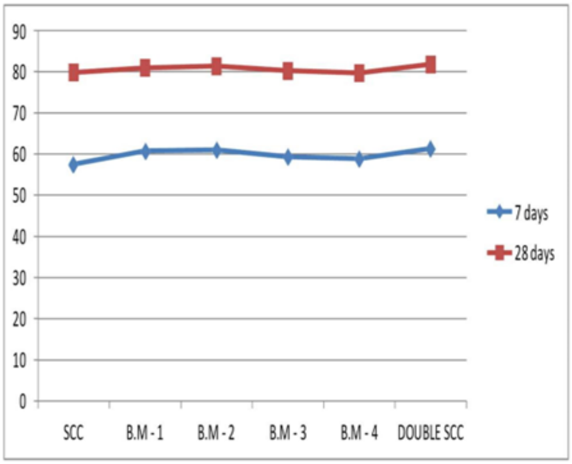
Fig 7. Flexural test



Graph – 1 Compressive strength of different mixes



Graph-2 Split tensile strength of different mixes



Graph-2 Flexural strength of different mixes

IV. CONCLUSION

1. The compressive strength, flexural strength and split tensile strength have been increased upto 30% replacement of cement by 20% Metakaolin, 10% GGBS.
2. In addition, the application of SCC is also benefit for making eco-friendly concrete and promoting the development of other types of ultrahigh performance concrete.
3. It can solve the problems brought by poorly compacted concrete, including unsatisfying physical appearance, strength, or durability issues.
4. The metakaolin and ground granulated blast furnace slag in place of cement shall be very economical and can also help in the utility of Industrial wastes and in maintaining the ecological balance, thus reducing the consumption of cement.
5. Higher dosages of super plasticizer are required for high strength concrete mixes particularly when mineral admixtures and were employed to maintain workability.
6. A double-blend approach to high performance concrete mix design can enable cost savings, increased performance and improved sustainability
7. There was an increase in the strength of SCC when the cement is replaced by metakaolin and ground granulated blast furnace slag up to 30%. This also reduces the cement content by increasing the metakaolin and ground granulated blast furnace slag thus reducing the further cost of SCC mixes developed.
8. The size of coarse aggregate controls the test results of L- Box test and hence it signifies that greater the size of aggregate less is the flow ability through the heavily reinforced structures.
9. Trail mixes have to be made for maintaining flow ability, self-compatibility and obstruction clearance.
10. Using mineral admixtures as partial replacement to cement in SCC reduces the permeability.

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