Effect of Combination of Mineral Admixtures on the Properties of Self Compacting Concrete

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Abstract Self-compacting concrete abbreviated as SCC is a recently developed concept in which the ingredients of the concrete mix are proportioned in such a way that the concrete is compacted by its own weight without or little vibration, assuring complete filling of formwork even when access is hindered by narrow gaps between reinforcing bars. Cement is the most important constituent material, since it binds the aggregates and resists the atmospheric action. Manufacturing of cement emits about 0.8 ton of CO_2 in atmosphere for every ton of cement manufacture. The utilization of supplementary cementing materials as natural pozzolans like dolomite powder, fly ash, GGBS etc. in concrete production is one of the solutions to reduce the cement content. This paper deals with the fresh and hardened properties of self compacting concretes made with combination of GGBS and dolomite, GGBS and fly ash as cement replacement in different amounts. The trial mixes are formed based on IS 10262: 2019. The workability properties of the mixes are evaluated by workability testes such as slump flow test, V-funnel test, L-box test. The hardened properties of the concrete are evaluated by compressive strength, flexural strength and tensile strength. The successful utilisation of fly ash, GGBS and dolomite powder in SCC mixes would not only lower the cost of SCC, but could also provide a solution to the disposal and environmental problems connected with these materials.

Keywords Self compacting concrete · Ground granulated blast furnace slag · Dolomite powder · Fly ash

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1 Introduction

Concrete is the basic civil engineering material used in most of the civil engineering structures. The recent development in the field of concrete technology represents a great step toward manufacturing of concrete. Self-compacting concrete abbreviated as SCC is a recently developed concept in which the ingredients of the concrete mix are proportioned in such a way that the concrete is compacted by its own weight without or little vibration, assuring complete filling of formwork even when access is hindered by narrow gaps between reinforcing bars. The main property that defines SCC is high workability in attaining compaction and specified hardened properties [1].

Cement, fine aggregate, coarse aggregate, mineral admixtures, chemical admixtures and water are the constituents of concrete. Cement is the most important constituent material, since it binds the aggregates and resists the atmospheric action. Manufacturing of cement emits about 0.8 ton of CO_2 in atmosphere for every ton of cement manufacture [2]. The utilization of supplementary cementing materials as natural pozzolans like dolomite powder, rice husk ash, fly ash, egg shell powder, silica fume, metakaolin etc. in concrete production is one of the solutions to reduce the cement content [3].

Dolomite is a carbonate material composed of calcium magnesium carbonate $CaMg(CO_3)_2$. Its use improves properties such as weathering action, reduces shrinkage, fissure development and water absorption. By the proper usage of dolomite powder, the objective of cost reduction of construction can be obtained. We found the cost of dolomite is very cheap than cement and it is easily available locally [4]. Fly ash or flue ash, also known as pulverized fuel ash is a coal combustion product that is composed of the particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases. Depending upon the source and composition of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata. Ground Granulated Blast furnace Slag (GGBS) is a by product from the blast furnaces used to make iron. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions [5]. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

Table 1 Chemical composition of GGBS

Characteristics	Test result
Specific gravity	2.85
Magnesia. Content (%)	7.73
Sulphide sulphur (%)	0.50
Sulphite content (%)	0.38
Manganese content (%)	0.12
Chloride content (%)	0.009
Moisture content (%)	0.10

Table 2 Chemical composition of fly ash and dolomite powder

Parameters tested	Fly ash	Dolomite powder (%)
Calcium oxide (CaO)	0.44%	33.27
Magnesium Oxide (MgO)	–	7.96
Silicon Dioxide (SiO_2)	63.8%	40.50
Aluminium Oxide (Al_2O_3)	1.29%	0.55
Ferric oxides (Fe_2O_3)	0.39	0.18

2 Experimental Program

2.1 Materials

Ordinary Portland Cement of 53 grade was used in the investigation. Ground granulated blast furnace slag (GGBS), fly ash and dolomite powder are used as supplementary cementitious material and their chemical compositions are given in Tables 1 and 2. Crushed granite angular aggregate from a local source, having a maximum size of 12.5 mm, was used as coarse aggregate and M-Sand used as fine aggregate.

2.2 Mix Proportions

For the study M25 grade concrete is designed as per IS 10262: 2019. Water binder ratio of 0.43 and 0.4% of admixture is adopted for all the mixes. The objective of the project is to study the (a) effect of GGBS and dolomite powder on the properties of SCC and (b) effect of GGBS and fly ash on the properties of SCC. To obtain the first objective five mixes with different proportions of GGBS and dolomite powder were prepared and tested. The designation of specimens with GGBS and dolomite is presented in Table 3.

To obtain the second objective five mixes with different proportions of GGBS and fly ash were prepared and tested. The designation of specimens with GGBS and fly ash is given in Table 4.

Table 3 Designation of specimen with GGBS and dolomite powder

Mix ID	Proportion of binder materials
D0	Cement 60% + GGBS 40% + DP 0%
D5	Cement 60% + GGBS 35% + DP 5%
D10	Cement 60% + GGBS 30% + DP 10%
D15	Cement 60% + GGBS 25% + DP 15%
D20	Cement 60% + GGBS 20% + DP 20%

Table 4 Designation of specimen with GGBS and fly ash

Mix ID	Proportion of binder materials
F0	Cement 60% + GGBS 40% + FA 0%
F10	Cement 60% + GGBS 30% + FA 10%
F20	Cement 60% + GGBS 20% + FA 20%
F30	Cement 60% + GGBS 10% + FA 30%
F40	Cement 60% + GGBS 0% + FA 40%

2.3 Testing of Specimen

The workability properties of the mixes were evaluated by slump flow test and the hardened properties were evaluated by compressive strength, flexural strength and tensile strength tests. Concrete cubes of size 150 × 150 × 150 mm, concrete cylinder of size 150 mm × 300 mm and concrete beams of 100 × 100 × 500 mm were prepared for compressive strength, split tensile strength and flexural strength test respectively.

3 Results and Discussion

3.1 Effect of GGBS and Dolomite Powder on SCC

3.1.1 Fresh Properties

The slump values were recorded as soon the concrete was mixed. The results of slump flow test for each mix are shown in Table 5. As per IS: 10262—2019 the acceptance range for slump flow and T_{50} slump flow of class SF2 is 660–750 mm and 2–5 s respectively. The slump flow test results obtained here is within this range.

3.1.2 Hardened Properties

Compressive strength, split tensile strength and flexural strength test results at different ages are given in Tables 6 and 7. It is observed that compressive strength

Table 5 Slump flow test results of SCC with GGBS and dolomite powder

S. No.	Mix ID	Flow diameter (mm)	T_{50} slump flow (s)
1	Control mix	674	4.5
2	D0	686	3.5
3	D5	684	3.6
4	D10	678	4
5	D15	676	4.1
6	D20	671	4.3

Table 6 Compressive strength of SCC with GGBS and dolomite powder

S. No.	Mix ID	7 day compressive strength (MPa)	28 day compressive strength (MPa)
1	Control mix	24.34	32.65
2	D0	26.52	33.78
3	D5	27.43	37.32
4	D10	28.46	38.87
5	D15	26.12	35.56
6	D20	24.85	34.92

Table 7 Tensile and flexural strength of SCC with GGBS and dolomite powder

S. No.	Mix ID	28 day tensile strength (MPa)	28 day flexural strength (MPa)
1	Control mix	2.57	5.9
2	D0	3.19	6.29
3	D5	3.21	6.31
4	D10	3.57	6.45
5	D15	3.33	6.39
6	D20	2.9	6.36

increases from 26.52 to 28.46 MPa at 7 days and 33.78 to 38.87 MPa at 28 days with the increase in dolomite powder content from 0 to 10%. SCC mix with 30% of GGBS and 10% of dolomite powder obtained maximum tensile strength and flexural strength of 3.57 MPa and 6.45 MPa respectively.

Table 8 Slump flow test results of SCC with GGBS and fly ash

S. No.	Mix ID	Flow diameter (mm)	T_{50} slump flow (sec)
1	Control Mix	674	4.5
2	F0	686	3.5
3	F10	680	3.9
4	F20	675	4.2
5	F30	670	4.5
6	F40	667	4.8

Table 9 Compressive strength of SCC with GGBS and fly ash

S. No.	Mix ID	7 day compressive strength (MPa)	28 day compressive strength (MPa)
1	Control mix	24.34	32.65
2	F0	26.52	33.78
3	F10	26.98	35.87
4	F20	28.12	38.62
5	F30	25.42	37.24
6	F40	25.04	34.08

3.2 Effect of GGBS and Fly Ash on SCC

3.2.1 Fresh Properties

The results of slump flow test for each mix are shown in Table 8. The slump flow test results obtained here is within the acceptance range specified in IS: 10262—2019 for SCC.

3.2.2 Hardened Properties

Compressive strength, split tensile strength and flexural strength test results at different ages are given in Tables 9 and 10. It is observed that compressive strength, tensile strength, flexural strength increases with the increase in fly ash content upto 20%. SCC mix which incorporates of powder material comprising of 60% ordinary Portland cement, 20% GGBS and 20% fly ash obtains high strength.

4 Conclusions

On the basis of the results obtained, the following conclusions have been drawn:

Table 10 Tensile and flexural Strength of SCC with GGBS and fly ash

S. No.	Mix ID	28 day tensile strength (MPa)	28 day flexural strength (MPa)
1	Control mix	2.57	5.9
2	F0	3.19	6.29
3	F10	3.52	6.33
4	F20	3.68	6.52
5	F30	3.31	6.46
6	F40	3.05	6.36

- Dolomite powder and GGBS can be used partially to enhance the strength properties of concrete which makes the mix economical than conventional concrete.
- All the mixes with GGBS and dolomite powder show acceptable fresh properties.
- Mix with 30% of GGBS and 10% of dolomite powder obtained maximum compressive, tensile and flexural strength.
- It is possible to manufacture self-compacting concrete using GGBS and fly ash with acceptable fresh and hardened properties.
- All the mixes with GGBS and fly ash show acceptable fresh properties.
- Maximum strength is obtained for mix with 20% of GGBS and 20% of fly ash.

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