

# Study on Fresh and Hardened Properties of Self-Compacting Mortar Containing GGBFS, Granite Powder and M-sand

Maruthish Babu S<sup>1</sup>, Bhavanishankar S<sup>2</sup>

<sup>1</sup>PG Student, Dept. of Civil Engineering, UVCE, Bengaluru, Karnataka, India

<sup>2</sup>Associate Professor, Dept. of Civil Engineering, UVCE, Bengaluru, Karnataka, India

\*\*\*

**Abstract** - The production of OPC approximately emits 5 - 7% of total global CO<sub>2</sub> emission, which is very detrimental to the environment. Granite powder, a waste produced in the cutting of granite stone effects the environment when deposited in landfills. It is necessary to reduce the environmental impact of industries. In the present study an attempt has been made to use the waste material like GGBFS as a partial replacement for cement in making cement mortar and Granite powder (GP) used as a partial replacement for fine aggregate. By replacing OPC by GGBFS we can minimize the emission of CO<sub>2</sub> due to production of cement, also GP is used as a replacement for fine aggregate so that the disposal problem of GP can be solved. The optimum percentage of GP as a replacement for M-sand is determined by conducting compressive strength test on conventional mortar mixes with varying percentage of replacement (10%, 15%, 20% and 25%) and the percentage of replacement of cement by GGBFS is kept at 30%. To develop the SCM, based on literature review Cement has been replaced by 0%, 20%, 30%, 40% and 50% of GGBFS and M-Sand has been replaced by GP with optimum percentage (15%). Suitable w/b ratio and SP dosage has been achieved by several trials satisfying fresh properties like mini slump cone test and mini V funnel test, Then the SCM specimens are cast and tested for hardened properties like Compression, Flexure, Drying Shrinkage.

**Key Words:** Self-Compacting Mortar, Granite Powder, GGBFS, Super plasticizer, Self-Compacting Concrete, Drying shrinkage.

## 1. INTRODUCTION

The Self-compacting mortar (SCM), is a highly flowable mortar which can be placed without any external compaction.

To select component materials and super-plasticizer requirements in order to optimize mixture proportions, cement paste or mortar tests are conducted as a previous step in SCC design.

Modern development of the construction and building industry is showing more tendencies towards cost effective energy-saving production technologies, while ensuring the high quality of building materials and structures. If the mineral admixtures can replace some or all of the chemical admixtures without affecting the

fresh properties of SCC or SCM, the damage to environment will be reduced. Moreover, the mineral admixtures will also increase the durability and long-term strength properties, a large amount of industrial waste by-products such as GGBFS is being produced every year throughout steel industries. It is reported that the annual worldwide production amount of GGBFS is 530 million ton every year. With the similar mineral and chemical composition to OPC, GGBFS can be potentially used as OPC replacement. The usage of GGBFS and Granite powder as cement and M-sand replacement respectively not only reducing the CO<sub>2</sub> emission but also solving industrial byproduct waste disposal problem.

## 2. OBJECTIVES

1. Study of fresh and hardened properties of developed different SCM mixes.
2. Utilizing available waste granite powder (GP) and GGBFS as resources in building industry.
3. Verifying the adoptability of granite powder and GGBFS in preparing workable self-compacting mortar mix.
4. Determining the degree of strength improvement in SCM of different trial mixes by replacing 0%,20%,30%,40% and 50% of weight of the cement by the GGBFS by keeping constant optimum percentage replacement of Granite powder with m-sand.
5. To determine the optimum percentage replacement of GP as fine aggregate with the average proportions of cement and GGBFS proposed in the study.
6. The investigation aimed at finding out optimum replacement percentages of granite powder and GGBFS for superior strength.

## 3. METHODOLOGY

The methodology based on the literature review for using laboratory to the development of self-compacting mortar mixes containing both GGBFS and Granite powder as a partial replacement for Cement and M-sand respectively, As it is unreliable to get the Optimum replacement of GGBFS and Granite powder to get the optimum strength by varying the percentages of both

GGBS and Granite powder simultaneously, So as the preliminary step Optimum percentage of Granite powder is find out by conducting compressive strength test on conventional mortar mixes. Then SCM mixes are produced using varying percentages of GGBFS with Cement and constant optimum percentage of Granite powder with M-sand.

The optimum percentage of Granite powder as a replacement for M-sand is determined by conducting compressive strength test on conventional mortar mixes with varying percentage of replacement (10%, 15%, 20% and 25%) and the percentage of replacement of cement with GGBFS is kept at 30%, 4 conventional mortar mixes with total 48 specimens are casted. Then the Self-compacting mortar (SCM) mixes are produced by replacing GGBFS with Cement and constant optimum percentage of Granite powder with M-sand. To develop the desired self-compacting mortar (DSCM), both cement and M-sand have been simultaneously replaced by GGBFS and Granite powder respectively by weight, based on literature review GGBS has been replaced by 0%, 20%, 30%, 40% and 50% and Granite powder has been replaced by M-sand with optimum percentage (15%). 1 conventional or Normal mortar mix and 6 SCM Mixes with total 140 specimens casted in the laboratory. Based on literature reviews water to binder ratio has been selected, and suitable mix proportion has been achieved by several trials by varying the ingredients satisfying fresh properties relevant to mini slump cone test and mini V funnel test, Then the self-compacting mortar specimens are casted and tested for 7,14 and 28 days for compressive test and flexural test, The SCM Prisms were tested for drying shrinkage of mixes at interval of 5 days up to 30 days.

## 4. MATERIALS

### 4.1. Ordinary Portland cement

The Portland cement is consisting of pulverized material obtained by burning a mixture of calcareous and argillaceous material at very high temperature with addition of small quantity of Gypsum and The cement is an excellent binding material in concrete and the cement used for the investigation was OPC Zuari 43 grade confirmed to the requirement of IS Specification IS: 8112-1989.

### 4.2. GGBFS

Ground granulated blast furnace slag (GGBFS) is a by-product produced from the blast-furnaces used to make iron, GGBFS is generally used to partially replace OPC for various Concrete, Masonry, Cement based product manufacturing and other purposes, and in the present investigation GGBFS from JSW steel plant is used.

### 4.3. M-sand

In this paper M-sand is using as a Fine aggregate, The fine aggregate is granular materials composed of finely divided rock and mineral particles. The aggregate is important for the volume stability, but it also plays an important role on the strength and stiffness of concrete and mortar depends on the aggregate quality, Grading and maximum sizes are also some of the important factors, M-sand of maximum size 2.36 mm and conforming to IS 383-1970 Specified as Zone II is used in the present work.

### 4.4. Granite powder

Granite powder is the by-product produced in granite factories while cutting huge granite rocks to the desired shape. To ease the process of cutting rock in to slices, thin jet of water is continuously sprayed while cutting the granite rocks, the slurry produced is carried by the water and this water is collected in settling tanks as wet granite slurry. The granite industry units are finding it difficult to dispose of this granite sludge. So they are collecting the waste granite powder in a slurry form and disposing off unscientifically in vacant sites, in unused open areas, tank bed, landfills etc...

With the properties of the granite powder, i.e. its size and fineness, it can be very effectively used as a filler material in the cement mortar & concrete, replacing the fine aggregate which will help in filling up the pores in the mortar which is otherwise porous. Filling up of the pores by the granite fines increase the strength of the cement mortar and also granite powder is abundantly available and which has a disposal problem can be made use effectively. Granite Powder of 0.125 mm downsizes and specified as Zone III is used in the experimental program.

### 4.5. Water

Water is an important material of mortar and concrete as it actively participates in the chemical reactions with OPC, binding action of the hydrated cement gel affects the strength of cement mortar. In the hardened cement paste in mortar and concrete the water content should be maintained correctly because excess water would lead to formation of undesirable voids.

Ordinary portable water which is free from all type of organic matter, harmful minerals and organic salts is used.

### 4.6. Super-plasticizer

Super-plasticizer is essential for the manufacture of SCC. The job of SP is to impart a high degree of flowability and deformability

Super plasticizer is a chemical compound used to increase the workability without adding more water. SP improves better surface expose aggregates to the cement gel. Super-plasticizer acts as a lubricant among the materials.

Master Glenium Sky 8233 is utilized in this project, which is High performance superplasticizer based on new generation modified polycarboxylic ether having a specific gravity of 1.08, Master Glenium SKY 8233 is free of chloride and low alkali. It is compatible with all types of cements.

**Table -1: MATERIAL PROPERTIES**

Materials	Test conducted	Results	IS-Code Specifications
Cement	Specific gravity	3.12	3.15
	Fineness (%)	7.5	10.0
	Normal consistency (%)	33	-
	Initial setting time (min)	95	30
	Final setting time (min)	360	600
	7-days Compressive Strength (MPa)	34.20	33
	28-days Compressive Strength (MPa)	43.04	43
GGBFS	Specific gravity	2.75	2.9
	Fineness (%)	8.0	10
M-sand	Specific gravity	2.65	2.75
	Fineness modulus (%)	2.76	3.20
Granite Powder	Specific gravity	2.57	-
	Fineness modulus (%)	1.95	-

## 5. EXPERIMENTAL PROGRAMME

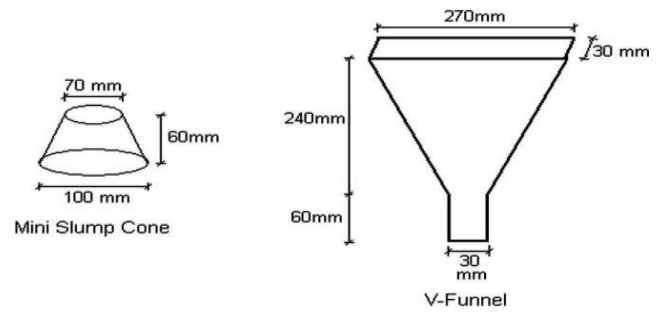
### 5.1. Fresh properties of SCM mixes

#### 5.1.1. Mini slump cone test

The flow ability of mortar mix is examined from the results of the mortar flow test. The ultimate spread diameter is recorded 2 min after lifting. The acceptable value of spread diameter is in the range of 240 to 260 mm (EFNARC 2005).

#### 5.1.2. Mini V-funnel test

The viscosity of the mortar mix is evaluated by the mortar mini V funnel test. The acceptable value of flow time for SCM should be in the range of 7-11 s reported by (EFNARC 2005).



**Fig -1:** Dimensions of mini slump cone and mini V-funnel

### 5.2. Developing Self-Compacting Mortar Mixes

The slump cone and V-funnel tests comprise many trials, beginning with a mortar ratio of 1 : 2. To obtain the desired homogeneous and consistent mix, the quantities of SP and W/P ratio is altered to obtain the proposed spread diameter of 240 to 260 mm and V-funnel time of 7 to 11 s in conformity with [EFNARC 2005]. Segregation and bleeding were visually observed during the slump flow test.: After a number of successful trials specific w/p ratio and Superplasticizer dosage is fixed for every mix and further tests were carried on each mix with the obtained W/P ratio and Superplasticizer dosage.

### 5.3. Hardened properties of SCM mixes

#### 5.3.1. Compression strength

Cube moulds of size 70.6x70.6x70.6 mm were used to cast SCM cubes, Cubes were used for the determination of compressive strength of 1:2 mortar mix, all the moulds were cleaned and oiled properly.

The compression strength of the mortar used in the construction of cube specimens was determined according to IS: 2250-1981.

#### 5.3.2. Flexure strength

Flexural strength is a material property defined as the stress in a material just before it yields in a flexure test. Prisms were used for the determination of Flexural strength of 1:2 mortar mix, Prism moulds of size 40x40x160 mm were used to cast SCM Prisms, all the moulds were cleaned and oiled properly. These were securely tightened to correct dimension before casting. Care was taken to avoid gaps in moulds from where leakage out of slurry is possible.

The Flexural strength of the mortar used in the construction of prism specimens was determined according to ASTM C 348-14.

#### 5.3.3. Drying Shrinkage

The drying shrinkage test of SCM used in the construction of prism specimens was determined according to IS 4031 (part 10) – 1988 or ASTM C 596 01, Steel Moulds

of size 25\*25\*285 mm were used for casting of specimens which is used for determining the effect of drying shrinkage of mortar.

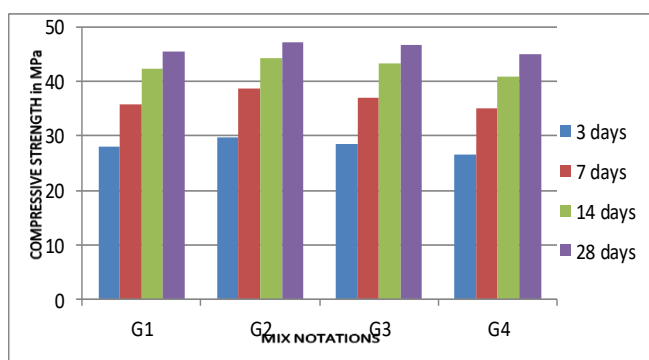
## 6. RESULTS AND DISCUSSION

### 6.1 Compressive strength of Granite powder mortar mixes

The compressive strength of conventional mortar mixes with varying percentage of Granite powder (10%, 15%, 20% and 25%) as a replacement for M-sand and the percentage of replacement of cement with GGBFS is kept at 30% obtained for different ages are reported in Table (2).

**Table -2: Compressive strength of Granite powder mortar mixes**

Age		3 DAYS	7 DAYS	14 DAYS	28 DAYS
Notation	Mix Proportions	Compressive Strength (MPa)			
G <sub>1</sub>	70% C + 30% GG & 10% MS+90% GP	28	35.7	42.36	45.53
G <sub>2</sub>	70% C + 30% GG & 85% MS +15% GP	29.76	38.76	44.13	47.03
G <sub>3</sub>	70% C + 30% GG & 80% MS+ 20% GP	28.43	36.97	43.23	46.6
G <sub>4</sub>	70% C + 30% GG & 75% MS+ 25% GP	26.43	35.03	40.73	44.9



**Chart -1: Compressive strength of Granite powder mortar mixes**

### 6.2 Fresh mortar properties

The test results computed relevant to the slump flow, V-funnel flow time are presented in the Table 3 and Fig 3. All of the SCMs were designed to give a slump flow diameter which was acquired by adjusting the dosage of SP used.

Thus, all of the fresh mixtures have slump flow diameter conforming to EFNARC recommendation.

**Table - 3: Fresh properties of Self-compacting mortar mixes**

Mix Notation	Mix Proportions	W/P Ratio	Superplasticizer (%)	Mini Slump flow dia (mm)	Mini V funnel flow Time (s)
S <sub>0</sub>	100% C & 100% MS	0.39	0.8	253	9.8
S <sub>1</sub>	100% C & 85% MS+15% GP	0.4	1	251	10
S <sub>2</sub>	80% C + 20% GG & 85% MS+15% GP	0.39	1	256	9.5
S <sub>3</sub>	70% C+ 30% GG & 85% MS+15% GP	0.39	1	256	9.18
S <sub>4</sub>	60% C+ 40% GG & 85% MS+15% GP	0.39	0.9	258	8.4
S <sub>5</sub>	50% C+ 50% GG & 85% MS+15% GP	0.4	0.8	259	7.6

### 6.3 Hardened mortar properties

#### 6.3.1. Compressive strength

The compressive strength of SCM mixes with mineral admixtures (GGBS and Granite powder) with respect to that of the SCM without mineral admixtures obtained for different ages are reported in Table (4).



**Fig -3: Casted samples of SCM cubes**

**Table -4: Compressive strength result of Self-compacting mortar mixes**

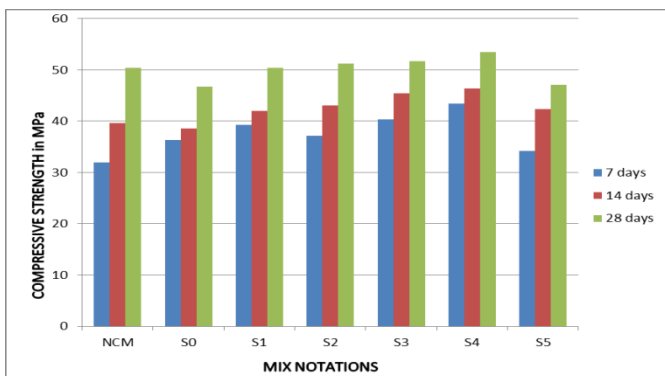
	Age	7 DAYS	14 DAYS	28 DAYS
Mix Notation	Mix proportions	Compressive Strength (MPa)		
NCM	100%C & 100% MS	31.96	39.66	50.43
S <sub>0</sub>	100%C & 100% MS	36.33	38.56	46.73
S <sub>1</sub>	100%C & 85%MS +15%GP	39.26	42	50.36
S <sub>2</sub>	80%C + 20% GG & 85%MS + 15%GP	37.16	43.06	51.2
S <sub>3</sub>	70%C + 30% GG & 85%MS + 15%GP	40.3	45.46	51.7
S <sub>4</sub>	60%C + 40% GG & 85%MS + 15%GP	43.43	46.4	53.5
S <sub>5</sub>	50%C + 50% GG & 85%MS + 15%GP	34.2	42.3	47.06



**Fig - 4: Casted samples of SCM prisms**

**Table - 5: Flexural strength result of Self-compacting mortar mixes**

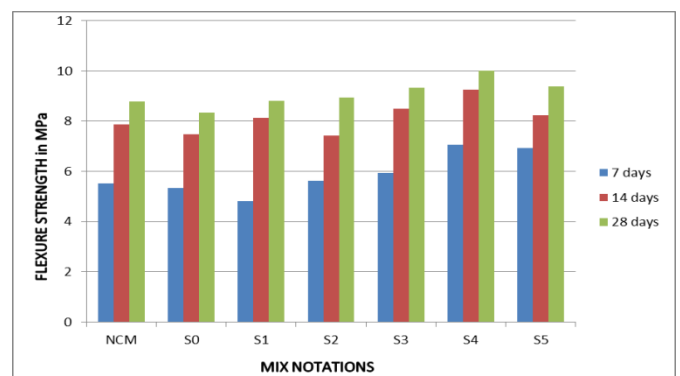
	Age	7 DAYS	14 DAYS	28 DAYS
Mix Notation	Mix proportions	Flexure Strength (MPa)		
NCM	100% C & 100% MS	5.53	7.88	8.77
S <sub>0</sub>	100% C & 100% MS	5.33	7.47	8.33
S <sub>1</sub>	100% C & 85%MS +15%GP	4.81	8.12	8.80
S <sub>2</sub>	80% C + 20% GG & 85%MS + 15%GP	5.61	7.42	8.93
S <sub>3</sub>	70% C + 30% GG & 85%MS + 15%GP	5.93	8.50	9.32
S <sub>4</sub>	60% C + 40% GG & 85%MS + 15%GP	7.05	9.26	10.02
S <sub>5</sub>	50% C + 50% GG & 85%MS + 15%GP	6.92	8.24	9.39



**Chart - 2: Compressive strength of SCM cubes at different ages**

**6.3.2. Flexural strength**

The Flexural strength of SCM mixes with mineral admixtures (GGBS and Granite powder) with respect to that of the SCM without mineral admixtures obtained for different ages are reported in Table (5).



**Chart - 3: Flexure strength of SCM cubes at different ages**

### 6.3.3 Drying shrinkage

The Drying shrinkage values of all SCM mixes were determined for every interval of 5 days till 30 days. The Shrinkage values of SCM mixes with mineral admixtures with respect to that of the SCM mixes without mineral admixtures obtained for different ages are reported in Table (6).



Fig -5: Casted samples of SCM prisms

Table - 6: Shrinkage values of Self-compacting mortar mixes

Mix Notation	Mix Proportions	Shrinkage values (µm) for different age in days					
		5	10	15	20	25	30
S <sub>0</sub>	100%C & 100%MS	171	358	556	621	716	789
S <sub>1</sub>	100%C & 85%MS +15%GP	153	321	479	586	671	768
S <sub>2</sub>	80%C + 20% GG & 85%MS + 15%GP	126	280	457	542	632	691
S <sub>3</sub>	70%C + 30% GG & 85%MS + 15%GP	121	243	448	532	641	749
S <sub>4</sub>	60%C + 40% GG & 85%MS + 15%GP	114	218	374	460	540	669
S <sub>5</sub>	50%C + 50% GG & 85%MS+15%GP	111	212	403	443	511	621

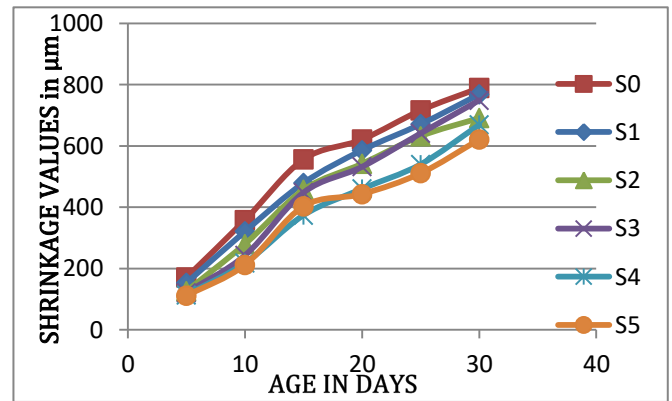


Chart - 4: Shrinkage values of SCM at different ages.

### 3. CONCLUSIONS

- SCM mixes can be achieved with replacement of GGBFS and Granite powder with Cement and M-sand respectively along with suitable SP dosages.
- The highest compressive strength of Conventional mortar mixes obtained with the 15% replacement of Granite powder with M-sand.
- In general as percentage of Mineral admixture increases the demand for super plasticizer also increases.
- The flowability of SCM mixes increases with increasing the amount of GGBFS replacement with cement.
- The flowability of SCM mixes decreases with increasing the amount of Granite powder replacement with M-sand.
- The Compressive strength of other SCM mixes increases with increasing amount of GGBFS and Granite Powder upto 40% replacement of GGBFS with cement.
- The SCM mix (S0) showed the lowest compressive strength of 46.73 MPa at 28 days.
- The SCM mix (S4) showed the highest compressive strength of 53.5 MPa at 28 days.
- Flexure strength of reference SCM mix (S0) is less when compared to that of conventional or nominal cement mortar (NCM).
- The Flexure strength of SCM mixes increases as the amount of GGBFS and Granite powder increases.
- The SCM mix (S0) showed the lowest Flexure strength of 8.33 MPa at 28 days.
- The SCM mix (S4) showed the highest Flexure strength of 10.02 MPa at 28 days.
- SCM mix S<sub>0</sub> shows highest shrinkage of 789 µm whereas SCM mix S<sub>5</sub> shows lowest shrinkage of 621 µm.
- As the content of GGBFS and Granite powder replacement with cement and M-sand increases drying shrinkage decreases.
- The difference in shrinkage values of SCM mix

increases as the age increases.

- The mineral additives viz. GGBFS and Granite powder significantly increased the workability and strength of SCM mixes.

## REFERENCES

- [1] J. Guru Jawahar, C. Sashidhara , I. V. Ramana Reddyb and J. Annie Peter, "Optimization of superplasticiser and viscosity modifying agent in self compacting mortar" (2013)
- [2] López , J.M. Tobes, G. Giaccio, R. Zerbino, "Advantages of mortar-based design for coloured self-compacting concrete" (2009)
- [3] Lidia Radu, Nastasia Saca, Claudiu Mazilu, Maria Gheorghe, Ionela Petre, "Practical model of cement based grout mix design for use into low level radiation waste management" (2015)
- [4] Lim, S.K., Ling, T.C., Hussin, M.W. "Strength properties of self-compacting mortar mixed with GGBFS". (2012)
- [5] Grzegorz Prokopskia , Vitaliy Marchukb , Andriy Huts, "The effect of using granite dust as a component of concrete mixture". (2020)
- [6] Dalibor Kocab<sup>1</sup>, Romana Halamová<sup>1</sup>, and Barbara Kucharczyková<sup>1</sup> , "Determination of the static modulus of elasticity of cement mortars in the early stage of ageing". (2020)
- [7] Efnarc - Specification and Guidelines for Self-Compacting Concrete.
- [8] IS 9103 (1999) - Specifications for Concrete Admixtures [CED: Cement and Concrete]