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Study of Self Compacting Concrete with Wollastonite Mineral Fiber for Standard Grade Concrete

S. Poornima[1*], Elizabath M. John[2]
[1]*M.Tech. Student, Department of Civil Engineering, Indira Gandhi Institute of Engineering & Technology, Kothamangalam, India*
[2]*Assistant Professor, Department of Civil Engineering, Indira Gandhi Institute of Engineering & Technology, Kothamangalam, India*
*Corresponding author: poornima.s001@gmail.com

***Abstract*: The fact that Self Compacting Concrete (SCC) does not require any supplementary compaction to fill in every corner of the structure without compromising with strength and durability makes it much more futuristic and desirable over conventional concrete. Present study highlights the behavioral changes in Self Compacting Concrete (SCC) at macro and mineral levels with the incorporations of Wollastonite Mineral Fiber (WMF). In this study Wollastonite Mineral Fiber (WMF) was incorporated as part replacement of cement in proportions of 0% - 40% with an offset of 10% in Self Compacting Concrete (SCC). After determining different properties of Self Compacting Concrete (SCC) mixes such as workability investigated in fresh state while mechanical properties including compressive strength, flexural strength and tensile strength were studied in hardened states, it compared with properties of conventional concrete such as workability in fresh stage and mechanical properties including compressive strength, flexural strength and tensile strength in hardened stage.**

***Keywords*: Wollastonite mineral fiber, Self-compacting concrete, Fresh property, Hardened properties.**

1. Introduction

Wollastonite is a naturally occurring, easily available, acicular, inert, white mineral of high elastic modulus and its fibers are less expensive than steel or carbon mineral-fibers. Fibers introduction into the concrete was never thought of for a self -compacting one because the inherent nature of fibers makes the flow of concrete apparently impossible. Over the period of time, researchers have pursued studies on Self Compacting Concrete (SCC) mixes using variety of mineral admixtures to evaluate the performance of Self Compacting Concrete (SCC) mixes. SCC in the past has been finding applications for structures having dense or congested reinforcements. During repair of concrete once the concrete is laid, it needs to be compacted properly to fill in the place and provide better bonding with existing pavement. This could be easily achieved by Self Compacting Concrete (SCC) mix owing to its self-flowing property. The objective of this study was to study the behavior and performance of Self Compacting Concrete (SCC) mix having wollastonite mineral-fiber (WMF) as a partial replacement of cement.

Ordinary fibers can't be used in concrete because they reduce the self-compacting ability of concrete. Hence it was decided to use mineral-fibers. Wollastonite mineral fibers (WMF) has been found to effect the matrix pore structure and enhance the ductility, compressive strength as well as flexural strength of concrete. Self-Compacting Concrete (SCC) as the name suggest is a concrete which does not required any external compaction and fills in the formwork by virtue of its self-flowing behavior. This property makes its application widely acceptable in structures with congested reinforcements where compaction otherwise would be a strenuous task.

The drawback of Self Compacting Concrete (SCC) is its higher cost when compared with conventional concrete due to involvement of expensive chemical admixture and cement in large quantity. Hence, material engineers are persistently looking for suitable low cost materials. As on today, in general practice, inert and reactive mineral additives are often incorporated as low, medium or high volume aggregate replacements to bring down the cost of Self Compacting Concrete (SCC). Self-Compacting Concrete (SCC) provides a shiny surface, which needs very little finishing. The basic difference from conventional concrete is that Self Compacting Concrete (SCC) has higher amount of super plasticizer; aggregate mixture, proportional in size to provide locking tendency to achieve desired compactness and altered fluid properties to deliver a cohesive mix. This study evaluates compressive strengths and other strength properties of concrete mixes with different proportions of wollastonite as partial substitute of fine aggregate for paving applications.

2. Materials

A. Cement

Ordinary Portland Cement (OPC) Of 43 grade conforming to IS: 8112-1989 was used in this study. Unless a project requires very high strength cement, the use of 43 Grade OPC is generally recommended in general civil construction works. Such as

residential, commercial and industrial structures. It is used in RCC works, preferably where the grade of concrete is up to M40

Fig. 1. Cement

B. Fine aggregate

Fine aggregate used was M-sand for concrete construction. M-sand having fineness modulus 2.68 conforming to grading zone II as per IS 2386 part III.

Fig. 2. M Sand

C. Coarse aggregate

SSC needs to be lean and cohesive at same time, this time requires aggregates to be smaller in size and maintain size proportionally to avoid segregation and bleeding. Coarse aggregate used was 20 mm size and specific gravity 2.67.

Fig. 3. Coarse Aggregate

D. Water

The water used was potable, fresh, colorless, odorless, and tasteless water that is free from organic matter of any type.

E. Wollastonite mineral fiber

Wollastonite is an industrial mineral containing chemicals like calcium, silicon and oxygen. Natural wollastonite may contain traces or minor amounts of various metals like iron, manganese etc. Surface modification enhances its physical properties. Ith also results in improved processing and improved dispersion if implemented in resin. Wollastonite find its plenty of applications which includes valid like ceramics, paints etc. It possesses properties like lower moisture content and oil absorption with low volatile content.

Fig. 4. Wollastonite Mineral Fiber

F. Super plasticizer

Conplast SP430 used as super plasticizer. It provides excellent acceleration of strength gain and early ages and major increases in strength at at all age by significantly reducing water demand in concrete mix. Particularly suitable for precast concrete and other high early strength requirements. Significantly improve the workability of site mixed and precast concrete without increasing water demand. Provide improved durability by increasing ultimate strengths and reducing concrete permeability.

Fig. 5. Super plasticizer

3. Material test results

Tests are conducted to determine physical properties of materials that are cement, coarse aggregate, fine aggregate and WMF. Test results are given in table 1.

4. Concrete mix designation and mix proportion

Six concrete mixes were used in this study. The mix used was M40 with w/c ratio 0.4 and wollastonite microfiber fiber is added as cement replacement. Table 2 presents concrete mix designations. Mix proportion details for the concrete mixes are given in the Table 3.

Table 1
Material test results

Material	Test	Result
Cement	Specific gravity	3.00
	Standard consistency	34 %
	Initial setting time	42 min
	Compressive strength test	64 N/mm2
Coarse aggregate	Specific gravity	2.67
	Percentage air voids	43.52 %
	Bulk density	1.54 g/cc
	Fineness modulus	7.1 %
Fine aggregate	Specific gravity	2.65
	Bulk density	1.55 g/cc
	Fineness modulus	2.68 %
	Percentage air voids	46.15 %
WMF	Specific gravity	2.9

Table 2
Concrete mix designation

Mix Designation	Description
NC	Normal concrete
SC	Self -compacting concrete
SCW1	10% cement replaced by WMF in SCC
SCW2	20% cement replaced by WMF in SCC
SCW3	30% cement replaced by WMF in SCC
SCW4	40% cement replaced by WMF in SCC

Table 3
Concrete mix proportion

Concrete mix	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	water ($liters/m^3$)	cement (kg/m^3)	WMF (kg/m)	Super plasticizer ($liters/m^3$)
NC	1135.27	567.63	199.17	497.93	0	0
SC	1135.27	567.63	199.17	497.93	0	4.98
SCW1	1135.27	567.63	199.17	448.13	49.80	4.98
SCW2	1135.27	567.63	199.17	398.34	99.59	4.98
SCW3	1135.27	567.63	199.17	348.55	149.38	4.98
SCW4	1135.27	567.63	199.17	298.76	199.17	4.98

5. Preparation of test specimen and curing

Experimentation was done on prepared mix of grade M40 with w/c ratio 0.4. Cement and sand are mixed thoroughly and to it aggregates are added and mixed thoroughly and then water is added and mixed thoroughly for making a homogeneous mix. The wollastonite added in percent by the weight of cement used. When cement is partially replaced with wollastonite, cement and wollastonite is thoroughly mixed first. Cubical specimens of 15cm x 15cm x 15cm, beam of 50cm x 10cm x 10cm and cylindrical specimen of 15cm x 30cm were prepared. After placing the mix in the mould it was vibrated and smooth off the surfaces. All the cast specimens were de-moulded after 24 hours and were placed in curing tank for a period of 7, 14 & 28 days. The present investigation mainly studies the behavior of concrete under different proportions of replacement materials. Mainly workability in fresh stage and mechanical properties like compressive strength, tensile strength and flexural strength in hardened stage of the concrete mix is compared.

6. Concrete test results

A. *Fresh property*

1) *Slump test*

The workability or consistency of fresh concrete mixes is measured in the term of slump. Table 4 represents the effect of the addition WMF on workability of concrete mixes.

Table 4
Slump value for concrete mix

Concrete mix	Slump of concrete (mm)
NC	95
SC	115
SCW1	118
SCW2	125
SCW3	120
SCW4	113

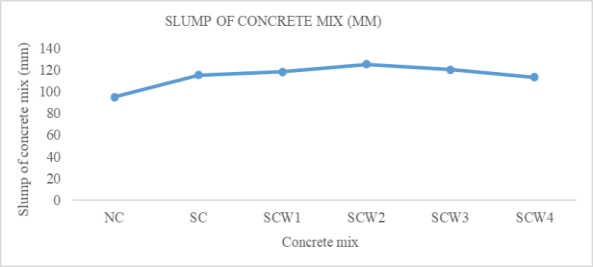

Fig. 6. Slump value for concrete mix

B. *Hardened properties*

1) *Compressive strength*

Test for compressive strength is carried out either on cube or cylinder. Here we used the cube testing. For this cubical mould of size 15cm x 15cm x 15cm are used. The specimens are tested by compression testing machine. The cubes were tested for 7-day strength, 14-day strength and 28-day strength. The compressive strength of concrete mixes is listed in the table 5.

Fig. 7. Specimen loaded to failure in compression

Table 5
Compressive strength of concrete

Concrete mix	Compressive Strength (N/mm^2)		
	7 Days	14 Days	28 Days
NC	28.00	38.10	42.40
SC	29.20	42.80	45.40
SCW1	31.07	43.02	47.80
SCW2	32.57	45.09	50.10
SCW3	34.32	47.52	52.80
SCW4	32.31	43.73	49.70

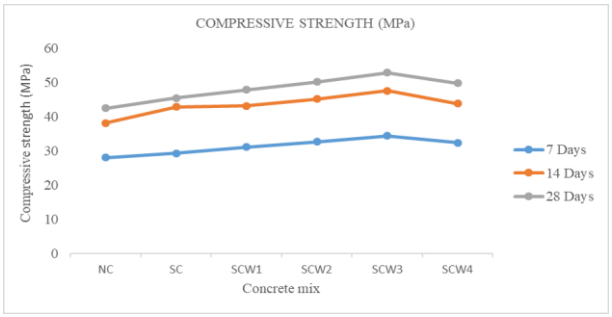

Fig. 6. Compressive strength of concrete

Fig. 10. Flexural strength of concrete

2) Flexural strength

Flexural strength is measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It measured by loading 150 x 150mm concrete beams with a span length at least three times the depth. The flexural strength of concrete mixes is listed in the table 6.

Table 6
Flexural strength of concrete

Concrete mix	Flexural strength (N/mm²)		
	7 Days	14 Days	28 Days
NC	4.70	6.02	6.69
SC	4.86	6.48	7.20
SCW1	4.98	6.80	7.48
SCW2	5.08	7.03	7.81
SCW3	5.33	7.38	8.20
SCW4	5.01	6.91	7.68

Fig. 8. Specimen loaded to failure in flexural strength testing machine

Fig. 9. Crack pattern

3) Tensile strength

Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The mean internal diameter of the mould is 15 cm and the height is 30 cm. Concrete cylinders are casted in this mould and after curing period conducted the tensile strength test. The tensile strength of concrete mixes is listed in the table 7.

Table 7
Tensile strength of concrete

Concrete mix	Tensile Strength (N/mm²)		
	7 Days	14 Days	28 Days
NC	2.67	3.63	3.82
SC	3.10	3.70	4.10
SCW1	3.18	3.82	4.32
SCW2	3.20	4.01	4.61
SCW3	3.27	4.52	5.02
SCW4	2.81	3.97	4.42

Fig. 11. Specimen loaded to failure in tensile strength test

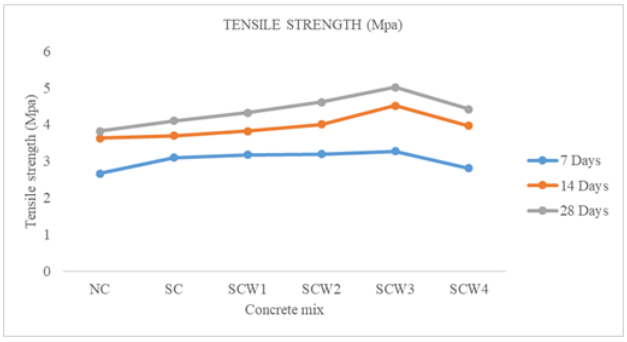

Fig. 12. Tensile strength of concrete

7. Conclusion

Inclusion of Wollastonite Mineral Fiber (WMF) provide better resistance against segregation. It helps to enhance the cohesiveness of Self Compacting Concrete mix. Wollastonite Mineral Fiber (WMF) is a promising material for use in SCC. It gives better result in mechanical properties. The compressive strength, flexural strength and tensile strength of SSC increases as the percentage of Wollastonite Micro Fiber is increased and obtained the maximum value at 30% replacement of cement by Wollastonite Mineral Fiber.

8. Future Scope

Further testing and studies on the Wollastinite micro fiber replacement in concrete are highly recommended to indicate the mechanical properties such as compressive strength, flexural strength & tensile strength. The application of Wollastonite Micro Fiber can be further extended in other types of special concrete such as High performance concrete.

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