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Effect of Wollastonite as Partial Replacement of Cement on Mechanical and Durability Properties of Concrete

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Abstract - *Concrete is durable and efficient binding material which is used for construction. India is second largest producer of cement. About 1.5 tons of raw material is required for every single ton production of cement. In order to reduce the consumption of cement, supplementary cementitious materials are used in concrete production. Wollastonite is one such naturally occurring mineral formed due to interaction of limestone with silica in hot magmas. In the present work, cement is partially replaced by Wollastonite at 0%, 110%, 12%, 14%, 16% and 18% in concrete. The effect of Wollastonite on strength properties of concrete for M30 grade mix is studied. IS 10262 (2019) is used to carry out the Mix Design. Slump and compaction factor are determined to measure workability. For various mixes of concrete, compression and flexural strengths are determined. Durability in terms of chloride and sulphate resistance is determined by immersing the cubes in HCl and MgSO4 solution for 28 days. The obtained results from various combination of mixes are then compared with conventional concrete mix.*

***Key Words*: Concrete, supplementary cementitious material, Wollastonite, workability, compression and flexural strengths.**

1. INTRODUCTION

Concrete is composed mainly of water, aggregate and cement. The second consumed man made material in the world after water is concrete. Cement is an essential ingredient of concrete, which binds aggregates to form strong building material. About 1.5 tons of raw materials are required for every single ton production of cement. It emits 0.8 tons of CO_2 and is responsible for environmental problems. In order to reduce the consumption of cement, supplementary cementitious materials are used in concrete production.

Using supplementary cementitious material and other additives such as admixtures, minerals and fibres have made the research field active during last few decades. Since concrete is weak in tension, it could be overcome by adding metal, mineral or synthetic fibres, but addition of these increases the cost of concrete. To increase the strength and durability properties, partial replacement of Portland cement is done by mineral admixtures such as fly ash, silica fume, metakaolin etc. Wollastonite is one of the materials among the admixtures which have not been investigated in detail.

1.1 Objectives of the Proposed Study

The main objectives of the present study, on the performance characteristics of concrete containing Wollastonite of M30 grade are to investigate the influence of varying percentage of Wollastonite on workability of fresh concrete, compressive strength and flexural strength of hardened concrete and to determine the acid and sulphate resistance of concrete.

2. LITERATURE REVIEW

Wahab et al. (2017)[37]: Investigated the Wollastonite as partial replacement of cement and sand with replacement levels of 10% to 30% with an interval of 10% as prescribed in BS EN 196-1-2016. The tests such as compression, flexural, drying shrinkage and initial setting time were conducted. Due to the incorporation of Wollastonite as 20% sand replacement, the compression and flexural strength were enhanced upto 45% and 28% respectively, which in turn delayed the initial setting time upto 60%. The incorporation of Wollastonite as 30% cement replacement showed reduction in 28 days flexural and compression strength upto 17% and 35% respectively. Drying shrinkage resistance was increased by incorporation of Wollastonite powder.

Dahiphale et al. (2018)[24]: Studied the properties by replacing the cement by Wollastonite upto 30% with w/c of 0.44. The Compression strength was tested for 3, 7 and 28 days. Compression strength increased at 10%, 12.5% and 15% of Wollastonite replacement, which is due to presence of silica in Wollastonite and then there is decrease in strength at higher percentages. It was found that, 15%

replacement of cement by Wollastonite is the optimum percentage from the strength point of view.

Zade et al. (2019)[38]: Investigated the mechanical properties of 20 N/mm^2 concrete grade with replacement levels of cement by 0% to 20% Wollastonite powder with W/C of 0.45. Mechanical tests were conducted for 7, 14 and 28 days. Mechanical strength values observed were increased with the percentage replacement of Wollastonite upto 15% and then it was reduced at 20%. But the strength observed at 20% was not less than the conventional concrete.

3. MATERIALS AND METHODOLOGY

3.1 Materials

Cement: OPC 43 grade conforming to IS 269 (2015).
Wollastonite: (Kemolit LG-25) is procured from Wolkem India Ltd. Udaipur, Rajasthan.
Fine aggregate: Crushed stone sand is used as a fine aggregate, procured from the local quarry.
Coarse aggregates: 20mm down size confirming to IS 383 (2016) obtained from local quarry.
Super plasticizer: 'Conplast SP430', procured from FOSROC Company.
Water: Normal potable water as per IS 456 (2000) is used for both mixing and curing.
Chemicals Used for Durability test: Magnesium Sulphate ($MgSO_4$) Solution and Hydrochloric (HCl) Acid.

Specific gravity of the materials are shown in Table 1.

Table – 1: Specific Gravity of Materials

Sl. No.	Materials	Specific Gravity
1	Cement	3.14
2	Wollastonite	2.9
3	Fine Aggregate	2.46
4	Coarse Aggregate	2.64

3.2 Mix Design

Mix design for M30 grade concrete for varying contents of Cement and Wollastonite is carried out as per IS 10262 (2019) codal provisions. Water cement ratio of 0.44 is used. Various mixes used in the study are tabulated in Table 2.

Table – 2: Mix Identity for M30 grade concrete

Sl. No.	Mix Identity	Content (%)	
		Cement	Wollastonite
1	M0	100	0
2	M10	90	10
3	M12	88	12
4	M14	86	14
5	M16	84	16
6	M18	82	18

3.3 Testing

Slump and Compaction Factor tests are conducted on fresh concrete. Compression and Flexural tests were conducted at 28, 56 and 90 days on strength properties of hardened concrete. Durability properties of hardened concrete were measured in terms of 28 days compressive strength when immersed in $MgSO_4$ and HCl solutions.

4. RESULTS AND DISCUSSION

1. Slump and compaction factor test results are given in Figure 1. From the test results obtained on fresh concrete, workability reduces with increment in Wollastonite % both in terms of slump and compaction factor.

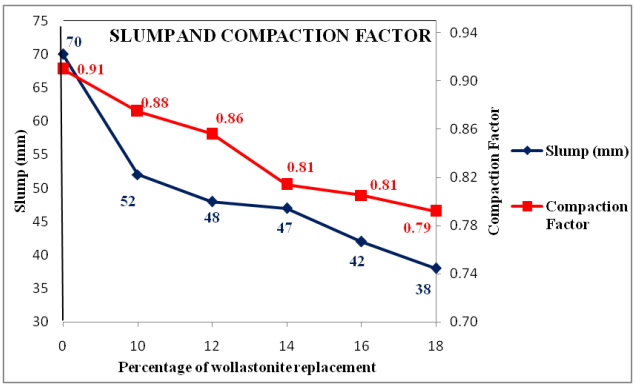

Figure – 1: Variation of Slump and Compaction Factor

2. There is a rise in compressive strength at 10%, 12%, 14% and 16% Wollastonite replacement and at 18% replacement, compressive strength decreases slightly. Maximum compressive strength is observed at 16% Wollastonite replacement. As per the codal provisions of IS 456 (2000), the compression strength has reached the expected strength of 30MPa for all the replacement percentages. The cube compressive strength of concrete mixes at the age of 28, 56 and 84 days results are shown in Figure 2.

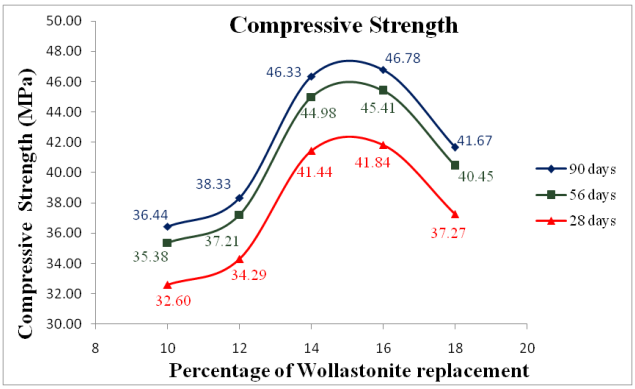

Figure – 2: Compressive strength of concrete

3. There is a rise in flexural strength at 10%, 12%, 14% and 16% Wollastonite replacement and at 18% replacement, flexural strength decreases slightly. Maximum flexural

strength is observed at 16% Wollastonite replacement. As per the codal provisions of IS 456 (2000), the flexural strength has reached the expected strength of 3.83MPa upto 16% replacement. But at 18% replacement flexural strength is found to fall below the expected strength. Flexural strength of concrete mixes at the age of 28, 56 and 84 days when cured in potable water are shown in Figure 3.

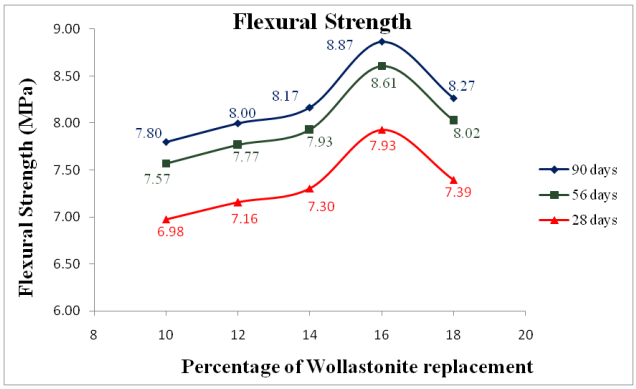

Figure – 3: Flexural strength of concrete

4. There is a rise in compressive strength for 12%, 16% and 18% at 28 days when immersed in both $MgSO_4$ and HCl solutions compared to the normal curing. Peak value observed for $MgSO_4$ and HCl is very near to 16% whereas for water cured specimens it is in between 14% to 16%. All the values of compressive strength observed for durability are above the reference value because of continued hydration before the effects of sulphate and acid attack are manifested. The compressive strength of concrete cubes at 28 days are shown in Figure 4 when immersed in $MgSO_4$ and HCl solutions separately.

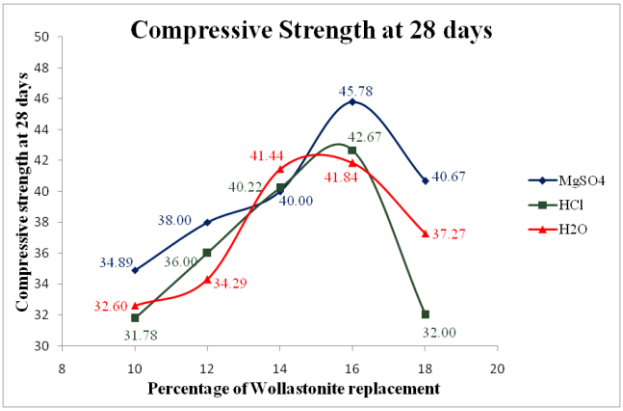

Figure – 4: Compressive strength of concrete at 28 days when immersed in $MgSO_4$ and HCl solutions separately.

5. CONCLUSIONS

The conclusions drawn from the effect of Wollastonite as Partial Replacement of Cement on Mechanical and Durability Properties of Concrete are as follows:

1. The workability of fresh concrete for M30 mix indicates increase in stiffness with increase in percentage of Wollastonite addition.
2. The optimum percentage of Wollastonite addition at which the study indicates maximum compression strength is observed to be in the range of 14 to 16 percent. Maximum increase in compressive strength is 24% of reference mix.
3. Compression strength variation is in agreement with the literature survey of Dahiphale.
4. The optimum percentage of Wollastonite addition at which the study indicates maximum flexural strength is observed to be at 16 percent. Maximum increase in flexural strength is 2% of reference mix.
5. The variation of flexural strength is in agreement with the literature survey given by Wahab.
6. Compression and flexural strength values for various percentage of Wollastonite addition show to satisfy the stipulation as per code.
7. The peak value observed for durability is very near to 16% and is above the reference value. The percentage of increase in compression strength when immersed in $MgSO_4$ and HCl solution with respect to reference mix is 36% and 27% respectively. Hence increases durability properties.
8. The variation of compression strength observed when cubes immersed in sulphate and acid attack are similar with literature survey of Venkatanarayanan. Due to continued hydration there is increase in the initial strength, before the effects of sulphate and acid attack are manifested.

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