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To Study the Strength of Concrete by Adding Wollastonite in It

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Abstract :*In the present year of grace, the most extensively used material in the construction industry is for sure the concrete. One of the main constituent of concrete is cement. And this fact should be one of the main concerns that cement production causes emission of large amount of carbon dioxide gas into the atmosphere and so this exhale of gases further leads to the contribution in the green house effect. So taking this unwell consequence into considersation we have come up with a choice. A choice to cement which is wollastonite. Wollastonite is naturally occurring mineral and is cheaper when compared to cement. So in this project particular we are studying the strength properties of concrete by adding wollastonite in it to some desirable percentage with simultaneously replacing the cement percentage by maintaining W/C ratio. This would further help in reducing cement production and thus the green house effect at some extent.*

I. Introduction:

Concrete is a material which is always there in construction project. The OPC is one of the most important and main ingredient used for the production of good concrete and has no alternative in civil construction. It also has some disadvantages like production of cement involves emission of large amount of carbon dioxide gas into atmosphere which causes global warming and green house effects. The search for any such material which can be used as an alternative or as supplementary for cement should lead to global sustainable development and lowest possible environmental impact. There are so many alternatives which can take place of cement and which also becoming and showing good results with like fly ash, blast furnace slag, rice husk ash. Wollastonite is an extremely interesting but little studied material can also use in concrete to get good strength as wollastonite have too many properties such as it has a low thermal conductivity, it is indispensable and also used in production of heat-insulating ceramics, metallurgy and automobile industry.

Physical Properties OfWollastonite

1. Specific Gravity:

The specific gravity of pure wollastonite (triclinic) can becalculated based on unit parameters to be 2.9 6. Measured specific gravities typically fall in the following range2.87-

3.09.variation is due to trace or minor amounts of various impurity ions such as aluminum,iron, magnes ium, manganese, potassium andsodium, which substitute for calcium and distort the crystal lattice.The specific g ravity of commercial wollastonite products is alsoaffected by the content of impurity minerals such as calcite (s.g. of 2.70-2.95), garnet (s.g. of 3.5-3.8), diopside (s.g. of 3.2-3.3)etc.The specific gravity is relative number that tells how wollastonite compares to water, which has a specific gravity of 1.00. this number is used in proportioning of concrete. As per the results obtained during test the specific gravity of wollastonite was found to be 2.84 which is lighter than Portland cement which has a specific gravity of 3.15. Thus, adding wollastonite to a concrete mixture will not "densify" the concrete in terms of increasing the density of concrete.

2. Bulk Density

Mixing, compounding, storing and shipping ground materials require knowledge of their apparent bulk densities. The bulk density of commercial wollastonite depends primarily on the fineness and aspect ratio, however specific gravity, moisture content and test method can also play a role. The volume weight test consistsof measuring volume of a given weight of material under specified conditions, and then calculating the weight per unit volume. This is done in the "loose" condition and in the tapped condition. Typical bulk densities of wollastonite are as follows:
Loose Bulk Density, 0.20 g/cc to 1.23g/cc.
Tapped Bulk Density, 0.35 g/cc to 1.66g/cc

3. Colour

When pure, the mineral is brilliantly white, but impurities even intrace amounts may color it cream, grey, pink, brown, or red. Thiscolor change is related to the presence of iron and other coloringions. Color may be impacte d by impurities on the crystal surface (deposited by the passag ofground water) or by impurities actually contained in the crystal structure. The luster i s glassy to silky(vitreous to pearly). Lustre is important in applications such as plastics, paints and coatings as it in turn imparts luster to surface finishes.

4. **Brightness**:The dry brightness and whiteness of wollastonite are important indetermining it's suitabilit y for certain filler and ceramicapplications. Brightness is determined bymeasuring thereflectance of finely grou nd powder against a standard that isassigned a brightness of 100. Magnesium oxide and bariumsulphate are the two standards used. G.E. Brightness, a term usedin North America, refers to brightness measured with a Genera lElectric reflectometer. Commercial wollastonite products usually have a G.E. Brightness ranging from 80 to 95 .

5. **Thermal Expansion:** A characteristically low coefficient of thermal expansion combined with aspect ratio, impart high thermal shock resistance and dimensional stability in high temperature applications such as fire resistant board or refractory linings. The coefficient of linear expansion is generally accepted as being 6.5 x 10^{-6} mm/mm/°C.

6. **Chemical Characteristic**

Wollastonite is an industrial mineral comprised chemically of calcium, silicon and oxygen. Its molecular formula is $CaSiO_3$ and its theoretical composition consists of 48.28% CaO and 51.72% SiO_2.

II. Methodology:

A procedure is adopted as follows :

1) Testing of materials –

<u>a) Tests on coarse aggregate -</u>

1) Sieve Analysis:

Particle size distribution influences the physical and chemical properties of solids. Therefore this criterion is of highest importance in the context of science and quality control. Only if the size distribution remains constant, a steady product quality can be guaranteed.The strength of concrete depends on the particle size of the cement.

2) Water absorbsion:

Water absorption is the amount of water taken up by the mixture to achieve the desired consistency or optimal end result. Usually defined based on mixture weight. For example, 60% water absorption would mean 60 lbs of water is required for every 100 lbs of mixture.

3) Specific gravity

Specific gravity is the ratio of the density of a substance to the density of a reference substance; equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume. Apparent specific gravity is the ratio of the weight of a volume of the substance to the weight of an equal volume of the reference substance. The reference substance is nearly always denseat its densest (4°C) for liquids; for gases it is air at room temperature (21°C). The temperature and pressure must be specified for both the sample and the reference.

4) Flakiness and elongation index test(thickness gauge):The particle shape of aggregates is determined by the % of flaky and elongated particles contained in it. The angularity number that is, flaky and elongation has considerable importance in the gradation requirements of various types of mixes such as bituminous ,cement concrete and soil aggregate mixes.

i) Flakiness index: The flakiness index of aggregates is the % by weight of particles whose least dimension is less than three-fifths(0.6)of their mean dimensions. The test is not applicable to sizes smaller than 6.3mm .the apparatus consist of standard thickness gauge of IS sieve sizes 63,50,40,3.15,25,20,16,12.5,10, &6.3 mm and a balance to weigh the samples.

ii) Elongation index

The elongation index of aggregate is the % by weight of particles whose greatest diamension is greater than one and four fifth times(1.8) their mean diamenions . The elongation test is not applicable to the sizes smaller than 6.3mm. the apparatus consist of standard length gauge of IS sieve sizes 50,40,31.5,25,20,16,12.5,10,&6.3.

5) This test is done to determine the aggregate impact value of coarse aggregates as per IS: 2386 (Part IV) – 1963. The apparatus used for determining aggregate impact value of coarse aggregates. Impact testing machine conforming to IS: 2386 (Part IV)- 1963,IS Sieves of sizes – 12.5mm, 10mm and 2.36mm, A cylindrical metal measure of 75mm dia. and 50mm depth, A tamping rod of 10mm circular cross section and 230mm length, rounded at one end and Oven.Preparation of Sample
i) The test sample should conform to the following grading:

–Passing through 12.5mm IS Sieve –100%.

– Retention on 10mm IS Sieve – 100%

ii) The sample should be oven-dried for 4hrs. At a temperature of 100 to 110^{o}C and cooled.

iii) The measure should be about one-third full with the prepared aggregates and tamped with 25 strokes of the tamping rod.

Impact value test result of aggregate passing through 12.5 mm sieve and retaining on 10mm sieve was found to be 7.2% hence the aggregates are exceptionally strong.

6) Crushing value test of aggregate passing through 12.5 mm sieve and 10 mm sieve should be less than 10% for exceptionally strong aggregate as per IS :283-1970.

7) Abrasion test by Los Angeles apparatus:
Abrasion value of the aggregate is found to be 25.8% which is suitable for construction.

b) Tests on fine aggregate:

1) Bulking of Sand:

The increase in moisture of sand increases the volume of sand. The reason is that moisture causes film of water around sand particles which results in the increase of volume of sand.

The bulking of sand observed to be 7.5% . Permissible limit for bulking of sand for 2% of water content is 15%.

2) Specific gravity of sand :

The specific gravity of sand is found to be 2.6 and water absorption is found to be 2%.

c) Tests on cement:

1) Colour of cement found was preferable. Cement should not contain lumps. Float test gave good results. Hence the quality of cement is good and preferable.

2) Fineness test on cement:

By performing fineness test, it found the 10% residue remained on the sieve no. 9 i.e 90micron which is desirable.

3) Consistency , initial and final setting time:

- The normal consistency for tested cement is found to be 40%.
- As per IS:8112,1989 – initial setting time for OPC 43 grade cement is 30 minutes.
- Final setting time for OPC 43 grade cement is 10 hours.

4) Soundness of cement :

As per IS requirement the distance between two pointers and after heating should not differ more than 10mm for all 33, 43, and 53 cement.

5) Compressive strength of a cement mortar cubes (7.06cm*7.06cm*7.06cm)
for 43 grade of cement should be 23 N/mm sq for 3 days, 33 N/mm sq for 7 days and 43 N/mm sq for 28 days.

2) Mix design

For this study, M20 grade of concrete was used. The quantities of materials used for w/c ratio worked out.

Mix design of concrete using wollastonite as a partial replacement of OPC.

Mix proportion for Cube (M20):-

a) Grade of concrete :- M20

b) Mix proportion :- 1:1.5:3 (1+1.5+3 =5.5)

c) Volume of concrete = 0.15 x 0.15 x 0.15
$= 3.375 \times 10^{-3} m^3$.

d) Dry volume of concrete = $1.52 \times 3.375 \times 10^{-3}$
$= 5.13 \times 10^{-3} m^3$.

e) Volume of cement = $\frac{5.13 \times 10^{-3}}{5.5} \times 1$
$= 9.327 \times 10^{-4} m^3$.

f) Volume of fine aggregate = $\frac{5.13 \times 10^{-3}}{5.5} \times 1.5$
$= 1.39 \times 10^{-3} m^3$.

g) Volume of coarse aggregate = $\frac{5.13 \times 10^{-3}}{5.5} \times 3$
$= 2.798 \times 10^{-3} m^3$.

Cement required = $9.327 \times 10^{-4} \times 1440$
= 1.34 kg
Fine aggregate = $1.39 \times 10^{-3} \times 1600$
= 2.224 kg
Coarse aggregate = $2.798 \times 10^{-3} \times 1560$
= 4.36 kg

For 9 Cubes:
Cement = 1.34 x 9 = 12.06 kg
Fine aggregate = 2.224 x 9 = 20.016 kg
Coarse aggregate = 4.36 x 9 = 39.24 kg
Water = 5.427 lit.
Wollastonite for 10% = 1.206 kg
Wollastonite for 15% = 1.809 kg
Wollastonite for 20% = 2.412 kg

Mix proportion for Beam (M20):-

a) Grade of concrete :- M20
b) Mix proportion :- 1:1.5:3 (1+1.5+3 =5.5)
c) Volume of concrete = 0.5 x 0.1 x 0.1
= 5×10^{-3} m^3.
d) Dry volume of concrete = $1.52 \times 5 \times 10^{-3}$
= 7.6×10^{-3} m^3 .
e) Volume of cement = $\frac{7.6 \times 10^{-3}}{5.5} \times 1$
= 13.81×10^{-4} m^3.
f) Volume of fine aggregate = $\frac{7.6 \times 10^{-3}}{5.5} \times 1.5$
= 2.07×10^{-3} m^3.
g) Volume of coarse aggregate = $\frac{7.6 \times 10^{-3}}{5.5} \times 3$
= 4.145×10^{-3} m^3.

Cement required = $13.81 \times 10^{-4} \times 1440$
= 1.988 kg
Fine aggregate = $2.07 \times 10^{-3} \times 1600$
= 3.312 kg
Coarse aggregate = 6.466 kg

For 9 Beams:
Cement = 1.988 x 9 = 17.89 kg
Fine aggregate = 3.312 x 9 = 29.80 kg
Coarse aggregate = 6.466 x 9 = 40.19 kg
Water = 8.05 lit.
Wollastonite for 10% = 1.789 kg
Wollastonite for 15% = 2.683 kg
Wollastonite for 20% = 3.578 kg

Mix proportion for Cylinder (M20):-

a) Grade of concrete :- M20
b) Mix proportion :- 1:1.5:3 (1+1.5+3 =5.5)
c) Volume of concrete = $\pi/4 \times 0.15^2 \times 0.3$
= 5.301×10^{-3} m^3.
d) Dry volume of concrete = $1.52 \times 5.301 \times 10^{-3}$
= 8.058×10^{-3} m^3 .
e) Volume of cement = $\frac{8.058 \times 10^{-3}}{5.5} \times 1$
= 1.465×10^{-4} m^3.
f) Volume of fine aggregate = $\frac{8.058 \times 10^{-3}}{5.5} \times 1.5$

$= 2.197 \times 10^{-3}\,m^3$.

g) Volume of coarse aggregate = $\frac{8.058 \times 10^{-3}}{5.5} \times 3$

$= 4.395 \times 10^{-3}\,m^3$.

Cement required = $1.465 \times 10^{-3} \times 1440$

= 2.109 kg

Fine aggregate = $2.197 \times 10^{-3} \times 1600$

= 3.5152 kg

Coarse aggregate = 6.856 kg

For 9 Cylinder:

Cement = 2.109 x 9= 18.981 kg

Fine aggregate = 3.512 x 9 = 31.608 kg

Coarse aggregate = 6.856 x 9 = 61.704 kg

Water = 8.54 lit.

Wollastonite for 10% = 1.89 kg

Wollastonite for 15% = 2.84 kg

Wollastonite for 20% = 3.79 kg

3) **MIXING**

Thorough mixing of the material is essential for production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in color and consistency. There are two methods adopted for mixing concrete:

1. Hand mixing
2. Machine mixing

Machine mixing is not only efficient, but also economical when the quantity of concrete to be produced is large. Mixers can be classified as batch-mixers and continuous mixers. Batch mixers produce concrete continuously without stoppage. Therefore, we have adopted machine mixing in our experimental investigation. Mixing of the ingredients was done in laboratory batch mixer with a mixing capacity of 35 liter.

Following procedure was adopted for ingredients

1. Dry mixing of the cement and aggregates was done for a minute.
2. Wollastonite powder were added gradually and further dry mixing was done for a minute.
3. Water was added gradually to the dry mix and the final mixing for a duration of 4 min to ensure that the resulting concrete is uniform in appearance an cohesive along with uniform distribution of powder throughout concrete. Thus the total time of mixing was 6 minutes.

4) Casting of cubes and beams

Compaction is the process adopted for expelling the entrapped air from the concrete. If the air is not remove fully , the concrete losses strength considerably. The following methods are adopted for compaction.

1 – Hand compaction.

2- Compaction by vibration

Casting and compaction of the concrete specimen was done according to IS : 516-1959. Metallic moulds in the shape of cubes and cylinder with the accurate required dimension were used for the purpose of casting. In assembling the mould for use, the joints between the sections of moulds were thinly coated with oil and a similar coating of oil shall was applied between the contact surfaces of the bottom of the mould and the base plate in the order to insure that no water escape during the filling. The interior surfaces of the assembled mould were thinly coated with oil to prevent adhesion of the concrete.

Concrete was filled into the mould in three layers, approximately 5 cm deep and the compaction of each layer was done using table vibrator. After the top layer was compacted the surface of the concrete is brought to the finished level with the top of the mould, using a trovel. Then, test specimens were stored in a place free from vibration at the room temperature of $27^o \pm 2^o$ C for a period of 24 hrs form the time of addition of water to the dry ingredients. After this period the specimens were marked and removed from the moulds. Then the specimens were immediately submerged in clean fresh water for the purpose of curing and kept there until taken out just prior to test.

5) Curing

Curing is the process of preventing the loss of moisture from concrete while maintaining a satisfactory temperature. More elaborately, curing is defined as process of maintaining satisfactory moisture content and favorable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement at service. Curing of the test specimen was done according to IS: 516-1959 by immersion in curing tanks.

6) Testing of cubes and beams

SLUMP TEST:

According to IS:1199-1959,workability is defined as the property of concrete which determines the amount of useful internal work necessary to produce complete compaction. For determining the workability of concrete slump test was adopted. Slump test is the most commonly used method for measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch. Slump test was conducted according toIS:1199-1959.

The mould for the test specimen shall be in the form of the frustum of a cone having the following internal dimensions:

Bottom diameter=20cm
Top diameter=10cm
Height=30cm

Compressive Strength Of Concrete:

The compressive strength of any material is defined as the resistance to failure under the action of compressive forces. Especially for concrete, compressive strength is an important parameter to determine the performance of the material during service conditions. Concrete mix can be designed or proportioned to obtain the required strengthanddurabilitypropertiesasrequireby the design engineer. The concrete specimens are casted and tested under the action of compressive strength of concrete. In simple words, compressive strength is calculated by dividing the failure load with the area of application of load, usually after 7,14and 28 days of curing. The strength of concrete is controlled by the proportioning of cement, coarse and fine aggregates, water and various % wollastonite powder. The ratio of the water to cement is the chief factor for determining concrete strength. The lower the water cement ratio, higher is the compressive strength.

Note: Minimum 3 specimens should be tested at each selected age. If strength of any specimen varies by more than 15% of average strength, results of such specimen should be rejected.

Flexural Strength On Concrete:

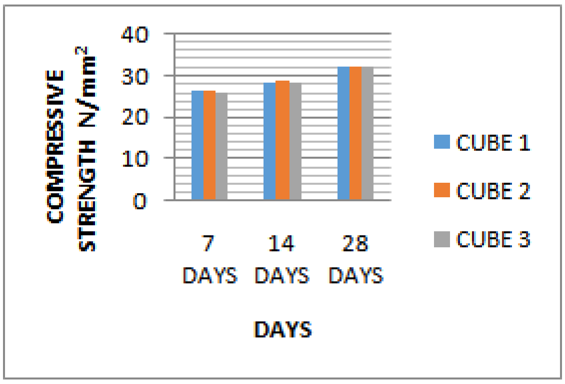
The specimen of standard beam size (500mm x 100mm x 100mm) was used to determine flexural strength of concrete. Three specimen were tested for 7, 14 and 28 days for various proportion of wollastonite content. Total 27 cubes were casted for flexural strength test. The material was weighed and the material was mixed in a electrical mixture. The w/c ratio adopted was 0.45. The concrete was filled in different layer and each layer was compacted. The specimen was removed from mould after 24 hours, cured in clean water for 7,14 and 28 days and then tested for flexural strength as per IS: 516-1959. The temperature of the cured water and the test room was 27 ± 2^{o} C. The materials for each batch of moulds mixed separately using quantities of dry materials, confirming to the proportion and the quantity of water was determined. The result of the flexural strength test for all concrete mixes after 7,14 and 28 days curing were determined and presented in table and flexural strength of concrete containing various percentage of wollastonite was studied. Conventional concrete strength was compared with strength of concrete containing different amount 10%, 15%, 20% of wollastonite that partially replaced by cement by its weight.

III. Results

Effect of wollastonite powder on compressive and flexural strength of concrete. The result of compressive and flexural strength tests using wollastonitepowder in varying percentages (i.e 0%, 10%, 15%& 20%) as partial replacement of cement at moist curing ages of 7, 14 and 28 days are represented in the table and are plotted in figures which show the variations of compressive and flexural strength of concrete with different replacement level of wollastonite powder and at various ages of moist curing.

For Conventional Concrete in MPa:

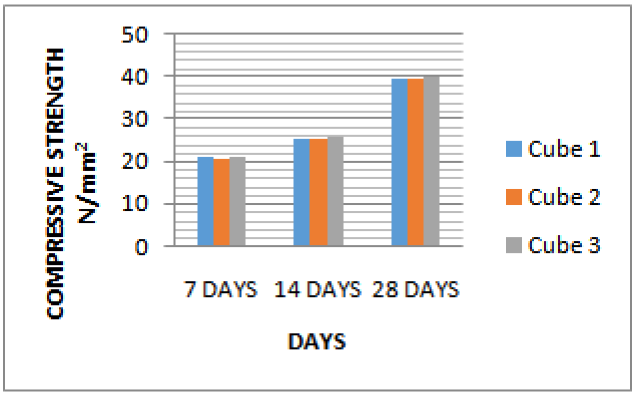
S. No.	7 Days	14 Days	28 Days
1	26.59	28.59	32.49
2	26.65	28.70	32.26
3	26.44	28.65	32.32



GRAPH NO. 1: Comparison of compressive strength for different cubes of conventional concrete at various days

Cubes of 10% Wollastonite and 90% Cement in MPa:

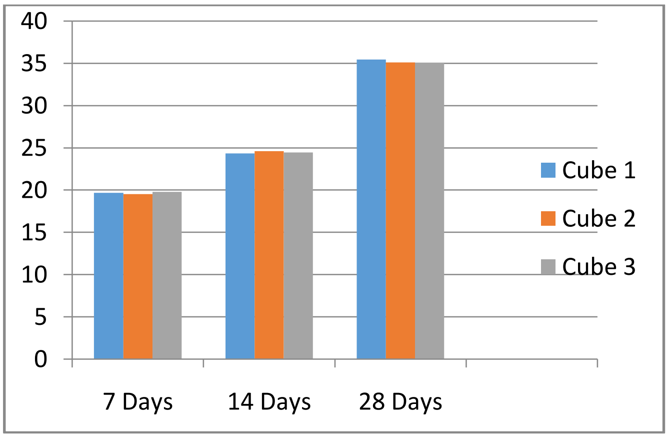
S. No.	7 Days	14 Days	28 Days
1	20.75	25.42	39.67
2	20.63	25.34	39.73
3	20.89	25.57	39.84



GRAPH NO. 2: Comparison of compressive strength of 10% wollastonite concrete cubes atvarious days

Cubes of 15% Wollastonite and 85% Cement in MPa:

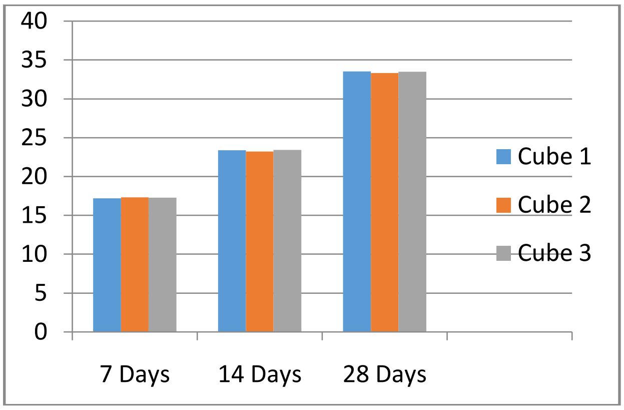
S. No.	7 Days	14 Days	28 Days
1	19.69	24.36	35.35
2	19.54	24.59	35.12
3	19.78	24.45	35.07



GRAPH NO. 3: Comparison of compressive strength of 15% wollastonite concrete cubes at various days

Cubes of 20% Wollastonite and 80% Cement in MPa:

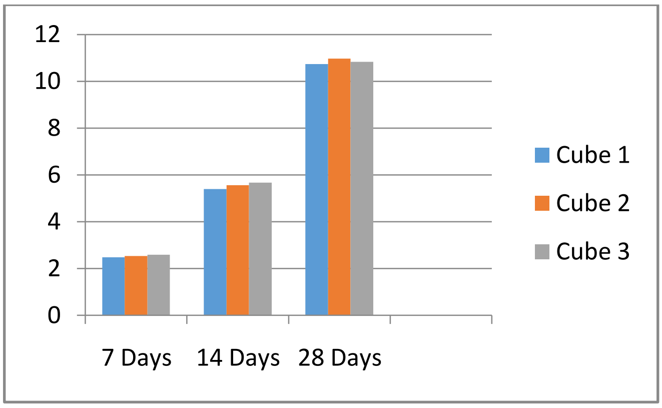
S. No.	7 Days	14 Days	28 Days
1	17.18	23.38	33.52
2	17.30	23.23	33.31
3	17.29	23.42	33.49



GRAPH NO. 4: Comparison of compressive strength of 20% wollastonite concrete cube at various days

8.2.2 Test result for Beam in Mpa:
Beams of10% Wollastonite and 90% Cement

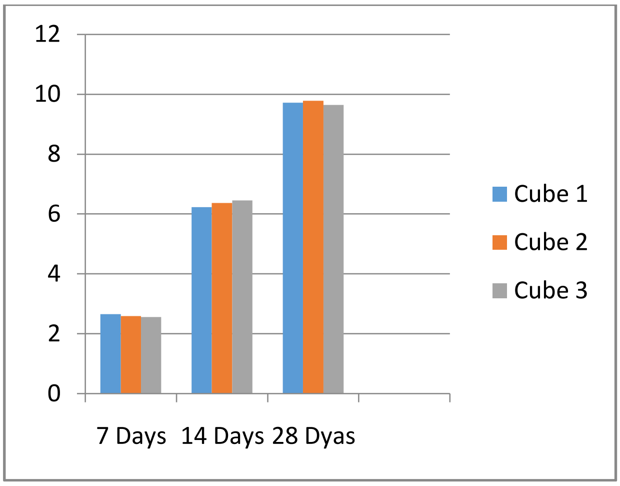
S. No.	7 Days	14 Days	28 Days
1	2.48	5.40	10.74
2	2.54	5.56	10.97
3	2.59	5.67	10.83



GRAPH NO. 5: Comparison of compressive strength of 10% wollastonite concrete beam at various days

Beams of 15% Wollastonite and 85% Cement in MPa:

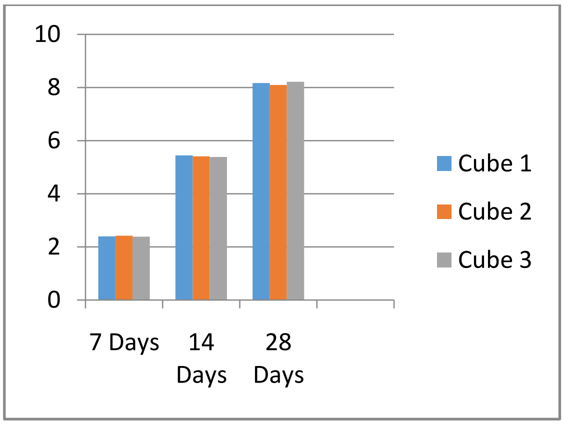
S. No.	7 Days	14 Days	28 Days
1	2.65	6.23	9.72
2	2.59	6.37	9.78
3	2.56	6.46	9.65



GRAPH NO. 6: Comparison of compressive strength of 15% wollastonite concrete beam at various days

Beams of 20% Wollastonite and 80% Cement in MPa:

S. No.	7 Days	14 Days	28 Days
1	2.4	5.45	8.17
2	2.42	5.41	8.10
3	2.38	5.38	8.22



GRAPH NO. 7: Comparison of compressive strength of 20% wollastonite concrete beam at various days

IV. Conclusion

- Due to use of wollastonite powder as an replacement, water cement ratio decreases with increase in its proportion.
- The cost of the structure can be reduce if the wollastonite is used as partial replacement of cement due to its low cost than cement.
- Hence the use of wollastonite acts as a sustainable material, which can be used in green building concept.

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