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Effect of Wollastonite, Flyash and Silica Fume on Strength of Concrete

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INTRODUCTION

Concrete is a composite material made essentially out of cement, aggregate and water. Cement is a mimicked material in which the aggregates both fine and coarse are strengthened together by the solid when blended with water. It is a for the most part used improvement material as a result of its essential reliability and quality.

Enthusiasm for the field of establishment headway has extended for the most part as a result of creating economy. Enormous measure of concrete is being used for building system including dams, ranges, submerged structures, roads and structures. Advancement industry spends a colossal measure of money on strong structures every year and these structures rot at a pre-created arrange on account of their poor whole deal sensibility. It is assessed that a liberal offer of the utilization being developed industry is spent on repair, upkeep and reclamation of existing structures.

With the movement of advancement and extended field of employments of cement and mortars, the quality, workability, strength and diverse properties of the typical strong need acclimations to make it sensible for testing necessities for improvement condition. Concrete has limitless open entryways for imaginative applications, layout and advancement frameworks. It shows magnificent versatility and relative economy in filling broad assortment of necessities which by various means has been made itself as forceful building material.

Portland cement is the key settling in concrete and it is considered as a champion among the most basic establishment building materials around the world. Portland cement era is joined by the release of carbon dioxide as a by-thing, which is huge concern worldwide and is a fundamental figure the "green house" affect.

There is a need to fight the growing cost and lack of cement with alternative materials. Thusly, researchers have been mulling over to improve the mechanical properties of concrete by joining of supplementary cementitious materials.

Under these conditions the use of supplementary cementitious materials with pozzolanic credits is seen to be and the use of pozzolanic materials in cement concrete cleared a response for

- Modifying the properties of the strong basic differentiating alternative to supplant broad degree of cement in concrete.
- Controlling the strong creation cost
- To overcome the lack of cement
- The money related gainful exchange of current misuses

With the expansive usage of cement in concrete, there has been some regular stresses the extent that mischief brought on by the extraction of unrefined material and CO2 radiation in the midst of solid make. This has conveyed weights to diminish the cement use in the strong. Meanwhile, there is a need for development in strong durability to deal with the changing condition which is clearly novel in connection to the long time past days.

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POZZOLANIC MATERIAL

Pozzolanic material is a siliceous and aluminous material which in itself possesses little or no cementitious value, but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitiousproperties.When siliceous and aluminous material reacts with calcium hydroxide, resulting reduction in calcium hydroxide content, in addition they form strength contributing cementitious products which can be termed as ''Pozzolanic Reaction''.

Examples for PozzolanicmaterialareMetakaolin, Flyash, Silica fume, Rice husk ash, GGBS.

POZZOLANIC REACTION

It will be assumed that all pozzolanic reactions are lime reactions with siliceous pozzolanic materials. Reactions with aluminous pozzolanic materials will be briefly considered below. The dominate hydration product of Portland cement is C-S-H (Calcium Silicate Hydrate). If it is assumed that the reaction of Pozzolana and lime produces the same hydration products as cement consider the following reaction:

$$3\,[Ca(OH)_2]\ +2\,[SiO_2] \rightarrow [\,3(CaO)\,2(SiO_2)\,3(H_2O)\,]$$

(Calcium Silicate Hydrate)

In contrast to siliceous reactions, pozzolanic reactions could be between lime and aluminiouspozzolanic materials. The dominate hydration product of Portland cement is C-A-H (Calcium Aluminate Hydrate).

$$3\,[Ca(OH)_2]\ +\ Al_2O_3 + 3\,[H_2O] \rightarrow [\,3(CaO)Al_2O_3\,6(H_2O)\,]$$

(Calcium Aluminate Hydrate)

TYPES OF CEMENT REPLACEMENT MATERIALS

The cement replacement materials that are used in this study are:

- Wollastonite
- Silica Fume
- Fly Ash

WOLLASTONITE

Wollastonite is a naturally occuring mineral named in honor of English mineralogist and chemist Sir W.H. Wollaston (1766–1828). Wollastonite is a calcium meta-silicate (CaSiO3) mineral with particles similar to cement particles by size. Wollastonite has chemical composition of 48.3% CaO and 51.7% SiO2. Although much wollastonite is relatively pure CaSiO3, it can contain some iron, magnesium, manganese, aluminum, potassium, sodium, or strontium substituting for calcium in the mineral structure. Pure wollastonite is bright white in colour, but the presence of type and amount of impurities can produce grey, cream, brown, pale-green, or red colour.

Fig 1 Wollastonite mineral

Wollastonite is formed by two processes. The first occurs when silica and limestone are raised to a temperature of 400°–450°C, either because of deep burial (regional metamorphism) or by being baked because of their proximity to an igneous intrusion, forming wollastonite and giving off carbon dioxide.

$$SiO_2 + CaCO_3 = CaSiO_3 + CO_2$$

(silica) (calcium carbonate) (wollastonite) (carbon dioxide)

The second way wollastonite form is by direct crystallization from molten rock (magma) that is unusually high in carbon content. The origin of these magmas occurs in the lower crust and upper mantle. The rocks they form, called carbonatites, are scattered in Rajasthan and Tamil Nadu states of India.

Table 1 Physical properties of wollastonite

Appearance	White
Molecular Weight	116
Specific Gravity	2.9
pH (10% Slurry)	9.9
Water Solubility (g/100cc)	0.0095
Density (lbs./cu.ft.)	181
Mohs Hardness	4.5
Coefficient of Expansion (mm/mm/°C)	6.5×10^{-6}
Melting Point (°C) – theoretical	1540

Wollastonite primarily consists of calcium oxide and silicon dioxide. Apart from these, there may be a presence of aluminum oxide, iron oxide, magnesium oxide, sodium and potassium oxides in the following proportions as shown in Table 2.

Table 2 Chemical composition of wollastonite

Material	Composition (%)
CaO	45-48
SiO_2	47-52
Al_2O_3	3-5
Fe_2O_3	1-3
MgO	3-4
Na_2O	0.08
K_2O	0.51

The calcium oxide present in the wollastonite mineral reacts with water to form calcium hydroxide. The calcium hydroxide reacts with silicon dioxide to form Calcium Silicate Hydrate (C-S-H) gel.

$$CaO + H_2O = Ca(OH)_2$$

$$Ca(OH)_2 + SiO2 = \text{C-S-H (Calcium Silicate Hydrate)}$$

SILICA FUME:

Silica fume (SF) is a by-result of the purifying procedure in the silicon and ferrosilicon industry. The lessening of high-immaculateness quartz to silicon at temperatures up to 20000C produces Silica vapors, which oxidizes and gather in the low temperature zone to modest particles comprising of non-crystalline silica. By-results of the creation of silicon metal and the ferrosilicon amalgams having silicon substance of at least 75% contain 85–95% non-crystalline silica. The by-result of the generation of ferrosilicon composite having half silicon has much lower silica content and is less pozzolanic. Along these lines, Silica substance of the Silica Fume is identified with the sort of composite being delivered. Silica smolder is otherwise called small scale silica, consolidated silica fume, volatilized silica or silica clean. The American solid organization (ACI) characterizes Silica Fume as a "fine non crystalline silica delivered in electric circular segment heaters as a by-result of creation of essential silicon or combinations containing silicon". It is normally a dark shaded powder, to some degree like Portland concrete or some fly slag. It would exhibit be able to both pozzolanic also, cementitious properties.

Fig 2 Silica fume

FLY ASH:

Fly ash remains is a by-result of the ignition of pounded coal in warm power plants. The clean gathering framework evacuates the fly powder as a fine particulate deposit from the ignition gasses before they are released into the environment. Fly ash remains particles are normally round, going in breadth from1µm up to 150 µm. The kind of tidy gathering gear utilized to a great extent decides the scope of molecule sizes in any given fly powder. The fly powder from boilers at some more established plants utilizing mechanical gatherers alone is

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coarser than from plants utilizing electrostatic precipitators. The sorts and relative measures of incombustible matter in the coal utilized decide the concoction structure of fly ash debris. Over 85% of most fly slag involve synthetic mixes and glasses framed from the components silicon, aluminum, iron, calcium and magnesium.

Fig 3 Fly ash

MATERIALS USED

CEMENT

In this work ULTRATECH cement of 53 grade was utilized for all solid blends. The cement was of uniform shading i.e. dark with a light greenish shade and was free from any hard knots. The different tests directed on concrete are introductory and last setting time, particular gravity, fineness and compressive quality and so forth.

WOLLASTONITE, FLY ASH AND SILICA FUME:

Wollastonite, fly ash and silica fume are used as cement replacement materials in the present study. Wollastonite is obtained from Royalty Minerals, Mumbai. Fly ash is obtained from Raichur Thermal Power Plant which is a class F fly ash. Silica Fume is obtained from Astra Chemicals, Chennai.

COARSEAGGREGATE

Locally available coarse aggregates having the maximum size of 20mm were used in the present work. Testing on coarse aggregates was done as per IS: 383-1970[24]. The results of various tests conducted on coarse aggregate are given in Table 6 and Table 7.

Table 6 Physical properties of coarse aggregate

Properties	Value
Type	Crushed
Maximum size	20 mm
Specific gravity (20 mm)	2.81
Fineness modulus (20	6.19

Table 7 Sieve analysis of 20 mm aggregates

I.S. Sieve Size	Weight retained in grams	Percentage weight retained	Cumulative percentage of weight retained	Percentage passing
40 mm	0	0	0	100
31.5 mm	58	0.58	0.58	99.42
25 mm	5616	56.16	56.74	43.26
20 mm	2273	22.73	79.47	20.53
16 mm	1224	12.24	91.71	8.29
12.5 mm	382	3.82	95.53	4.47
10 mm	343	3.43	97.96	2.04
6.3 mm	101	1.01	99.97	0.03
4.75 mm	3	0.03	100	0
			$\sum = 621.96$	

Fineness Modulus of Coarse aggregate (20mm) = 622/100 =6.22

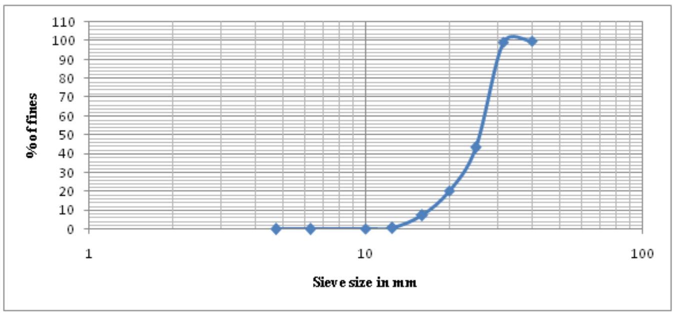

Fig 4 Semi log graph of Coarse Aggregate

FINE AGGREGATE

The sand used for the experimental programme was locally procured and conformed to grading zone II as per IS: 383-1970.The sand was sieved through 4.75 mm IS sieve. Physical properties and sieve analysis results of fine aggregates are listed in Table 8 and Table 9 respectively.

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Table 8 Physical properties of fine aggregates

Properties	Value
Type	Uncrushed(natural)
Specific gravity	2.65
Fineness modulus	3.21
Grading zone	ZoneII

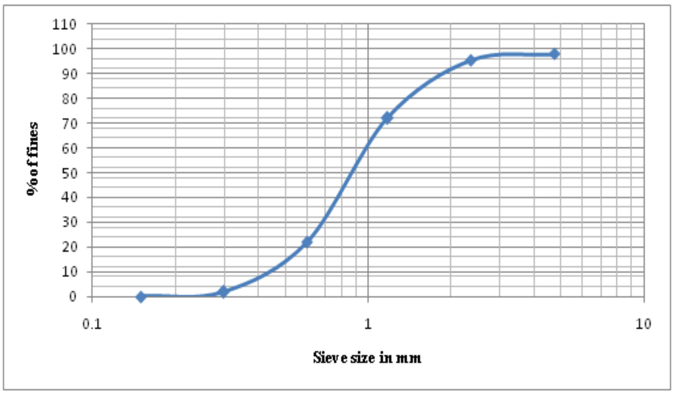
Total weight taken =1000gms
Fineness Modulus offineaggregate=ΣF/100 =322/100 =3.22

Table 9 Sieve analysis of fine aggregate

I.S. Sieve Size	Weight retained in grams	Percentage weight retained ingrams	Cumulative percentageof weight	Percentage passing	IS: 383-1970 Requirement forZoneII
4.75mm	20	2.0	2	98	90-100
2.36mm	25	2.5	4.5	95.5	75-100
1.18mm	285	28.5	33	67	55-90
600µm	499	49.9	82.9	17.1	35-59
300µm	154	15.4	98.3	1.7	8-30
150µm	17	1.7	100	0	0-10
			∑ = 321.70		

Total weight taken =1000gms
Fineness Modulus offineaggregate=ΣF/100 =322/100 =3.22

Fig 5 Semi log graph of fine aggregate



WATER

In this project, casting and curing of specimens were done using potable water which shall be free from deleterious materials. It helps in the hydration of the mix.

COMPACTIING FACTOR TEST

Compacting factor test is based on the definition, that workability is that property of the concrete that determines the amount of work required to produce full compaction. The test consists essentially of applying a standard amount of work to standard quantity of concrete and measuring the resulting compaction as shown in Fig 6.

Figure 6 Compacting Factor apparatus

TESTS CONDUCTEDON STRENGTH PROPERTIES OF CONCRETE

COMPRESSIVESTRENGTH TEST

This test is performed on 150 mm size cube specimens to determine compressive strength of concrete at 28 days curing.

Apparatus: -Compressive Testing Machine (CTM)

The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified. The permissible error shall be not greater than ±2 percent of the maximum load. The testing machine shall be equipped with two steel bearing platens with hardened faces. One of the platens (preferably the one that normally will bear on the upper surface of the specimen) shall be fitted with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the

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platen. The other compression platen shall be plain rigid bearing block. The bearing faces of both platens shall be at least as large as, and preferably larger than the nominal size of the specimen to which the load is applied.

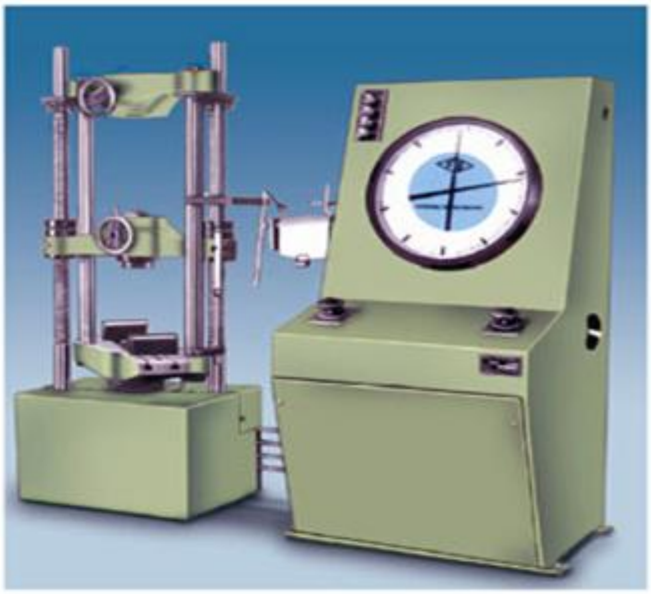

Figure 7 Compressive strength test

Compressive strength of concrete is calculated using following

$$C=\frac{P}{A}$$

WhereP is the maximum load at failure in " N"
A is the area of the Cube specimen in " mm"

Table 13 Calculation of compressive strength of reference mix of M30 grade concrete

S.NO	Load in KN	Average strength in MPa
1	890	40.22
2	920	
3	905	

SPLITTENSILESTRENGTH TEST

This test is conducted on cylinder specimen to evaluate its split tensile strength of concrete at 28 days curing.
Apparatus: - Compressive Testing Machine (CTM)
Compressive Testing Machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified.The permissible error shall be not greater than ±2 percent of the maximum load. The testing machine shall be equipped with two steel bearing platens with hardened faces. One of the platens (preferably the one that normally will bear on the upper surface of the specimen) shall be fitted with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the platen. The other compression platen shall be plain rigid bearing block. The bearing faces of both platens shall be at least as large as, and preferably larger than the nominal size of the specimen to which the load is applied.

Figure 8 Split tensile strength test

Split Tensile Strength of concrete is calculated using following

$$S=\frac{2P}{\pi DL}$$

Where P is the maximum load at failure in N
LandD are the length and diameter of the cylindrical specimen in mm

Table 14Calculation of split tensile strength of reference mix of M30 grade concrete

S.NO	Load in KN	Average strength in MPa
1	190	2.76
2	205	
3	190	

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FLEXURAL STRENGTH TEST

This test is performed on beam specimens to determine Flexural strength of concrete for 28 days curing.

Apparatus: -Universal testing machine (UTM)

The test for flexural strength of concrete beams under middle point loading utilizes a beam testing machine which permits the load to be applied normal to the loaded surface of the beam. The specimen is tested on its side with respect to its moulded position. The beam is centred on the bearing supports. The dial indicator of the proving ring is placed at the zero reading. The load is applied at a uniform rate and in a way to avoid shock. The load required to cause specimen failure is obtained from the dial indicator's final reading.

Figure 9 Flexural strength test

Flexural strength of concrete is calculated using following

$$F = \frac{3Pa}{bd^2} (a > 13.0\text{cm specimen})$$

$$F = \frac{Pl}{bd^2} (a < 13.0\text{cm specimen})$$

Where P is the maximum load at failure in KN.

a is the length of crack in mm.

l is the supported length in mm

b an dd are the breadth and width of the beam specimen in mm.

Table 15 Calculation of flexural strength of reference mix of M30 grade concrete

S.NO	Load in kgf	Value of 'a' in cm	Average strength in MPa
1	1630	13.8	3.2
2	1680	15.5	
3	1620	14.6	

RESULTS AND DISCUSSIONS

COMPRESSIVESTRENGTH

The compressive strength of reference mix (M0) and all other mixes cast using wollastonite, fly ash, silica fume are shown in Table 16.

It was observed that the increase in compressive strength was observed gradually up to 10% replacement of cement by wollastonite and then decreased. The maximum compressive strength 45.38 N/mm2 was obtained with mix (M2) 10% wollastonite which was 13.35% more compared to reference mix. Variation of compressive strength of M30 grade with different percentage replacement of cement by wollastonite is as shown in Figure 10.

Compressive strength of M30 grade were studied with combination of 10% wollastonite and 5%,10%,15% and 20% fly ash replaced with cement. Mix with M30 grade with 10% wollastonite and 15% fly ash obtained maximum strength among all fly ash replacements. It was observed that as fly ash percentage in concrete increased, its compressive strength increased up to 15% and then decreased. The maximum compressive strength was obtained at 10% wollastonite and 15% fly ash (M7) obtained a compressive strength 46.11N/mm2 which was 15.27% more than the reference mix (M0). Variation of compressive strength of concrete with 10% wollastonite and different percentages of fly ash is as shown in Figure 11.

Compressive strength of M30 grade were studied with combination of 10% wollastonite and 5%,10%, 15% and 20% silica fume replaced with cement. Mix with M30 grade with 10% wollastonite and 10% silica fume obtained maximum strength of all silica fume

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replacements. It was observed that as silica fume percentage in concrete increased, its compressive strength also increased up to 10% silica fume replacement and then decreased. Mix with 10% wollastonite and 10% silica fume (M11) replacement obtained compressive strength 47.20 N/mm2 which was 18% more than the reference mix. Variation of compressive strength of concrete with 10% wollastonite and different percentage of silica fume is as shown in Figure 12. Percentage of compressive strength variation of different mixes with reference mix is shown in Table 17.

Table 16 Strength properties of concrete

MIX	Compressive Strength in MPa	Split Tensile Strength in MPa	Flexural Strength in MPa
M0	40	2.71	3.05
M1	41.20	2.63	3.10
M2	45.38	3.12	3.50
M3	44.31	2.69	3.41
M4	42.03	2.80	3.30
M5	45.40	3.00	3.29
M6	45.29	3.09	3.35
M7	46.11	3.10	3.41
M8	45.20	3.06	3.30
M9	45.23	3.06	3.31
M10	47.20	3.12	3.43
M11	46.27	3.06	3.40
M12	45.21	3.00	3.37

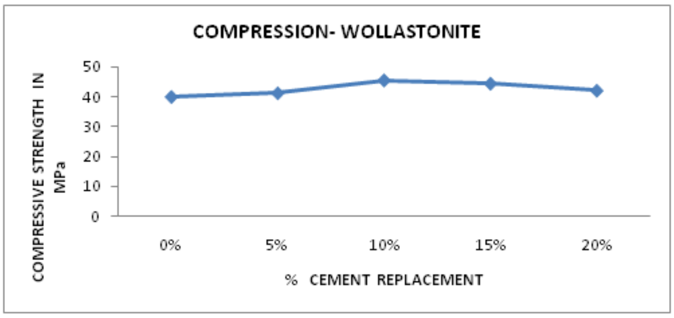

Fig 10 Relation between % wollastonite replacement and compressive strength

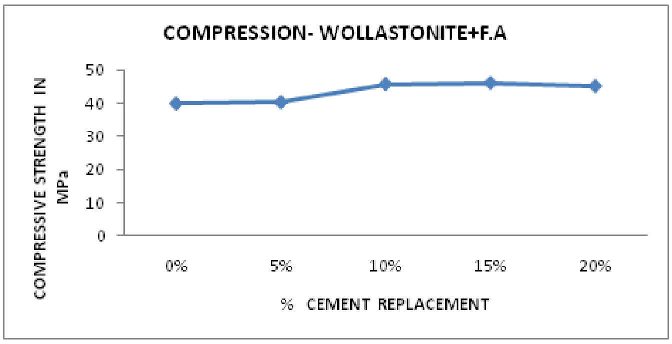

Fig 11 Relation between opt wollastonite +% fly ash replacement and compressive strength

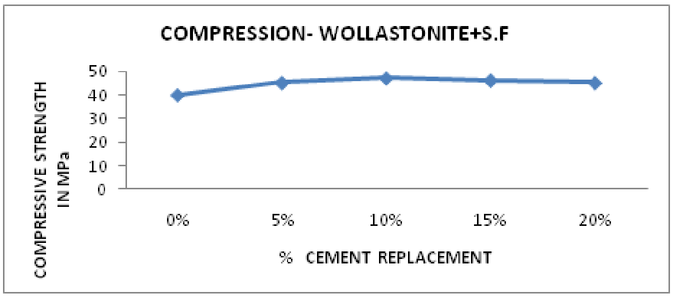

Fig 12 Relation between opt wol +% silica fume replacement and compressive strength

CONCLUSIONS

In view of above review, the accompanying perceptions are made with respect to the quality properties of cement on fractional substitution of cement by wollastonite and minerals admixture, for example, fly ash and silica fume

1. As rate substitution of wollastoniteincreased ,its workability reduced.

2. The most extreme compressive strength of 45.32 N/mm2 (M2) was acquired concerning M30 review solid when 10% cement supplanted by wollastonite. Most extreme compressive quality was obtained at with mix (M2) was 13.3% more contrasted and reference mix M0 (40 N/mm2).

3. The greatest compressive strength of 46.18 N/mm2 (M7) was acquired as for M30 review solid when concrete supplanted by 10% wollastonite and 15% fly cinder. Most extreme compressive quality acquired with mix (M7) was 15.45% more contrasted and reference mix M0 (40 N/mm2).

4. The greatest compressive strength of 47.20 N/mm2 (M10) was was obtained at as for M30 review solid when cement supplanted by 10% wollastonite and 10% silica fume. Most extreme compressive quality was obtained at with mix (M10) was 18% more contrasted and reference mix M0 (40 N/mm2).

5. The greatest split tensile strength of 3.12 N/mm2 (M2) was acquired as for M30 review solid when 10% concrete supplanted by wollastonite. Greatest split elasticity acquired with mix (M2) was 15.13% more contrasted and reference mix M0 (2.71 N/mm2).

6. The highest split tensile strength of 3.09N/mm2 (M7) was acquired regarding M30 review solid when concrete supplanted by 10% wollastonite and 15% fly ash. Most

extreme split elasticity was obtained at with mix (M7) was 14.39% more contrasted and reference mix M0 (2.71 N/mm2).

7. The most extreme split tensile strength of 3.19 N/mm2 (M10) was was obtained at as for M30 review solid when concrete supplanted by 10% wollastonite and 10% SILICA FUME. Greatest split elasticity acquired with mix (M10) was 17.17% more contrasted and reference mix M0 (2.71 N/mm2).

8. The most extreme flexural quality of 3.50 N/mm2 (M2) was acquired regarding M30 review solid when 10% concrete supplanted by wollastonite. Most extreme flexural quality acquired with mix (M2) was 14.75% more contrasted and reference mix M0 (3.05 N/mm2).

9. The greatest flexural strength of 3.41 N/mm2 (M7) was acquired as for M30 review solid when concrete supplanted by 10% wollastonite and 15% FLYASH debris. Most extreme flexural quality acquired with mix (M7) was 11.80% more contrasted and reference mix M0 (3.05 N/mm2).

10. The greatest flexural strength of 3.43 N/mm2 (M11) was was obtained at as for M30 review solid when cement supplanted by 10% wollastonite and 10% silica fume. Most extreme flexural strengthwas obtained at with mix (M11) was 12.46% more contrasted and reference mix M0 (3.05 N/mm2).

11. Based on test comes about, it is watched that there is essentialness change in the quality properties of cement with wollastonite and SILICA FUMEmix when contrasted with wollastonite and FLYASH remains.

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