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Experimental study on the influence of fly ash, lime powder and hybrid fibres on the properties of concrete

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Abstract The main objective of this study is to characterize the optimum percentage of fly ash, Lime powder with hybrid fibres (steel and polypropylene). The above blending is to be tried, to meet the strength requirements in compression, split and flexural along with durability tests. The steel fibres are used to increase the strength of concrete. The addition of fly ash and lime powder by replacing the cement content. Specimens are cast with M_{30} concrete. To save our earth resources to control the pollution from the manufacturing of cement (1 ton of cement releases 1 ton of CO_2) we have to utilize the easy available and waste materials like Fly ash & Lime powder. The production of blended cements results in lower emission and lower energy consumption since less clinker from the energy intensive process is needed to produce such blended cements. Polypropylene fibres and steel fibres are used to increase the flexural strength. Addition of the Supplementary Cementitious Materials (SCMs) not only reduces the permeability of concrete, but also increases the strength of the concrete. Addition of steel fibres increases the compressive strength from 6% to 17%, tensile strength from 18% to 47%, flexural strength from 22% to 63%.

Index Terms— fly ash; Lime powder; hybrid fibres; Polypropylene fibres; steel fibres

1 Introduction Recycling of large amount of waste materials such as fly ash, Lime powder (LP) etc is being done in large extents in the manufacture of cement and cementitious products. Addition of these Supplementary Cementitious Materials (SCMs) not only reduces the permeability of concrete, but also increases the strength of concrete by the formation of CHS gel by reacting with lime which is a by-product during cement reaction with water. This pozzolanic property of SCMs has been the reason for the enormous utilization of SCMs in cement. The replacement of cement by supplementary material not only results in savings of the materials, but also reduces the CO_2 emission in the atmosphere, since one ton of cement production results in one ton of CO_2 emitted in the atmosphere.

A lot of work has been done on replacement of cement with fly ash, which has shown good results with respect to strength and durability. Fly ash has given good results upto a replacement of 20% of cement have increased the performance of concrete with about 15% replacement in most of the research findings. Ternary blended pozzolanic material with LP contributes to hydration improving the early age and the long term compressive and flexural strengths also with durability which was verified by acid test and chloride ion penetration tests. The corrosion resistance of ternary blend mortar is higher than that of containing single pozzolano and the use of ternary blend OPC and FA is very effective in reducing chloride induced corrosion of mortar.

The Compressive strength and durability aspects have been studied for the Portland cement replaced by limestone powder. Less work has been done on the flexural strength of lime stone powder cement. In limestone quarries, considerable amount of limestone powders are being produced as by-products of stone crushers. High amount of powder are being collected and utilization of this by product is a big problem from the aspects of disposal, environmental pollution and health hazard. The benefits of limestone as a partial replacement of Portland Cement (PC) are established. High early strength has been reported by about 10%, which intern fills the voids as CSH gel, preventing the negative properties of leaching at the later stages.

The significance of the present study deals with the optimum percentage of replacement of cement with FA, which is a waste from the thermal power plants and limestone powder, generated from the limestone quarries with hybrid fibres (steel and polypropylene).

2LITERATURE REVIEW

1. Xuiping feng et al (2011) studied the Evaluation of the Physical and Chemical Properties of Fly Ash Products for Use in Portland cement Concrete.

Fly ash is a by-product of the combustion of pulverized coal in electric powder generating plants. It was the most widely used supplementary cementitious material in concrete.

The replacement level of class F fly ash was often replaced at 15-25% by mass of cementitious materials. The properties of fly ash can greatly affect the properties of both fresh concrete and hardened concrete. It was generally recognized that the addition of fly ash has been a beneficial effects on the rheological properties of cement paste and on the workability of fresh concrete.

2. Vikrant S. Vairagade et al (2012) studied the effects of seel fibre Reinforced Concrete on Engineering Performance of Concrete

Fibre reinforced concrete had been successfully used in slabs on grade, shotcrete, architectural panels, precast products, offshore structures, structures in seismic regions, thin and thick repairs, crash barriers, footings, hydraulic structures and many other applications. The observation indicate that compressive strength of fiber concrete reached a maximum at 1.5%volume fraction, being 15.3% improvement over the HSC. The split tensile and Flexural Strength improved by 98.3% and 126.6% at 2.0% of volume fraction.

3. Dr S L Patil et al (2012) studied the compressive strength of Fly Ash concrete.

Fly ash, a waste generated by thermal power plants is as such a big environmental concern. The investigation reported in this paper was carried out to study the utilization of fly ash in cement concrete as a partial replacement of cement as well as an additive so as to provide an environmentally consistent way of its disposal and reuse.

4. Amit rana (2013) carried out some studies on Steel Fiber Reinforced Concrete.

From the exhaustive and extensive experimental work it was found that with increase in steel fibre content in concrete there was a tremendous increase in Flexural strength. Even at 1 % steel fibre content flexural strength of 6.46 N/mm2 was observed against flexural strength 5.36 N/mm2 at 0% hence increase of 1.1% flexural strength was obtained. Fibre reinforced concrete (FRC) was Portland cement concrete reinforced with more or less randomly distributed fibres. In FRC, thousands of small fibres are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties in all directions.

5. M.Tamil Selvi et al (2013) studied effects on the Properties of Steel and Polypropylene Fibre Reinforced Concrete without any Admixture.

In this paper the strength of concrete cubes, cylinders and prisms casted using M30 grade concrete and reinforced with steel and polypropylene fibres are presented. Also, hybrid fibres with crimped steel and polypropylene were used in concrete matrix to study its improvements in strength and durability properties. The steel, polypropylene and hybrid polypropylene and steel (crimped) fibres of various proportion i.e, 4% of steel fibre, 4% of polypropylene fibre and 4% of hybrid polypropylene and steel (crimped) fibres each of 2% by volume of cement were used in concrete mixes.

3 materials and methodology

3.1 Testing of cement

Cement is the most important binding material of concrete. The cement used for the experimental study is Ordinary Portland Cement of 53 grade. **ordinary portland cement (opc)**

Ordinary Portland cement is most common type of cement and is used around the world as a basic ingredient of concrete. It is

Table 1: Chemical properties of cement

CHEMICAL PROPERTIES	*PERCENTAGE*
SiO_2	*1.8*
Al_2O_3	*.1*
Fe_2O_3	*.9*
CaO	*4.8*
MgO	*1.7*

sulphate. As per definition sited on the Ethiopian Standard ES Portland cement means the product obtained by grinding clinker with the possible addition of a small quantity of calcium sulphates and or water and it is manufactured by thoroughly mixing together calcareous or other lime bearing materials with argillaceous and other silica, alumina or iron oxide bearing materials burning them at a clinkering temperature and grinding the resulting clinker so as to produce a cement capable of complying with the requirements stipulated in the same standard.

3.1 consistency test

The vicat apparatus consist of a frame to which is attached to a movable rod. The movable rod is provided with an indicator. The indicator moves on a vertical scale and it gives the penetration. The vicat mould is in the form of a cylinder. It can split into two halves. This mould is placed on a non-porous plate. The apparatus consists of three attachments they are:

1. Plunger of 10mm diameter and 50mm long.
2. Needle of 1mm^2 section
3. Needle with annular attachment

Result

The % of water required for obtaining cement paste of standard consistency is 32

3.1.b specific gravity of cement

Specific gravity of cement = 3.15

3.1.c initial setting time of cement

Initial setting time of cement is 30 minutes

3.1 d fineness of cement

Average fineness of cement = 4.33

3.2. testing of coarse aggregate

Machine crushed granite obtained from a local quarry was used as coarse aggregate. The maximum size of the coarse aggregate used is 20mm is chosen and tests to determine the different physical properties as per IS 383-1970.The density of coarse aggregate is 2.55 g/cm^3 and that of bulk density is 1597 kg/m^3.

5.2.a specific gravity of coarse aggregate

Specific gravity of sand is = 2.74

3.2.b fineness modulus of coarse aggregate

The fineness modulus of coarse aggregate is = 1.4

3.3 testing of fine aggregate

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The fine aggregate used for the concrete is natural river sand. Fine aggregates are used to make a greater binding strength between cement and coarse aggregate.

3.3.a specific gravity of sand

Specific gravity of sand =2.74

3.3.b fineness modulus of fine aggregate

Fineness modulus of the fine aggregate = 4.923

3.4 slump test

Concrete is said to be workable if it can be easily mixed, placed, compacted and easily finished. A workable concrete should not show any segregation. Bleeding, segregation is said to occur when coarse aggregate tries to separate out for finer material and we get concentration of coarse aggregate.

Fig No. 5.1: Slump for ordinary concrete

observation

Height of mould = 30 cm

Height of concrete obtained after removal of mould = 30 – 17 = 13 cm

Mix proportions

Cement	= 389.62 kg/m^3
Fine aggregate	= 740.53kg/m^3
Coarse aggregate	= 1158.28kg/m^3
Water	= 197 litres
Cement : FA: CA	**= 1 : 1.90 : 2.97**

4 RESULTS AND DISCUSSIONS

4.1 compressive strength test

4.1.1 compressive strength of replaced concrete (15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre) after 7 days curing

Table 2 compressive strength for 7 days

FLY ASH %	COMPRESSIVE STRENGTH (N/mm^2)
0%	*24.33*
5%	*26.25*
15%	*28.15*
25%	*26.95*

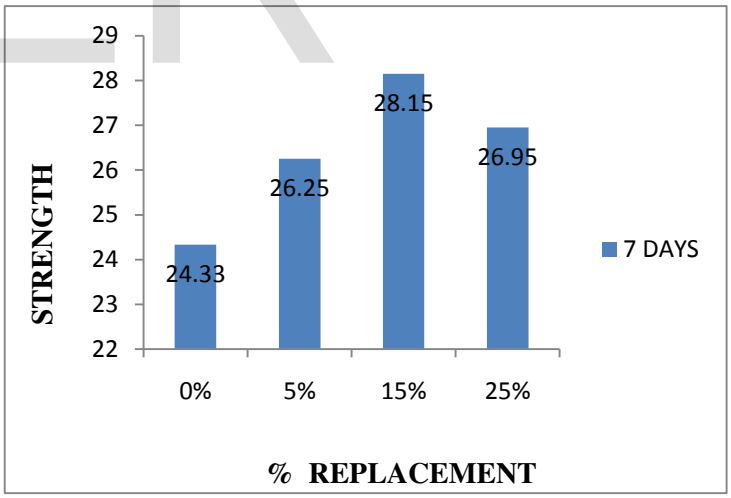


Fig No. 1 Compressive strength for 7 days

From the above graph we can observe that the compressive strength increases up to 8% with the addition of 5% fly ash, 15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre when compared to conventional concrete and there is an increase of 11% strength with the addition of 15% fly ash and for 25% fly ash, the compressive strength will reduces. It was

observed that 15% is found to be the optimum percentage.

4.1.2 compressive strength of replaced concrete (15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre) after 14 days curing

table no. 4.1.2 compressive strength for 14 days

FLY ASH %	*COMPRESSIVE STRENGTH (N/mm²)*
0%	*29.92*
5%	*32.94*
15%	*34.53*
5%	*33.16*

Fig No. 2 Compressive strength for 14 days

From the graph we can observe that the compressive strength increases up to 10% with the addition of 5% fly ash, 15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre when compared to conventional concrete and there is an increase of 15% with the addition of 15% fly ash and for 25% fly ash, the compressive strength will reduces. It was observed that 15% is found to be the optimum percentage.

4.1.3 COMPRESSIVE STRENGTH OF REPLACED CONCRETE (15% LIME POWDER, 0.8% STEEL FIBRE AND 0.2% POLYPROPYLENE FIBRE) AFTER 28 DAYS CURING

Table No. 4.1.3 Compressive strength for 28 days

FLY ASH %	COMPRESSIVE STRENGTH (N/mm²)
0%	*36.25*
5%	*40.38*
15%	*43.16*
25%	*41.45*

From the above graph we can observe that the compressive strength increases up to 12% with the addition of 5% fly ash, 15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre when compared to conventional concrete and there is an increase of 19% with the addition of 15% fly ash and for 25% fly ash, the compressive strength will reduces. It was observed that 15% is found to be the optimum percentage.

4.1.4 AVERAGE COMPRESSIVE STRENGTH

Table No. 4.1.4 Average compressive strength

FLY ASH %	*7 DAYS (N/mm²)*	*14 DAYS (N/mm²)*	*28 DAYS (N/mm²)*
0%	*24.33*	*29.92*	*36.25*
5%	*26.25*	*32.94*	*40.38*
15%	*28.15*	*34.53*	*43.16*
25%	*26.95*	*33.16*	*41.45*

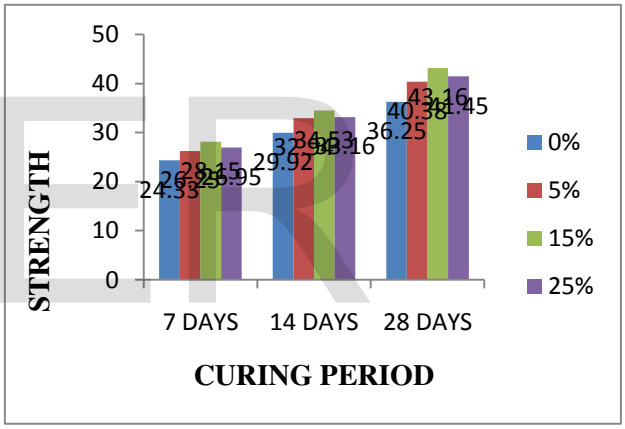


Fig No. 4 Average compressive strength

From the graph we can observe that the optimum percentage is at 15% that is, for 15% addition of fly ash along with 15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre, concrete gains maximum compressive strength and after 15% the strength will gradually decreases. Specimens were cured for 7, 14 and 28 days. 28 day specimens attain more strength when compared to 7 and 14 days.

4.2 SPLIT TENSILE STRENGTH TEST

The split tensile strength is the indirect measurement of the tensile strength by placing a cylindrical specimen horizontally between the loading surfaces. This method consists of applying a diametric compressive force along the length of a cylindrical specimen. This loading includes tensile stresses on the plane containing the applied load. Tensile failure occurs rather than compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder and the load

is applied until failure of the cylinder, along the vertical diameter. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength of concrete are the ASTMC 496 splitting tension test and the ASTMC 78 third-point flexural loading test.

Split tensile strength (T) =2p/πLD

4.2.1 split tensile strength of replaced concrete (15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre) after 7 days curing

Table No. 4.5 Split tensile strength for 7 days

FLY ASH %	SPLIT TENSILE STRENGTH (N/mm²)
0%	1.85
5%	2.46
15%	2.97
25%	2.68

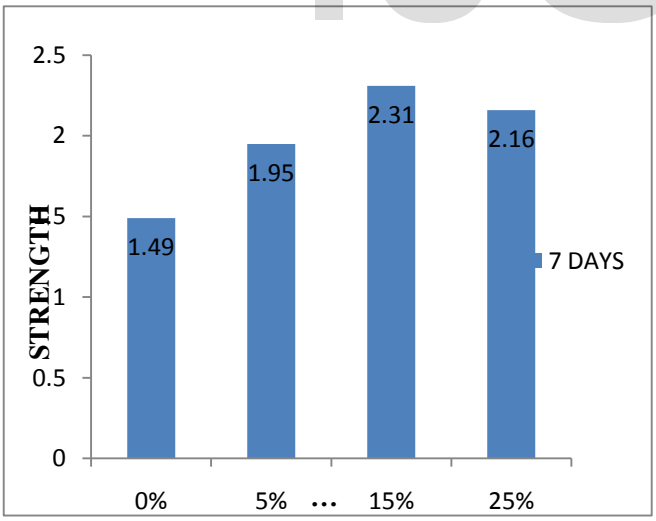


Fig No. 5 Split tensile strength for 7 days

From the graph we can observe that the split tensile strength increases up to 30% with the addition of 5% fly ash, 15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre when compared to conventional concrete and there is an increase of 55% strength with the addition of 15% fly ash and for 25% fly ash, the tensile strength will decreases. That is 15% is the optimum percentage.

7.2.2 split tensile strength of replaced concrete (15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre) after 14 days curing

FLY ASH %	SPLIT TENSILE STRENGTH (N/mm²)
0%	*1.49*
5%	*1.95*
15%	*2.31*
25%	*2.16*

Table no. 4.6 split tensile strength for 14 days

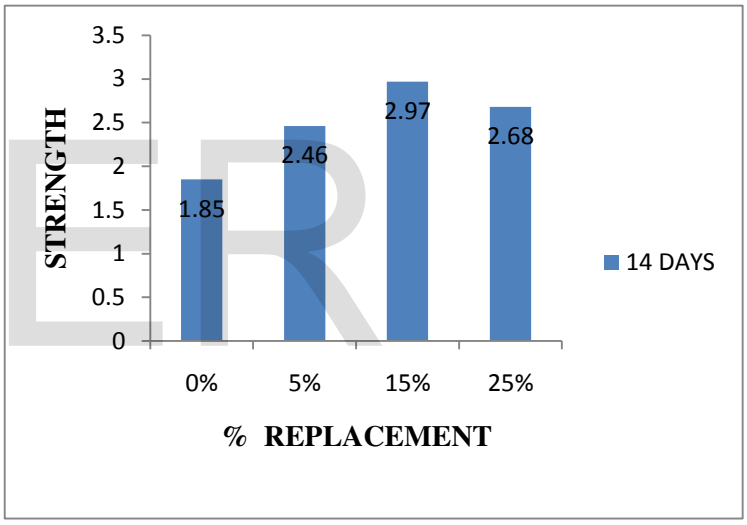


Fig No.6 Split tensile strength for 14 days

From the above graph we can observe that the split tensile strength increases up to 35% with the addition of 5% fly ash, 15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre when compared to conventional concrete and there is an increase of 60% strength with the addition of 15% fly ash and for 25% fly ash, the tensile strength will reduces. It was observed that 15% is found to be the optimum percentage.

4.2.3 SPLIT TENSILE STRENGTH OF REPLACED CONCRETE (15% LIME POWDER, 0.8% STEEL FIBRE AND 0.2% POLYPROPYLENE FIBRE) AFTER 28 DAYS CURING

Table No. 4.7 Split tensile strength for 28 days

FLY ASH %	*SPLIT TENSILE STRENGTH (N/mm²)*
0%	*2.56*
5%	*3.27*
15%	*3.89*
25%	*3.34*

Fig No. 7.9 Split tensile strength for 28 days4

From the graph we can observe that the split tensile strength increases with the addition of 5% fly ash, 15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre when compared to conventional concrete and maximum strength attains with the addition of 15% fly ash and for 25% fly ash, the tensile strength will reduces. It was observed that 15% is found to be the optimum percentage.

7.2.4 AVERAGE SPLIT TENSILE STRENGTH

Table No. 4.8 Average tensile strength

FLY ASH %	7 DAYS (N/mm²)	14 DAYS (N/mm²)	28 DAYS (N/mm²)
0%	1.49	1.85	2.56
5%	1.95	2.46	3.27
15%	2.31	2.97	3.89
25%	2.16	2.68	3.34

Fig No. 7 Average tensile strength

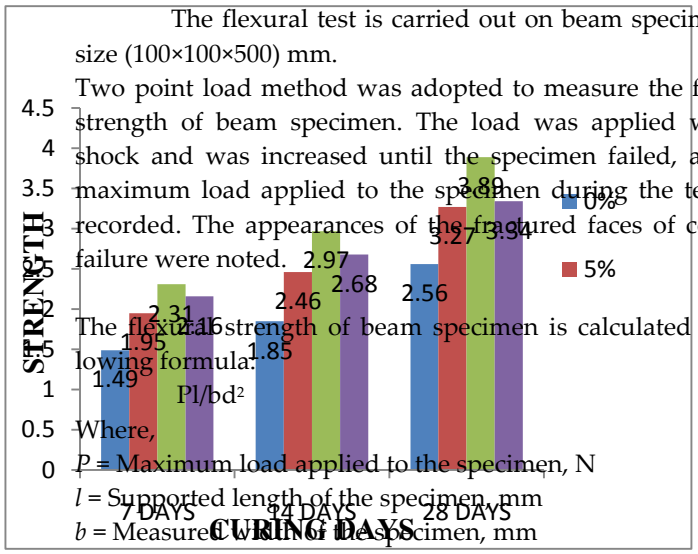
From the above graph we can observe that the optimum percentage is at 15% that is, with 15% addition of fly ash along with 15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre, concrete gains maximum tensile strength and after 15% strength will gradually decreases. Specimens were cured for 7, 14 and 28 days. 28 day specimens attain more strength when compared to 7 and 14 days.

Fig No. 8 Tested specimen after failure

4.3 FLEXURAL STRENGTH TEST

The flexural test is carried out on beam specimens of size (100×100×500) mm.

Two point load method was adopted to measure the flexural strength of beam specimen. The load was applied without shock and was increased until the specimen failed, and the maximum load applied to the specimen during the test was recorded. The appearances of the fractured faces of concrete failure were noted.



The flexural strength of beam specimen is calculated by following formula:

$$Pl/bd^2$$

Where,

P = Maximum load applied to the specimen, N

l = Supported length of the specimen, mm

b = Measured width of the specimen, mm

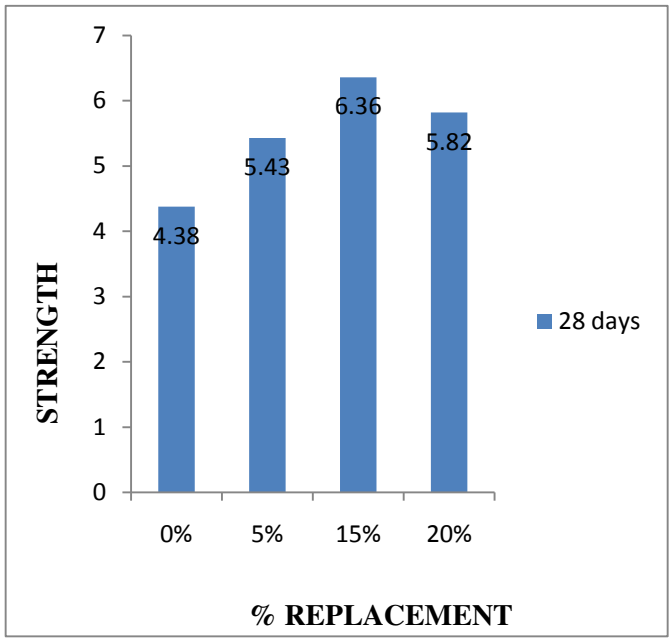
d = Measured depth of the specimen at the point of failure, mm

7.3.1 flexural strength of replaced concrete (15% limepowder, 0.8% steel fibre and 0.2% polypropylene fibre) after 28

days curing

Table No. 4.9 Flexural strength for 28 days

FLY ASH %	FLEXURAL STRENGTH (N/mm²)
0%	*4.38*
5%	*5.43*
15%	*6.36*
25%	*5.82*



strength. Increase in compressive strength of hybrid concrete was increased by 3 per cent to 22 per cent for 7 to 28 days when compared to conventional concrete.

Fig No. 8 Flexural strength for 28 days

From the above graph we can observe that the flexural strength increases up to 24% with the addition of 5% fly ash, 15% lime powder, 0.8% steel fibre and 0.2% polypropylene fibre and there is an increase of 45% with the addition of 15% fly ash.

CONCLUSION

Due to addition of fly ash there is a considerable improvement in compressive strength of the concrete and due to the addition of steel fibre there is an improvement in tensile strength. With the replacement in concrete by fly ash the concrete prepared is environment friendly and cost effective. The workability of concrete is improved considerably by addition of fly ash. With the addition of steel fibres and fly ash in concrete ductility is improved considerably. The workability of high strength concrete improves with increase in fly ash content. Limestone powder has a greater surface area and the smooth texture and spherical shape of enhance inter particle friction and ensuring greater packing. The slump of concrete relatively increases with increase in lime powder content. The increase in the amount of lime powder increases the viscosity of concrete. With suitable proportions of limestone powder, the compressive strength was increased can increases the strength, mostly due to the micro-filling ability and pozzolanic activity of Limestone Powder. The calcium carbonate in limestone powder reacts very little with cement hydrates, and improvement in strength are essentially due to void filling and acting as nucleation sites for cement hydrate crystals, mechanically improving the microstructure of the bulk paste matrix and transition zone and leading to increased compressive

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