Optimization of cement & Fine Aggregate with "High Lime Fly Ash & LCMS Filing in Concrete"

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Abstract: India's construction industry is progressing at a very fast rate therefore demand of cement and natural sand is very massive but these are costly as well as scarce. Their extensive production/extraction and usage leads to high energy consumption and greenhouse effects.

An attempt is made by partial replacement of Cement & Fine Aggregate with Fly Ash and Industrial Wastes (Low Carbon Mild Steel Filings – LCMS filings) respectively in concrete mixes to fulfill the demand of raw material required for the production of concrete at a lower cost without compromising on strength and mechanical properties.

Concrete Grade of M30 has been taken for the work. The mixes where designed using IS Code Method. Effect of replacement of cement by Fly Ash and fine Aggregate by LCMS filings at various percentages are explored & their Mechanical properties are discussed in this paper.

Key words: *Concrete, Compressive Strength, High LimeFlyAsh, LCMS filing.*

INTRODUCTION

LOW CARBON MILD STEEL (EN1A) Filing, here after addressed as "LCMS Filings" is a solid waste product from the steel industry in India. LCMS Filing includes a certain scale mineral such as EN1A which is a very popular grade of low carbon-manganese free cutting steel, the recycling of LCMS Filing will inevitably become an important measure for the environment protection and therefore can lead to great social significance also the manufacturing of Portland cement is a highly energy-intensive process. One of the most significant activities stressed by the engineers and scientists related to concrete industry aims at a high percentage of replacement of clinker in cement with secondary raw materials, with the possibility of improvement of cement characteristics and durability of concrete. The less energy intensive and easily available industrial by-products with little or no pyro-processing and have inherent or latent cementitious properties together with the reduced of CO_2 emissions being most sought after, such industrial by-products are commonly called as supplementary cementitious materials or admixtures. Admixtures are usually available in large quantities and can be used to replace Portland cement in green concrete, which include Fly Ash (Fly Ash is a solid waste product dumped in large quantities by thermal Power Plants in India). These admixtures are added to the concrete as extra binding materials, and the benefits of using these materials in terms of workability are well established. When compound admixture with LCMS filing and Fly Ash is mixed with concrete, the performance of concrete can be improved further due to the synergistic effect and activation of each other. Therefore, the proposed admixture will be a perfect component of green concrete and its utilization will be a valuable resource for recycling. Mechanical properties of concrete made with the partial replacement of cement, fine aggregate with high lime Fly Ash and LCMS filing in concrete were studied in this work.

BACKGROUND RESEARCH

Aarthylakshmi, K., Kiruthika, M., Rathod.J.D, Sunilkumar. R. and Premkumar, S. (2014)

Test were conducted on concrete using chemically activated fly ash at various cement replacement levels of 10%, 20%, 30%, 40%, 50% & 60% with w/c ratio of 0.5 to observe verities in compressive strength. The resulting strength was compared with the concrete made up of 100% OPC. Their experiments showed that the 28 days compressive strength for M20 grade concrete is attained by the replacement of Fly Ash with cement up to 50% .Though the strength obtained by the control cube is greater than that of Fly Ash replaced concrete, the required strength is obtained after 40% replacement with Fly Ash. The micro silica in activated Fly Ash was reported to be resistant against sulphate attack and corrosion.

Adiyanju, A. andManohar, K. (2011)

Experimental study on the thermal properties of iron filings and steel-fiber-reinforced concrete for solar/thermal energy storage application was conducted. The experimentation was carried out to test concrete aggregate mixtures with three different sizes and same quantity of steel fibers; two different quantities of iron filings and one plain concrete. Results indicated that the steel fibers and iron filings have influence on the thermal and mechanical properties of the concretes tested, thus they have concluded that the iron filings and steel fibers reinforced concrete is suitable for better solar/thermal energy storage due to an increase in storage capacity over plain concrete.

Bentz, D., Ferraris, C. andSynder, K. (2013)

Their experimental study has considered all aspects of High Volume Fly Ash (HVFA) concrete production in its fresh and hardened states. The results presented have demonstrated that HVFA concretes can offer substantial performance benefits, in addition to their sustainability advantages in terms of reductions in cost, embodied energy, and CO_2 emissions.

Bhavsar, J.,Mistry, S., Patel, S., Pitroda, J., Umrinagar, S. andZala, L. (2011)

In their research work they have reported the production process of Fal-G brick, uses of rap-trap bond in Fal-G brick masonry prism test study and its economy has also been described. According to their case study, the fly ash bricks with conventional masonry work have 28% saving in cost with common red brick and conventional masonry work.

Burden, D. (2003)

Conducted experimental study to know the effect of curing on the carbonation and permeability of high-volume fly ash concrete (HVFAC).Concrete mixtures were produced at a range of water/cement ratios (0.34, 0.40 and 0.50) and fly ash replacement levels (0%, 30%, 40% and 50%) using fly ashes of different compositions (Type F, CI and CH).

Bronka, J., Korjakins, A.,Kazjonovs,J. andMironovs, V.(2011)

Conducted experimental study dealing with rational use of highly dispersed metal waste as an important issue of material science and Environment protection. Their research presented an analysis of several kinds of metal waste such as iron and steel powders, mill scales, steel punching, metal shavings and other iron-containing waste from mechanical engineering and metallurgy industries, and the possibility of their use in the manufacturing of concrete products like fillers.

Cross, D. andStephens, J. (2006)

Experimental study on concrete cubes with 100 percent Class C fly Ash from the Corette power plant in Billings, MT, was used as a binder. The specific objectives of their project were:

1) To identify additional fly ashes that could be used in 100 percent Fly Ash Concretes.

2) To develop fly ash concrete mixtures with entrained air.

3) To determine the durability of these concretes under various environments.

Gandhimathi, R., Nidheesh, P.V., Ramesh, T., Rajakumar, S. andSubramani, P. (2013)

Conducted experimental study to obtain low cost building materials using industrial wastes (Welding and furnace slags). The objective of the study is to use these wastes in low-cost construction with adequate compressive strength. Different fine aggregate replacements have been studied by substituting 5%, 10%, and 15% of slag. The waste material was substituted for replacement of fine aggregates and for the preparation of concrete blocks.

Islam, M. and Islam, S. (2010)

Conducted experimental investigation to study the effects of fly ash on strength development of mortar and the optimum use of fly ash in mortar. During their experiments, Cement was partially replaced with six percentages (10%, 20%, 30%, 40%, 50% and 60%) of “Class F Fly Ash” by weight.

Compressive as well as tensile strengths of the specimens were determined at 3, 7, 14, 28, 60 and 90 days .

Their test results showed that strength increased with the increase of fly ash up to an some optimum value, Among the six fly ash mortars, the optimum amount of cement replacement in mortar was about 40%, which provided 14% higher compressive strength and 8% higher tensile strength when compared to ordinary Portland cement (OPC) mortar.

Jatale, A., Tiwari, K. andKhandelwal, S. (2013)

Conducted experimental study dealing with the effect on strength and mechanical properties of cement concrete by using fly ash. They studied the effect of partial replacement of cement by fly-ash, on concrete mixes with 300 to 500 kg/cum cementious materials at 20%, 40%, 60% replacement levels. In this study, the effect of fly-ash on workability, setting time, density, air content, compressive strength, modulus of elasticity have been studied.

Joshi, R. (2013)

Conducted experimental study to examine the effect of adding industrial waste in the form of Gray Cast Iron (GCI) and Ductile Cast Iron (DCI) from the casting industry in the concrete mixes for fine aggregates.

Partial replacement of fine aggregates by increasing percentage (0% to 30%) of GCI and DCI was done. The mix with 30% sand replacement by GCI and DCI turnings showed 32.5% increase in compressive strength in comparison to the target strength i.e. 38.25 MPa and 63.83% increase in the flexural strength as compared to the controlled specimen i.e. 23.5 MPa on 28th day.

Murali, G., Mohammad, J.A., Mohammad, Z. and Suresh, T. (2012)

Conducted experimental investigation on recycled metals. They have investigated the influence of addition of waste materials like lathe waste, soft drink bottle caps, empty waste tins, waste steel powder from workshop at a dosage of 1% of total weight of concrete as fibres. Experimental investigation was done using M25 mix and tests were carried out. The results were compared with conventional concrete and it was observed that concrete blocks incorporated with steel powder increased their compressive strength by 41.25% and tensile strength by 40.81%. Soft drink bottle caps reinforced blocks exhibited an increase in flexural strength of concrete by 25.88%.

Naik, T. andRamme, B. (1989)

Conducted experimental research with the fundamental objective to develop mix proportioning information for structural grade concrete using high proportions of Fly Ash. Concrete mixes with and without air entrainment was produced in which fly ash was substituted for cement in quantities up to 70 percent of total cement replacement. Compressive strength, air content, density, setting, and workability characteristics were observed.

Skanda, B.N., Srishaila, J.M., Suhas, R. andUttam, S. (2006)

In the present study Iron Ore Tailings (IOT) procured from Kudremukh Lakya Dam site (KIOCL Ltd.) are used as partial replacement to fine aggregates at levels of 10, 20,30,40,50 percent and the basic material properties, strength parameters are studied. It is found that as that IOT percentage increases in the mix workability is reduced. At 40% replacement level the 28 days compressive strength is more than the reference mix.

NEED AND SCOPE OF POTENTIAL AREA FOR RESEARCH:

1. Combination of Fly Ash and LCMS filing as a replacement has not been studied.
2. Parametric study involving different combinations of Fly Ash and LCMS filing is the need of the hour.

The paper presents the maximum strength parameters with partial replacement of Cement, Fine Aggregate with High Lime Fly Ash (10%, 20%.....60%) and LCMS Filing (Upto15%) in M30 mix concrete.viz. Optimization.

MATERIALS USED

Cement

Ordinary Portland cement of 53 grades conforming to IS 12269–1987, was used though out the experimental program. Tests were conducted and the results were as follow:-

Residual left on sieve=5.70gm,specific gravity 3.08, consistency 37%, initial setting time 2hrs 30min and final setting time 3hrs 30min.

Coarse Aggregate

Crushed Natural Coarse Aggregate size 25-20 mm was used and it had the following properties:

Specific gravity-2.65, water absorption-0.1%, crushing value-15.24% impact value-7.14%, Fineness test was found to be appropriate

Fine Aggregate

Sand (Crushed Sand) was used for preparing the mix and Fineness test was found to be appropriate

Fly Ash

Table no. 1 & table no. 2 shows the result for physical & chemical test conducted on Fly Ash**.**

Sr. No.	Name of Test	Result obtained	Limits as Per (IS :3812) 2003
1	Fineness-Specific Surface of cement	350	Min. 320 m²/Kg
2	Lime reactivity	5.0	Min 4.5 N/mm²
3	Particles retained on 45 micron, IS Sieve	13.60%	Max. 34%
4	Soundness by Autoclave method	0.016%	Max. 0.8%
5	Specific gravity	2.24	-

Table no. 1 “Physical test for Fly Ash”

Sr. No.	Name of test	Result obtained	Limits As Per (IS :3812) 2003
1	Silicon dioxide (s)+(Al_2O_3)	82%	Min. 70%
2	Silicon dioxide(SiO_2)	43%	Min. 35%
3	Magnesium oxide (MgO)	1.42%	Max. 5%
4	Total Sulphur (Sio3)	1.31%	Max. 3%
5	Sodium oxide (Na_2o)	0.084%	Max. 1.5%
6	Total Chlorides	NIL	Max. 0.05%
7	Loss of ignition	0.98%	Max. 5%

Table no. 2 "Chemical test for Fly Ash"

Table no. 3 shows the analysis of Fly Ash test report.

Sr. No.	Test	Test Method	Test Result ECOPOZZ	Permissible Limits as Per IS 3812 (Part 1) : 2003 use as pozzolona
1	Finesse by Wet Sieving (%)Retain on 45 micron sieve	IS 1727 : 1967 Clause 6.2	9.78%	Max. 34%
2	Loss on Ignition (%)	IS 4032 : 1985 Clause 4.2	1.68%	Max. 5%

Table no. 3 "Fly Ash test report"

Low Carbon Mild Steel (LCMS) Filing

Table no. 4 & table no. 5 shows the chemical & mechanical properties of LCMS filing respectively.

230m07 (EN1A) specification chemical composition	
Carbon	0.07
Silicon	0.06
Manganese	0.81
Sulphur	0.25
Phosphorus	0.056
Chromium	-
Molybdenum	-
Nickel	-

Table no. 4 "Chemical analysis"

230M07 (EN1A) - Mechanical properties	
Max Stress	370-480 N/mm^2 Min
Yield Stress	240-400 N/mm^2 Min
0.2% Proof Stress	225-360 N/mm^2 Min
Elongation	6-10% Min

Table no. 5 "Mechanical properties"

Super plasticizer
Naphthalene Sulphonated Super plasticizer was used.

METHODOLOGY:-

1. **Test on fresh concrete**

In this investigation, the workability tests were conducted on fresh concrete. Workability affects the rate of placement and the degree of compaction of concrete. Slump test were conducted on fresh concrete.

SLUMP TEST

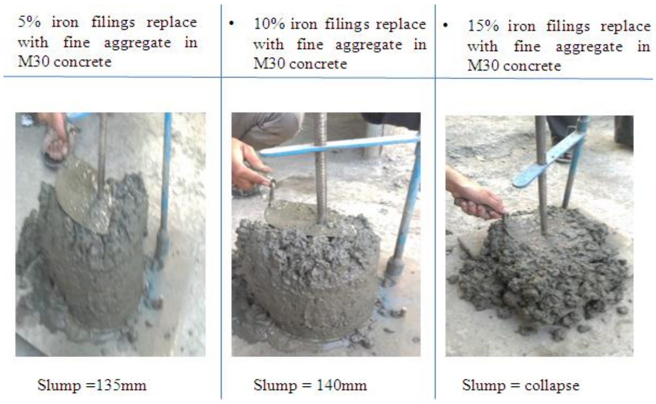


Figure no. 1 "slump test on fresh concrete"

Thus, percentage of iron fillings was restricted to 10% as replacement of 15% iron filings give collapse slump which is not desirable.

2. **Test on hardened concrete**

COMPRESSIVE STRENGTH OF CONCRETE CUBES

To calculate the compressive strength of concrete cubes, Compression Testing Machine (CTM) having capacity of 300 tonne was used. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area calculated from mean dimensions of the section and shall be expressed in N/mm². Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one can judge whether concreting has been done properly or not. For cube test cubical moulds of sizes 15cm×15cm×15cm are used. These Specimens are tested by CTM after 7 days curing and 28 days curing. Load should be applied gradually till the specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

SPLIT TENSILE STRENGTH OF CONCRETE CYLINDERS

Tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may develop crack. The cracking is a form of tension failure. The usefulness of the splitting cube test for accessing the tensile strength of concrete in the laboratory is widely accepted and the usefulness of the above test for control purposes in the field is under investigation. The standard has been prepared with a view to unifying the testing procedure for this type of test for tensile strength of concrete. The load at which splitting of specimen takes place then shall be recorded.CTM having capacity of 150tonne was used for the splitting tensile strength of the concrete cylinders.

FLEXURAL STRENGTH OF CONCRETE BEAMS

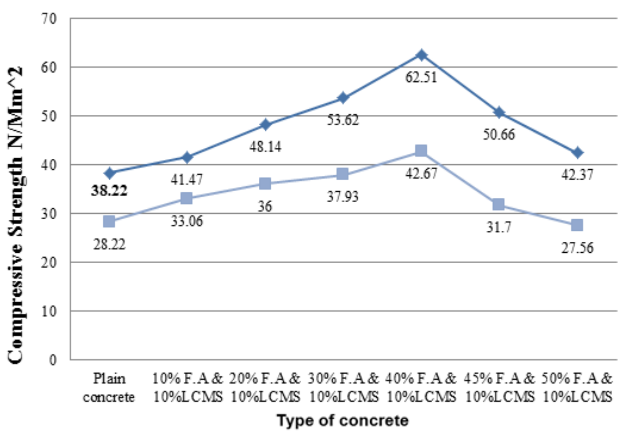
For this test, the beams of mould dimensions 150mm×150mm×700mm were casted. Flexural strength, also known as modulus of rupture, is defined as a material`s ability to resist deformation under load. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. The beam tests are found to be dependable to measure flexural strength. The value of the modulus of rupture depends on the dimensions of the beam and manner of loading. In this investigation, to find the flexural strength by using third point loading. In symmetrical two points loading the critical crack may appear at any section not strong enough to resist the stress with in the middle third, where the bending moment is maximum. Flexural modulus of rupture is about 10% to 20% of compressive strength depending on the type, size and volume of coarse aggregate used.

RESULTS AND DISCUSSION

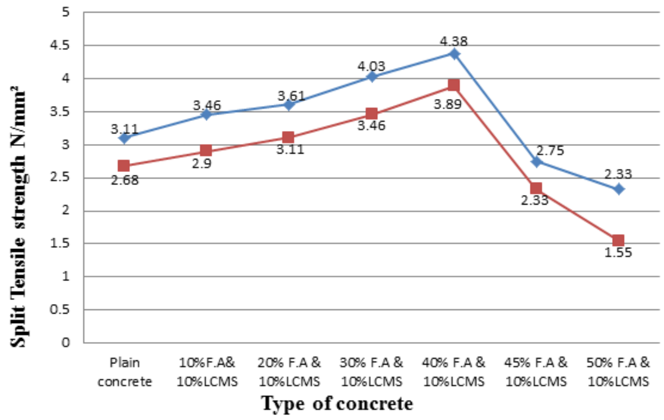
The workability of M30 grade concrete for partial replacement of fly ash and iron fillings in varying proportion for 7 & 28 days for cubes, cylinders and beams are given in table 6. The combined strength parameters for compressive test, tensile test, flexural test is shown in fig 2, 3 & 4.

Type of mix	Avg. Compressive strength on cubes		Avg. split tensile test on cylinder		Avg. flexural test on beams	
	7days	28days	7days	28days	7days	28days
Plain concrete	28.22	38.22	2.68	3.11	6.43	7.15
10% F.A& 10% LCMS	33.06	41.47	2.9	3.46	7.26	7.56
20% F.A& 10% LCMS	36	48.14	3.11	3.61	7.26	7.88
30% F.A & 10% LCMS	37.93	53.62	3.46	4.03	7.57	8.60
40% F.A & 10% LCMS	42.67	62.51	3.89	4.38	8.39	9.85
45% F.A & 10% LCMS	31.70	50.66	2.33	2.75	5.59	7.15
50% F.A & 10% LCMS	27.56	42.37	1.5	2.33	3.31	6.43

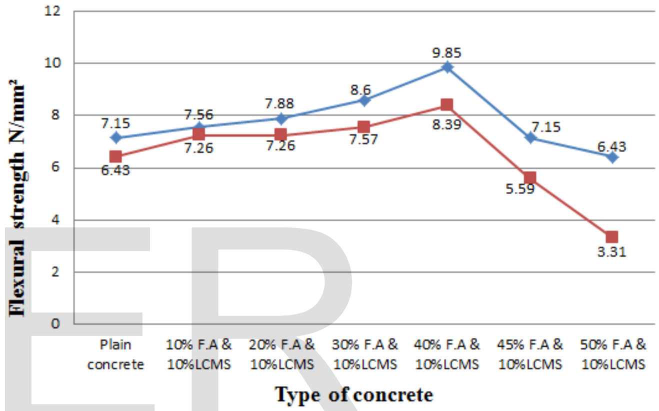
Table no. 6 "Result Analysis"



"Figure 2 Combined Compression Test Result"



"Figure 3 Combined Split Tensile Test Result"



"Figure 4 Combined Flexural Strength Test Result"

Normal concrete mix (Zero admixtures) was made initially and moulds were casted with 10% increment of Fly ash by weight of cement and while the amount of LCMS filings was maintained as 10% (Constant) in all cases.

Compressive strength

Compressive load sustained by a sample kept on increasing with an increase in Fly Ash content. The load goes on increasing for replacements of fly Ash up to 40% & iron filings as 10% constant after then the Compressive load bared by the sample (Cubes) got reduced.

Tensile Strength

Tensile strength attained was maximum for replacements of fly Ash up to 40% & iron filings as 10% constant there after the Split Tensile Strength bared by the sample (Cylinders) got reduced.

Flexural strength

Measurement of their weight, load (Two point symmetrical) sustained by each beam were measured. While the load sustained by a sample kept on increasing with an increase in Fly Ash content up to 40% of Fly Ash and 10% of LCMS filings (Constant in all cases except for the first proportion). There after the load bared by the sample (beam mould) get reduced.

CONCLUSION

Fly Ash and LCMS Filings replacement in concrete offers several economic benefits over Portland cement concrete
The degree of workability of concrete mix was found to be:-

- 7 days compressive cube strength increase by 51.20%.
  28 days compressive cube strength increase by 63.55%
- 7 days split tensile strength increase by 45.15%.
  28 days split tensile strength increase by 40.84%.
- 7 days Flexural strength increase by 30.48%.
  28 days Flexural strength increase by 37.76%.

The Cost of one ton of Fly Ash is Rs.500 in India. Cost of M60 grade concrete with OPC is estimated per meter cube to be about Rs.6000 to 7000 and cost analysis by replacement of Fly Ash and Iron Filings gives compressive strength of 62.51Mpa with the cost between Rs.3500 and 4500.

Thus it shows that the cost by partial replacement of Fly Ash and LCMS Filings in concrete and OPC concrete there is a vast difference and strength is almost same for both (High grade concrete).

In addition, the Fly Ash is finer thus concrete will be more impermeable.

Cement concrete requires repairing after every 10-15 years if situated in coastal areas due to ingress of salts which corrode the reinforcement. The Fly Ash being finer it prevents the leaching of salts into body of concrete thus rendering it more durable concrete. So fly ash and iron filings can be used as a substitute for cement which will reduce the cost of cement in concrete and also reduce the consumption of cement.

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