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Influence of Partial Replacement of Fine Aggregates by Stone Crusher Sand with Cement by Fly Ash and Lime Powder on Concrete.

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***Abstract*— In today's world concrete technology related to green environment and sustainable development are the two major issues worldwide. Presently non-accessibility of river throughout the year, large scale illegal depletion, rapid growth of construction activities, river water contamination by the harmful chemical wastes from the industry sectors, transportation all the reasons are making the good quality river sand scarcer and costlier. To tackle this problem stone crusher sand (SCS) a waste material obtained from the crusher plants can be an economical and alternative material .Similarly huge amount of fly ash (FA) is a finely divided by-product powder thrown out as a waste material produced from many thermal power plants .This can be replaced with Ordinary Portland Cement (OPC) with certain amount due to having some cementitious properties efficiently. Lime powder (LP) is used additionally as it is a good binder. This research paper presents the experimental study undertaken to investigate the possible feasibilities of using partial substitution of sand by SCS and OPC by FA with LP in an effective manner .To obtain this, M3O mix design was carried out with replacement of SCS from 0 to 50 percent at 10 percent and FA from 0 to 25 percent at 5 percent interval ranges respectively. After studying the effect of LP on blended cement based concrete its substitution value was fixed as 6 percent. A comparative study was taken at the age of 7 & 28 days strength tests viz. Compressive, split tensile and flexural tests for each replacement with the reference concrete.**

Keywords*— Concrete, Fly ash, Stone crusher sand, Natural river sand, Lime powder.

I. INTRODUCTION

In the modern world, concept of green concrete is using of ecofriendly materials to make the system more sustainable. For past a century concrete is the most versatile construction material used in various applications. It is the mixture of basic ingredients like binding materials, fine aggregates, coarse aggregates and water in predetermined proportion. Rapid growth of construction activities causes acute shortage of all the natural building materials. In order to make concrete industry more sustainable with green environment, one of the best approach is to use the waste materials in place of natural resources without compromising the structural performances.

In most of the countries coal is a major source of fuel for electricity production .In the electricity generation process large quantity of fly ash get produced. It is a fine by-product residue resulting from the combustion of pulverized coal in thermal power stations transported by the flue gases and collected in the Electrostatic preceptors (ESP). This product has the tendency to travel far in air. It is an inorganic pollutant. Lack of disposal due to non-availability of large dumping pads it pollute the air and water by contamination and causes serious respiratory health problems by inhalation into the body. Production of fly ash is more than 400 million tons per year right now on global basis but in the same ratio it is not utilized which makes it matter of serious concern. Instead of dumping this can be used in concrete which will enhance the solid waste management in a better way. Due to having some cementitious properties fly ash utilization in cement concrete in suitable proportion has many technical benefits. It will further improves the workability in fresh concrete, strength and durability in hardened concrete respectively. It makes the concrete more strong and durable by reducing the permeability, alkali-aggregate reaction, increase resistance to sulfate attack and corrosion. It is profitable because its use reduces the requirement of cement for same strength which is a major advantage. By a supplementary material it can reduce the CO_2 emission problems causing by the cement industries.

For last thousands of years lime is being used as a building materials all over the world. Many historical monuments, sculptures are made by lime are standing till now without failure. In nature it is sufficiently available .Lime is known as a good binder. But it is an unimportant material in the concrete chemistry. Many times due to surplus SiO_2 content in the whole concrete mix, extra Calcium hydroxide is required for formation of additional C-S-H gel which will strengthen the concrete. By this Calcium hydroxide can be converted to insoluble cementitious materials by addition with finely divided pozzolanic materials such as fly ash. Addition of hydrated lime with fly ash enhances the properties of concrete in early days. It acts as a good corrosion resistance material due to having pH value more than 10. It was studied that a small quantity of lime is effective varying from 5 to 10% on blended based cement concrete. So in this study investigation, lime substitution in Ordinary Portland Cement (OPC) is considered as only 6% blended with fly ash.

In the present scenario good quality of natural river sand becomes scarcer and costlier .The main reason behind this are rapid increase of illegal dredging and depletion, non-accessibility of river throughout the year, rapid increase of illegal dredging, vast consumption of sand in construction activities, contamination of river water by the harmful chemical wastes from the industry sectors, transportation of sand from the source to the site etc. At the same time the river water level bed also reducing which causes side slope failure, ecological imbalances. So Governments are restricting the river sand escalation from the river beds. To overcome this situation, stone crusher sand (SCS) can be an economical and alternative material to the natural river sand. It is a by-product generated during the process of production of coarse aggregates in the stone crushing plants. This is producing in a large scale but only for dumping in free land it pollutes the surround environments. Its properties like color, size &shape, surface texture are very similar to the natural sand making it a good substitute. This is cost effective, easily available. This can be effectively used as a partial replacement material for river sand keeping in view of technical, commercial & environmental requirements. The main objective of the present research work is to study the influence of the combined application of fly ash with lime and stone crusher sand on various strength properties of concrete.

II. LITERATURE REVIEW

Imbabi et al. (2012) on their studies reported that globally 3.6 billion metric tons of OPC production causes 5 to 6% all carbon emission which will touch 5 billion metric tons by 2030.Energy resources,CO2emission and the use of alternative materials are the most challenging factors for cement industry right now. Cost of energy is rising unavoidably due to huge depletion of fuel sources. Therefore the price of cement has been increasing every year. So there is need of alternative materials which will reduce the emission efficiency along with the process efficiency.

Jain and Dwivedi (2014) have made a review on fly ash waste management. They have reported that fly ash has been regarded as a solid waste material all over the world as it contains many toxic metals and it is easily pollute the air and water bodies. In addition to this they also presented the various effective applications of fly ash as a raw material.

Barbhuiya et al. (2009) have investigated that fly ash concrete incorporating with hydrated lime and silica fume enhances the properties of concrete by increasing the early strength as well as the 28 days compressive strength, minimizes the total porosity and air permeability significantly .The Ca(OH)2 content increased due to addition of hydrated lime and decreased due to silica fume. For both hydrated lime and silica fume the amount of Ca(OH)2 decreased with time in fly ash cement paste.

Alfi et al. (2004) have experimented on the effect of lime-stone fillers and silica fume pozzolana on the characteristics of sulfate resistant cement pastes. They studied the characteristics of sulfate resistant cement paste containing 5wt. % limestone as well as silica fume cured up to 90 days. Incorporation of lime consumes Calcite, forms carbo-aluminates, accelerates the effect on the hydration of C3A, C3S and forms transition zone between filler and cement paste. They found that addition of 10wt. % of both limestone and silica fume to cement paste gives better mechanical properties are shown at all curing periods.

Diab et al. (2016) have made an experimental investigation on long term durability properties by replacing limestone 0 to 25 % by 5% interval range with silica fume in 5 to 25% in OPC on various proportions. They found that limestone up to 10% had not any significant changes in concrete properties. In addition they have recommended not to use blended limestone cement in case of sulfate attack but can be used for corrosion resistance up to 25%.

Tosun et al. (2009) have conducted experiment on the effect of limestone replacement ratio on the sulfate resistance of Portland limestone cement mortars. At the end they concluded that for severe sulfate environment the limestone replacement is restricted to 10% by weight of cement. Further increase in limestone causes sulfate deterioration possibly due to their relatively lower strength and increased capillary water absorption properties.

Acharya et al. (2016) have worked out on effect of lime on mechanical and durability properties of blended cement based concrete. They have incorporated hydraulic lime in 5%, 7%& 10% on blended cement concrete and found 7% is the suitable dose per achieving good results.

Nanda et al. (2010) have conducted test on stone crusher dust as fine aggregates in concrete for making paving blocks. They found that replacement of fine aggregates by crusher dust up to 50% by weight has a negligible effect on the reduction of compressive, flexural and split tensile strength.

Singh et al. (2016) have done an experimental report on the comparable study between Granite cutting waste (GCW) and Marble slurry (MS) as a replacement of fine aggregates. They observed the microstructural studies by using Scanning Electron Microscopy (SEM) test and Energy Dispersive Spectroscopy (EDS) test and inter particle behavior of the ingredients with the matrix. They found the optimal re-placement percentages for GCW and MS are 25% and 10% respectively in the concrete mix.

Thirougnaname and Segaran (2014) have experimented on the use of unsieved stone dust as fine aggregates in mortar in different proportions as 1:3, 1:4, 1:5 and 1:6. By comparing the various age strengths with the conventional mortar in the same proportions they found that 5% compressive strength was to be more in every ratio expect the 1:3 ratio cement mortar.

Patel and Shah (2016) have made a review regarding utilization of quarry waste replacing the fine aggregates in concrete and concluded that above 30% replacement of sand by quarry sand is not good for the strength criteria.

III. EXPERIMENTAL PROGRAM

A. Materials Used

i. Cement

OPC (43) Grade of RAMCO Company was tested and used in this investigation. Various physical test properties are presented in TABLE 1.

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TABLE 1.Physical properties of cement.

Sl No.	Properties	Results Obtained
1	Normal consistency	32%
2	Fineness (dry sieve)	7%
3	Specific gravity	3.12
4	Initial setting time	109 minutes
5	Final setting time	297minutes
6	3days compressive strength	25.40MPa
7	7days compressive strength	34.44MPa
8	28days compressive strength	45.14MPa

ii. Aggregates

(a) Fine Aggregates

Natural river sand having maximum 4.5 mm size and confirming to zone III of IS: 383: 1970 used. The sand with properties of fineness modulus 2.21, specific gravity 2.62, and water absorption 0.7% were found.

(b) Coarse Aggregates

Crushed granite natural stone aggregates of maximum 20mm size were used. The aggregates with properties of fineness modulus 6.6, specific gravity 2.64, and water absorption 0.9% were found. Properties of coarse aggregates are given in TABLE 2.

TABLE 2.Physical Properties of Coarse Aggregates

SL No	Properties	Value Obtained
1	Maximum size	20mm
2	Shape	Well graded, angular
3	Fineness modulus	6.66
4	Specific gravity	2.64
5	water absorption	0.9%
6	Moisture content	nil

iii. Fly ash

Fly ash of class F was collected from a local fly ash brick factory, Chandaka lane (Khurda,Odisha). They have purchased it from NALCO (Angul,Odisha). The specific gravity of fly ash was found to be 2.1.

iv. Hydrated Lime Powder

Commercially available limestone was brought from a local Fly ash brick factory, (Angul,Odisha). The limestone i.e. in the form of quicklime was converted to (slaked lime) hydrated lime powder by adding a specific quantity of normal water.

Fig1. Cement-Class F fly ash-Lime powder sample

v. Stone Crusher Sand

Raw crusher dust was collected from a stone crusher plant, Hindol (Dhenkanal,Odisha). It was then sieved with a normal sand sieve to separate out the maximum particle sizes i.e. more than 4.75mm and further washed thoroughly in water to remove excess fine silt particles size less than 150 microns. Then it was dried for 1 to 2 days to get the required shaped, graded in sand form comparable to natural river sand. Now it is named as Stone Crusher Sand (SCS). This sand of different properties of fineness modulus 2.143, specific gravity 2.68, and water absorption 1.10% were found. Properties of NRS & SCS are given in the TABLE 3. Typical Sieve Analysis comparison between Natural River Sand & Stone Crusher Sand are shown in TABLE 4.

TABLE 3.Physical Properties of NRS and SCS

SL NO	Properties	Value Obtained for NRS	Value Obtained for SCS
1	Maximum Size	4.75 mm	4.75 mm
2	Zone	III	III
3	Fineness Modulus	2.21	2.14
4	Specific Gravity	2.62	2.68
5	Water Absorption	0.7%	1.10%
6	Moisture Content	nil	nil

TABLE 4.Sieve Analysis Comparison between NRS & SCS

IS Sieve size	% wt. passing for NRS	% wt. passing for SCS	Zone III (As per IS:383:1970)
4.75 mm	99.587	100	90-100
2.36 mm	99.024	99.00	85-100
1.18 mm	90.257	88.80	75-100
600 µ	76.624	72.80	60-79
300 µ	12.00	20.8	12-40
150µ	0.734	4.30	0-10
75 µ	Max 3	Max 15	Max 15
	Zone III	Zone III	

Fig 2. Fine aggregate samples after sieving

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vi. Super plasticizer

Modified Naphthalene based Formaldehyde Sulphonate admixture Sika® Plasocrete® was used. It is a water reducing and water proofing admixture for all types of concrete and mortar. Its color is of brownish liquid having specific gravity 1.04 at 25° c and pH value more than 6.The dosage was taken as 0.6% by weight of cementitious material for the entire investigation.

vii. Water

It is a vital material to prepare a uniform mix. Here fresh potable water from Civil Engineering Lab, CET campus was used for mixing as well as for curing purposes.

B. Mix Proportions

A design mix M30 proportion of 1:1.58:3.09 with water to cement ratio of 0.4 was carried out as per IS: 10262-2009 in the investigation. Mix Proportion is shown in the TABLE 5. Detailed Material percentages (%) replacement for all the mixes are presented in TABLE 6. Various abbreviations are used such as FA-Fly ash, LP-Lime Powder, CA-Coarse aggregates, NRS-Natural river sand, SCS-Stone crusher sand.

TABLE 5. Designed M30 Mix Proportion (By Weight)

Water	Cement	Fine aggregates	Coarse aggregates
0.4	1	1.58	3.09
160	400 kg/m3	632.111 kg/m3	1236.407 kg/m3

TABLE 6.Detailed Material Percentage Replacement

Mix	Cement (%)	FA (%)	LP (%)	NRS (%)	SCS (%)	C.A (%)
Mix 1	100	0	0	100	0	100
Mix 2	89	5	6	90	10	100
Mix 3	84	10	6	80	20	100
Mix 4	79	15	6	70	30	100
Mix 5	74	20	6	60	40	100
Mix 6	69	25	6	50	50	100

C. Test Specimens

Concrete test specimens consist of cubes of sizes 150mm×150mm×150mm, cylinders of 100mm diameter and 200mm height, 100mm×100mm×500mm prisms were used.

D. Test Procedure:

The slump test, compressive strength, split tensile strength and flexural strength test were conducted. For concrete preparation all the ingredients were first weigh batched and dry mixed manually. Then water mixed with super plasticizer were added to the dry mixture. After getting a homogenous mix slump test was done for every casting. After that the concrete mixture were poured into the pre lubricated moulds in 2 to 3 layers each layer tampered 20 to 30 blows and table vibrated for full compaction. Then the test specimens were smooth surface finished and leave in 27±2°c room temperature for 24 hours. On the next day the specimens were demoulded and kept in water curing tank till the desired testing periods i.e. 7 and 28 days .Before testing the specimens were wiped out, dried and placed in the testing machines. Per each testing three samples were tested and the average value was reported in this paper. Finally all the results were compared with the reference concrete i.e. Mix 1.

IV. RESULT ANALYSIS

A. On Fresh Concrete

Slump Workability Test was conducted on fresh concrete. Workability (slump) of concrete was measured as per IS: 7320-1974 and IS: 1199-1959.

Table 7. Slump Value Obtained for Various Mix

Mix	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Slump value in (mm)	40	35	32	28	25	22

During slump workability tests it was observed that, as the percentages of fly ash (FA) plus lime powder (LP) with Stone crusher sand (SCS) increases the slump values goes on decreasing. This was most probably due to the effect of water absorption capacity of fly ash & stone crusher sand.

B. On Hardened Concrete

ii. Compressive Strength Test

The ability of cement concrete to resist the compressive forces acting on it is called compression. It is described in terms of stress. The cubes were tested in Compression Testing Machine (CTM) having capacity of 3000KN.The ultimate failure loads were noted till the dial gauge needles reversed its direction of motion. The ultimate load divided by the cross sectional area of the specimen is equal to the ultimate cube compressive strength.

$$\text{Compressive Strength} = P/A \qquad (1)$$

Where P is the Compressive Failure Load is in Newton and A is the cube failure cross sectional area is in mm2.

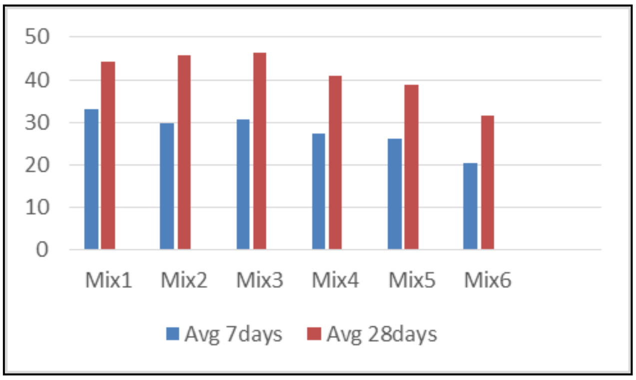

Fig .3 Average Compressive Strength at 7 & 28 Days

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For Mix1; 7 & 28 days compressive strengths were found to be 33.18MPa and 44.16MPa respectively. The optimum strengths were found to be for mix3. (i.e. FA10%+LP6% with cement and SCS20% with natural river sand).The maximum average compressive strength for Mix3 i.e. 46.370MPa was found to be 3.828% higher than the reference concrete.

ii. Flexural Strength Test

The ability of cement concrete beam or slab to resist the bending moment due to loading is called as flexural strength. It is also termed as ''Modulus of Rupture''. The beams were tested in the Universal Testing Machine (UTM) having capacity 100 Tons subjected to 3-point loading setup.

$$Fb = P \times l / b \times d2 \qquad (2)$$

Where b = measured width of the specimen in mm, d = measured depth of the specimen at the point of failure in mm, l = length of the span on which the specimen was supported in mm, P = maximum load applied to the specimen in Newton. Results are shown in the Fig 4.

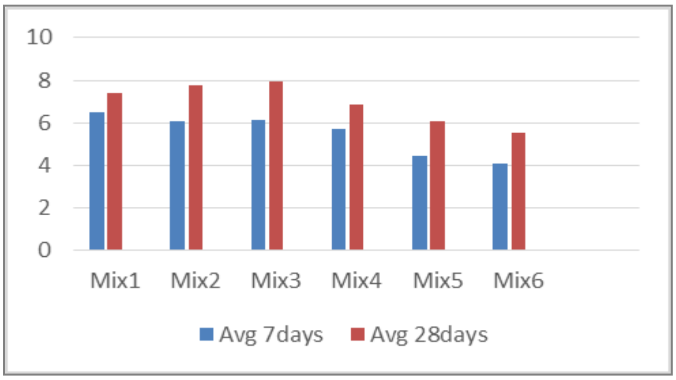

Fig .4 Average Flexural Strength at 7 & 28 Days

The 7 & 28 days flexural strengths were found to be 6.464MPa and 7.4MPa for Mix1.The maximum average flexural strength for Mix3 i.e. 7.932MPa was found to be 7.189% more than the reference concrete.

iii. Split Tensile Test

Concrete is strong in compression but weak in tension. Here split test was done by indirect application of tensile forces. The cylinders were tested in a compression Testing Machine (CTM) having capacity 100Tons. The failure occurred along the diameter of the samples.

$$F = 2P/\pi LD \text{ in } (N/mm2) \qquad (3)$$

Where, P is the Failure compressive load on the cylinder in Newton, L is the length of cylinder in mm, and D is the diameter of the cylinder in mm. Results are shown in the Fig 5.

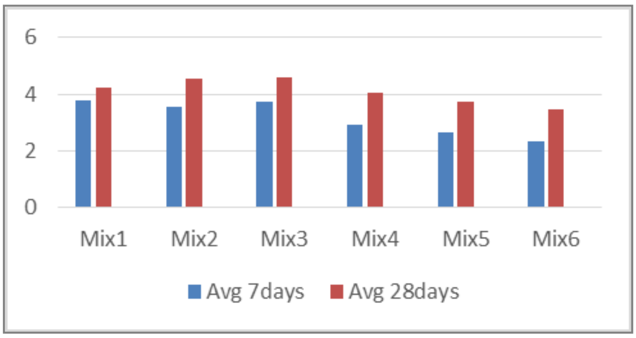

Fig.5 Average Split Tensile Strength at 7 & 28 Days

The 7 & 28 days split tensile strengths for Mix1 were found to be 3.7665MPa and 4.244MPa.The maximum average tensile strength for Mix3 i.e. 4.610MPa was found to be 8.623% more than the reference concrete.

V. DISCUSSION AND CONCLUSION

All the mix proportions strength results were compared to the reference concrete mix i.e. mix1. The similar manner variation of percentage strengths were noticed for all the test strength results. All the mixes attained the target mean strength at 28 days except Mix6. The maximum % of replacement was found up to Mix5 (i.e. FA20%+LP6% & SCS40%).As the fly ash (FA) % increases the early strength for 7 days values goes on decreasing but it can be said that by addition of lime powder (LP) for mix2 and mix3 the 7 days strength achievement is very much nearly comparable to the reference concrete. It was mostly possible due to the filling effect and reaction of Calcium hydroxide with pozzolanic materials (SiO2 and Al2O3) in presence of moisture and additional formation of C-S-H gel densification in the concrete mix. Addition of SCS had performed better within 10% to 20%.It was found that the 6%hydrated lime powder(LP) can be effectively compensate with fly ash & SCS ranges up to 20% and 40% respectively. Addition of 6% hydrated lime powder can be well consumed by 5% and 10% fly ash. Stone crusher sand replacement up to 40% performed satisfactorily comparing to natural river sand. By the use of discussed alternative supplementary materials we can achieve a sustainable green concrete environment to some extent. These can be used as partial replacement in construction works without compromising the structural performances. The results are somehow may be affected by the type, origin, compositions of the materials. So the use of these alternative materials is purely dependent on the hands of the site engineer as per field conditions, suitability and feasibility. The major factors like energy and cost efficiency can be effectively achieved by the addition of these waste supplementary materials.

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