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Study on Strength of Concrete by Partial Replacement with Crushed Sand and Egg Shell Powder

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ABSTRACT

Uninterrupted infrastructural development is an important aspect for continuous development of a country. Concrete is an integral part most of this construction. Thereofit is to be made environment friendly and economical but for last few year unsustainable digging of River Sand (RS) caused depletion of natural sand resources. In consequence of that ecological imbalance rises up and hence sand excavation is restricted by government in many states of India. Thus shortage of RS drastically increases in its cost. Crushed Sand (CS) also known as stone industry wastes were used in this research work as fine aggregate replacement. M30 grade of concrete has been prepared with RS replacement of 0% Control Concrete (CC), 25%, 35%, 45%, 55%, and 65% to reduce the RS consumption as well as to solve land fill related problem of CS. 5% Egg Shell Powder(ESP) was also used as replacement of cement with CS. ESP is also a waste material. It has a large potential to be used as supplementary cementitious material due to its high calcium content. So in this study we have analyzed the combined effects of these two waste materials on Compressive Strength and Flexural Strength properties of concrete.

Keywords: ***River Sand, Replacement, Crushed Sand, Egg Shell Powder, Compare, Compressive Strength, Flexural Strength***

1. INTRODUCTION

From its origin dated back to 1300 B.C.E in Middle Eastern country concrete has a long history of using limestone and river sand as its raw material. Till today most widely used conventional concrete has mainly four constituents i.e. cement, fine aggregate, coarse aggregate and water. Among these constituents aggregates (fine & coarse) makes up approximately 80% of total volume of concrete. Previously aggregate was thought as inert filler within concrete mix but studies in this field revealed influence of it on both fresh and hardened propert6ies of concrete. In India rapid uses of concrete in infrastructure between1991 to 2005 caused sudden outburst of 266% increase in its demand. This demand leads to unsustainable sand mining. Unscientific digging up of river reduced its sediment carrying capacity that resulted in reduced water head. In the year 2019 River Ken and Betwa dried up due to excess digging in Madhya Pradesh. Second to aggregate most important material used in concrete is Cement contributing to about 18% volume of it. Another mentionable fact is that now India is the 2nd largest producer of cement in the world with 329 MT productions in 2020.

It is uncertain that glory of cement industry also welcomed pain of air pollution with its uncontrolled carbon emission. So this is the high time we consider for alternative concrete options by reusing wastes materials which could make inexpensive concrete without compromising strength & durability properties. In this research work we have used crushed sand and egg shell powder; both are waste material in nature but from two different industries. Crushed sand is generated from stone quarrying industry in the time of crushing process whereas egg shell powder is generated from food processing industry. These has also land disposal problem due to its large generating volume. Crushed sand has a size less than 4.75 mm greater than 600 µ can be used as a fine aggregate supplement. Considering broken egg shells, only in India it creates 1.5 billion metric ton of wastes from food industries. It has high concentration of calcium also chemical composition similar to limestone that makes it a perfect supplementary cementitious material. The present research work mainly deals with different replacement proportion of sand with crushed sand along constant percentage of egg shell powder. This study is planned to check the feasibility of crushed sand and egg shell powder to be used in normal concrete and assess the rate of strength development.

2. LITERATURE SURVEY

B Balapgol& SA Kulkarniinvestigated the hardened properties of concrete with use of crushed basalt stone fine aggregate as a substitute to natural sand. The researchers concluded that there was significant increase in compressive strength with crushed sand. The compressive strength was increased by 19.44% to 40.38% and 8.33% to 25.9% at 7 days & 28 days age respectively as grade of mixes was increased. The flexural strength of concrete with crushed sand was marginally increased about 1 to 5% as compared to natural sand. According to B Balapgol& SA Kulkarni crush sand gives more strength than natural sand because of properties of crush sand i.e. shape size, strength etc. It gives higher strength than that of natural sand as in [1].

A.K. Sahu et al. (2003) investigated the suitability of crushed stone dust waste as fine aggregate for concrete comparing its basic properties with that of conventional concrete. Test results indicated that crushed stone dust waste can be used effectively to replace natural sand in concrete. Concrete made with this replacement can attain the same compressive strength, comparable tensile strength, modulus of rupture and lower degree of shrinkage as the control concrete. It can be concluded that if 40% sand is replaced by stone dust in concrete, it will not only reduce the cost of the concrete but will also save large quantity of natural sand when replaced by quarry dust by 20 and 40% and found concrete made with this replacement can attain the same compressive strength as control concrete as in [2].

Ukpata and Ephraim identified the flexural and tensile strength properties compared with those for normal concrete. Hence, concrete proportion of lateritic sand and quarry dust can be used for construction provided the mixture of lateritic sand content is reserved below 50%. Both flexural strength and tensile strength are increased with increase in lateritic content as in [3].

Shyam Prakash K examined compressive strength of quarry dust on M20,M25, M30 & M40 grade of concrete. 20%, 25% and 30% replacement of quarry dust was used for M25 and M30 grades and for M20 grade quarry dust was added from 10 % to 100 % with 10% increment at each stage. It was found that with 40% replacement of sand quarry dust gives highest results in compressive strength compared to normal concrete and then it decreases from 50% as in [4].

The study of **Ilangovana et al.** has given attention to physical and chemical properties of quarry dust with respect to requirements of standard code provision which are satisfied. The 100% replacement of sand with quarry dust gives better results in terms of compressive strength studies as in [5].

Amarnath Yerramala (2014)described the usage of poultry waste in concrete and studied the properties of concrete with eggshell powder (ESP) as cement alternative. Different ESP concretes had been prepared through replacing 5-15% of ESP for cement. Compressive strength and split tensile strength increased than normal concrete for 5% of ESP alternative and it had lower strength than normal concrete with greater than 10% of substitute on the age of 7 & 28 days as in [6].

S. Karthikeyan (2012) Reduce and Reuse of the opportunity substances is a whole lot energetic to preserve our strength assets. In the field of construction, the use of admixtures and re-utilization of available wastage substances is not a new one. But it is deals with a look at of Egg Shell Powder as a partial substitute of cement in concrete, to improve the strength in addition to reuse & reduce the egg shell wastage. The various traits of ESP are examined and it's far allowed to concrete as a partial alternative of cement. The numerous proportions such as 2.5, 5 and 7.5% are tried on this research and the strength performed by way of ESP concrete is much higher than a nominal concrete. Every admixture has its own strength. There became a pointy decrease inside the power while the proportion of ESP is beyond the extent of 5% as in [7].

3. MATERIALS AND METHODOLOGY

A. Cement

In this experiment fly - ash based Portland Pozzolona Cement (**PPC**) conforming to IS: 1489 (Part – I) – 2015 of Ultratech brand obtained from single batches was used throughout the investigation. Physical Properties of cement are given in Table1**.**

Table 1: ***Physical Properties of Cement***

Properties	Test Results
Fineness (% retained on 90 μ IS sieve)	4.9
Standard Consistency (%)	31
Specific Gravity	2.8
InitialSetting Time(minutes)	65
Final Setting Time(minutes	585
% Fly- ash added	33

B. Coarse Aggregate

Two aggregate of 20 mm and 10 mm sizes were mixed in the proportion of **60:40**.The aggregates thoroughly passed through 40 mm IS sieve and retain on 4.75mm IS sieve.IS: 2386- 1(1963) was followed for physical tests of aggregates.The specific gravity of 20 mm and 10 mm coarse aggregates are 2.86 and 2.58 respectively.

C. Fine Aggregate

Natural River Sand is resourced from Mayurakshi River of Birbhum District and collected from local market. It was used for preparing test samples of First Series and Second Series. All samples passed through 4.75 mm sieve and retained completely on 150 **µ**sieve. Physical Properties of fine aggregate are given in Table 2 and IS: 383-1970 was followed for determining zone gradation.

Table 2: ***Physical Properties of Fine Aggregate***

Properties	Value
Specific Gravity	2.621
Fineness Modulus	2.815
Zone	II
Water Absorption (%)	0.6
Shape	Natural Round
Size	4.75 mm down

D. Crushed Sand

Crushed sand was collected from local stone crushing units of Bharatpur , Rewa Road , Uttar Pradesh. It was initially dry in condition when collected and completely retained on 150 **µ** sieve before mixing in concrete. Crushed sand was of grey color and shape of particles was irregular. It followedIS: 383-1970 specifications for zone gradation. Specific gravity of crushed sand is 2.24 and its sieve analysis is mentioned in Table 3.

Table 3: ***Physical Properties of Crushed Sand***

Properties	**Value**
Specific Gravity	2.24
Fineness Modulus	2.59
Zone	II
Water Absorption (%)	nil
Shape	Irregular
Size	4.75 mm down
Color	Grey

E. Egg Shell Powder

Egg Shell Powder is prepared ourselves for this experimentation purpose and used as a cement replacement. For this research work broken egg shells were collected from nearby restaurants and thoroughly washed in tap water and then put to boil at 110°c for 10 minutes. Boiling process sterilizes those harmful organic substances present in broken cells. After that all broken cells are sundried and turned into powder at 18000 RPM using 750 watt dry grinding machine. Egg Shell Powder used in this research work had specific gravity of 2.16, white in color, has powdered texture. It was used for making second series concrete beams and cubes. Chemical properties of ESP determined by using X- ray Fluorescence Spectrometer is presented below.

Table 4: ***Physical Properties of Egg Shell Powder***

Properties	Value
Specific Gravity	2.16
Texture	Powdered
Fineness (% retained on 90 µ IS sieve)	3.8
Color	White

Table 5: ***Chemical Properties of Egg Shell Powder***

Elements	Concentration (%)
***Aluminiumoxide*(Al_2O_3)**	0.001
***Silicon dioxide* (SiO_2)**	0.001
***Sulphur*(S)**	0.001
***Chlorine*(Cl)**	0.009
***Calcium oxide*(CaO)**	99.81
***Chromium oxide*(Cr_2O_3)**	0.003
***Manganese oxide* (MnO)**	0.001
***Cupric oxide*(CuO)**	0.001

F. Super plasticizer

In this experiment we have used Sika® **Plastocrete® Super** conforming to **IS 9103-1999, IS 2645- 1975 and ASTM C- 494** as superplasticizer. It is brown color liquid with chemical base Modified Naphthalene Formaldehyde Sulphonate. At 25° C its specific gravity is 1.04.

G. Water

Throughout the study potable quality tap water was used for making concrete which was free from any short of insoluble substances, color or turbidity according to IS:456-2000.

H. Mix Design

Mix Design of M30 grade of concrete was done using IS: 10262 – 2009 with the help of collected data in lab. Thus we had used standard deviation value 5 and w/c ratio 0.4 in this method. Mix design proportions and ratio are mentioned in Table 5**.** We had strictly maintained this ratio throughout the research process.

Table 6: ***Mix Design Proportions***

Water	Cement	Fine Aggregates	Coarse Aggregates		Chemical Admixture
			20 mm	10 mm	
142 (kg/ m^3)	355 (kg/ m^3)	806.5 (kg/ m^3)	717(kg/ m^3)	478(kg/ m^3)	7.1(kg/ m^3)
0.4	1	2.27	3.36		@2% of cement weight

I. Mehod of Casting and Curing

We have used designed mix M30 proportions and constant water – cement ratio accordingly to make concrete with PPC, FA, and CA. In this research work experiments are done in two series. In First Series RS was replaced with 0%, 25%, 35%, 45% and 55% of CS as supplement of FA. Concrete with 0% replaced RS is called Control Concrete (CC). Then in Second Series RS was replaced with 25%, 35%, 45%, and 55% of CS with 5% ESP addition in each variation. For comparative study between different concrete samples we have tested Compressive Strength test, Flexural Strength Test in this study. We have used 6 samples for each replacement variation. For this purpose 2 types of steel moulds have been used - 150 mm X 150 mm X 150 mm cube and 100 mm X 100 mm X 500 mm rectangular beam.

In this research work 60 samples in first series and 48 samples in second series were casted. A total of 108 samples had been prepared taken in count both series. Firstly we have measured each component of concrete through weigh batching and kept those items on a clean dry mixing pan. Water was measured separately using volumetric cylinder. Then poured water accordingly and hand mixed those ingredients to achieve workable consistency. After that steel moulds were prepared with grease for casting. Cubes and Beams were casted respectively for Compressive Strength testand Flexural Strength Test. After 24 hours of casting, concrete moulds were loosened and samples were taken off to immerse them in fresh water of 27 ° C temperature for proper curing. On completing curing period of 7days, 28 days cubes and beams were taken out on test days and kept for 24 hours in open air and details of concrete samples casted in two series are given in Table 6.

 # PPC – Portland Pozzolona Cement, FA – Fine Aggregate, RS – River Sand, CS – Crushed Sand, CA – Coarse Aggregate, CC – Control Concrete, ESP – Egg Shell Powder.

Table 7: ***Details of Sample ID***

Sample ID	Type	Cement %	RS %	CS %	CA %	ESP %
C0	CUBE	100%	100%	0%	100%	0%
C1-25	CUBE	100%	75%	25%	100%	0%
C2-35	CUBE	100%	65%	35%	100%	0%
C3-45	CUBE	100%	55%	45%	100%	0%
C4-55	CUBE	100%	45%	55%	100%	0%
C12-25	CUBE	95%	75%	25%	100%	5%
C22-35	CUBE	95%	65%	35%	100%	5%
C32-45	CUBE	95%	55%	45%	100%	5%
C42-55	CUBE	95%	45%	55%	100%	5%
F0	BEAM	100%	100%	0%	100%	0%
F1-25	BEAM	100%	75%	25%	100%	0%
F2-35	BEAM	100%	65%	35%	100%	0%
F3-45	BEAM	100%	55%	45%	100%	0%
F4-55	BEAM	100%	45%	55%	100%	0%
F12-25	BEAM	95%	75%	25%	100%	5%
F22-35	BEAM	95%	65%	35%	100%	5%
F32-45	BEAM	95%	55%	45%	100%	5%
F42-55	BEAM	95%	45%	55%	100%	5%

4. TEST FOR SPECIMENS

Compressive Strength Test

Cubes with 150 X 150 X 150 mm size were tested for calculating compressive strength using Compression Testing Machine (CTM) as per **IS: 516 – 1959 .** After completing 7 days and 28 days of curing cubes were kept in open air for 24 hours.Then crushing strength test of concrete is determined by breaking those concrete cubes under CTM at uniform rate of loading at 140kg Sq.cm/min and 3 cubes were tested for each set of concrete.

Flexural Strength Test

Beams of 100X 100 X 500 mm sizes casted previously in First and Second series was used for testing Flexural Strength. **IS: 516 – 1959** was followed for loading on beam using Two Point Load method. Then those beams were brought to Flexural Strength Testing Machine after proper surface drying. Firstly the beams were marked with chalks , two marking at a distance of 50 mm between two supports and 20 mm from the end of the beam to the supports. The beams were supported at the marking. Two point loads were provided with the help of steel bars over which steel plate was placed; load was transferred with the loading gauge which is placed above the plate. In Flexural Strength Testing Machine the reading dial shows the load at failure.

5. RESULTS AND DISCUSSIONS

Results of Compressive Strength Test

Compressive Strength is determined for every concrete mix considering 3 cubes each for 7 days and 28 days curing with sizes of 150 X 150 X 150 mm. Cubes strength was determined for C0, C1-25, C2-35, C3-45, C4-55, and C5-65 in First Series and for C12-25, C22-35, C32-45, C42-55, and C52-65 in Second Series. In this work chemical admixture was also used to enhance the Compressive strength of concrete for both series. Compressive strength values for CC cubes were determined 26.88 MPa and 37.56 MPa at 7 days and 28 days respectively. In the first series compressive strength of cubes range from 27.09to 29.05 MPa at 7 days and 38.86 to 43.49 MPa at 28 days (shown in Table 8&Fig.1). From detailed analysis of compressive strength of cubes we have noticed 8.07% and 15.78% increase in strength for 7 days and 28 days with 35% crushed sand replacement than Control Concrete.

Table 8: ***Compressive Strength of Cubes with CS***

CUBE ID	AVG. COMPRESSIVE STRENGTH (Mpa)		Replacement Percentages
	7 DAYS	28 DAYS	
C0	26.88	37.56	0% CS
C1-25	27.42	39.54	25%CS
C2-35	29.05	43.49	35%CS
C3-45	28.27	42.23	45%CS
C4-55	28.11	41	55%CS
C5-65	27.09	38.86	65%CS

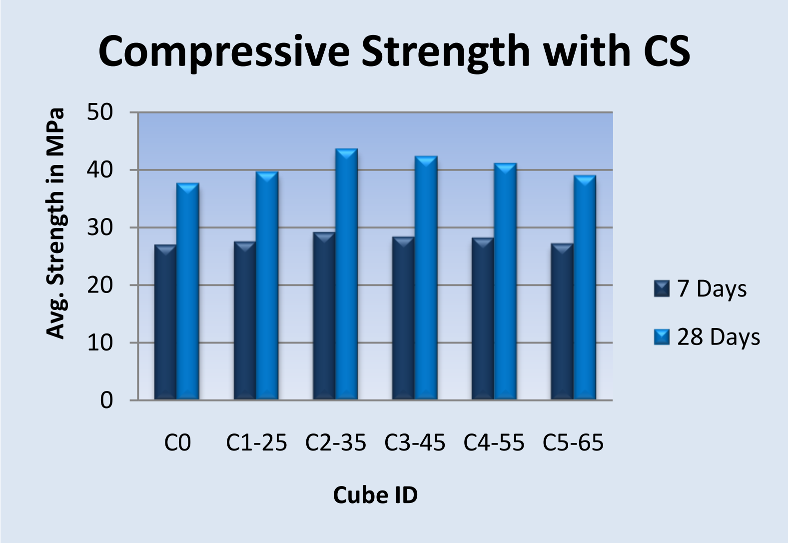

Figure 1: ***Graphical Representation of Compressive Strength of Cubes with CS***

Table 9: ***Compressive Strength of Cubes with CS and ESP***

CUBE ID	AVG. COMPRESSIVE STRENGTH (Mpa)		Replacement Percentages
	7 DAYS	28 DAYS	
C12-25	28.85	42.34	25%CS + 5%ESP
C22-35	30.5	44.95	35%CS + 5%ESP
C32-45	28.63	43.35	45%CS + 5%ESP
C42-55	28.05	41.61	55%CS + 5%ESP
C52-65	27.22	40.44	65%CS + 5%ESP

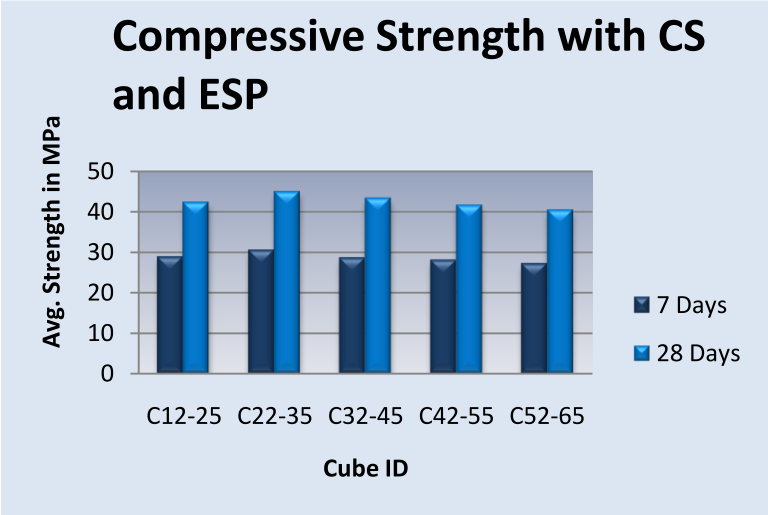

Figure 2: ***Graphical Representation of Compressive Strength of Cubes with CS and ESP***

Again in second series, highest compressive strength for 7 days and 28 days (shown in Table 9 &Fig.2) were noted as 29.21 MPa, 44.95 MPa respectively. Comparing these values with Control Sample there was 8.6% and 19.67% increase in strength. When we compared maximum strength values of second series in respect of first series, there was 3.35% increase at 28 days. Thus a close view of experimental results confirms that the compressive strength of concrete made with 5% ESP and35% CS shows higher compressive strength value than natural aggregate concrete and also has an edge for 28 day strength over concrete with single CS replacement. Combined effect of these two waste materials on M30 concrete has positive result in improving compressive strength.

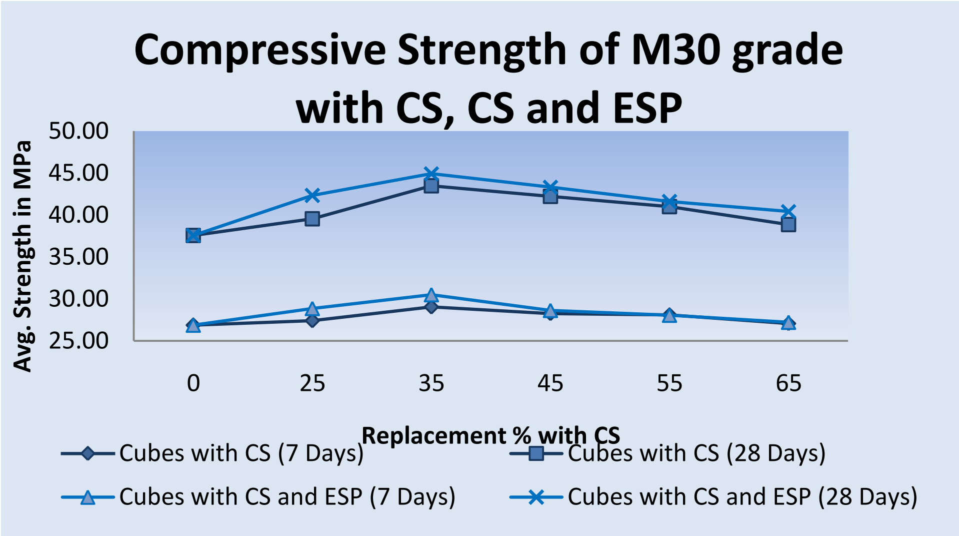

Figure 3: ***Comparative Graphs of Compressive Strength***

Results of Flexural Strength Test

Flexural Strength are determined for beams of sizes 100 X 100 X 500 mm considering 3 numbers of beam each for 7 days & 28 days with each variation of concrete. Beam strength was determined for F0, F1-25, F2-35, F3-45, F4-55, F5-65 in first series and for F12-25, F22-35, F32-45, F42-55, F52-65 in second series.

Table 10: ***Flexural Strength of beams with CS***

BEAM ID	AVG. FLEXURAL STRENGTH (Mpa)		Replacement Percentages
	7 DAYS	28 DAYS	
F0	3.23	4.7	0% CS
F1-25	3.51	5.14	25%CS
F2-35	3.76	5.37	35%CS
F3-45	3.57	5.29	45%CS
F4-55	3.53	5.22	55%CS
F5-65	3.42	5.13	65%CS

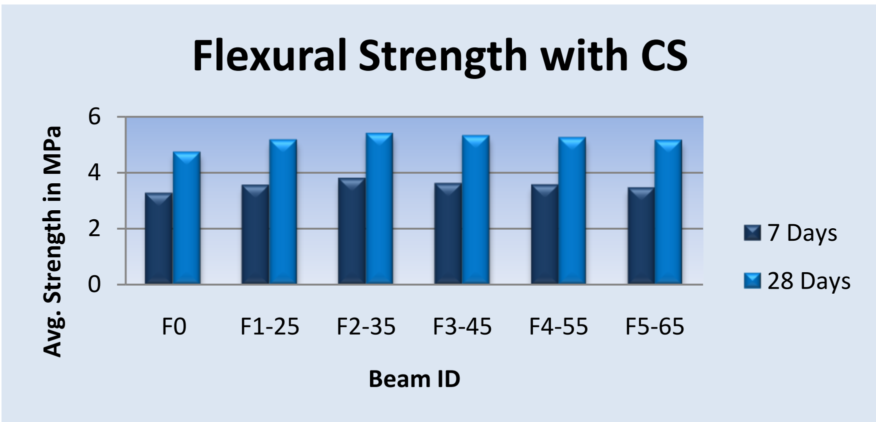

Figure 4: ***Graphical Representation of Flexural strength of Beams with CS***

Flexural strength of CC beams was 3.23 and 4.7 MPa at 7, 28 days respectively.In first series flexural strength of concrete range from 3.42 to 3.76 MPa at 7 days and 5.13 to 5.37 MPa at 28 days (shown in Table 10& Fig. 4). We have noticed maximum 13.83% increase in the strength for 7 day whereas for 28 day there is max 14.35% increase in strength than CC. In this case both highest values are with 35% crushed sand replacement. So from Experimental Results it is clear that the flexural strength of concrete made with 35% CS shows higher flexural strength value than natural aggregate concrete mix.In second series flexural strength ranges from 5.34 to 5.71 MPa at 28 days (shown in

Table 11 and Fig. 5). It has also been observed that concrete with 35% CS and 5% ESP resulted 24.51% increase in flexural strength comparing referral concrete at 28 days.

Table 11: ***Flexural Strength of Beams with CS and ESP***

BEAM ID	AVG. FLEXURAL STRENGTH (MPa)		Replacement Percentages
	7 DAYS	28 DAYS	
F12-25	3.81	5.71	25% CS+ 5% ESP
F22-35	3.87	5.85	35% CS + 5% ESP
F32-45	3.72	5.62	45%CS + 5% ESP
F42-55	3.57	5.34	55% CS+ 5% ESP
F52-65	3.45	5.14	65% CS + 5% ESP

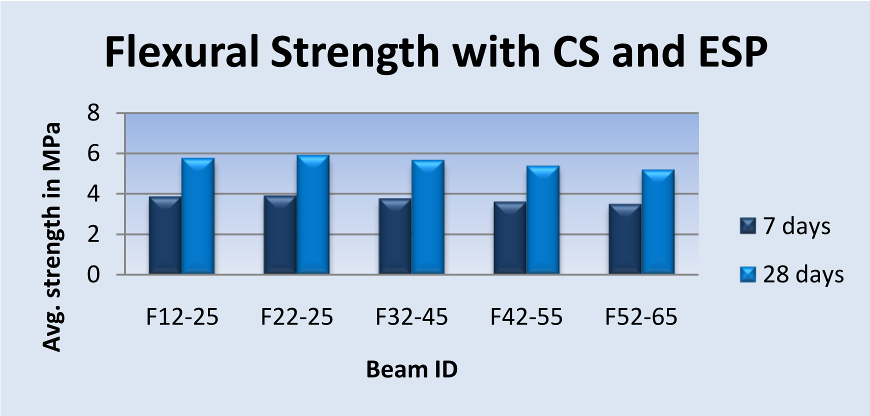

Figure 5: ***Graphical Representation of Flexural strength of Beams with CS and ESP***

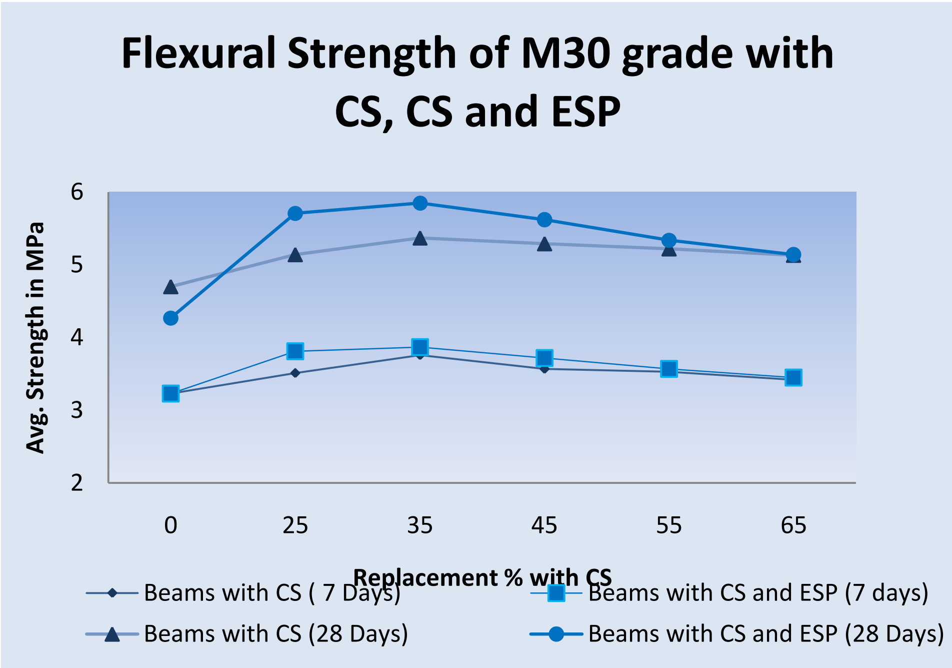

Figure 6: ***Comparative Graph of Flexural Strength***

CONCLUSION

The concept of replacement of fine aggregate by crushed sand with inclusion of egg shell powder as cement replacement indicated that these waste materials could significantly reduce use of river sand in concrete in this study. Thus this study could also help in restoring ecological balance through land fill reduction and river rejuvenation. After obtaining results of compressive strength and flexural strength following are the conclusive points derived at the end of the study:

- In Second Series concrete with 5% ESP and 35% CS replacement produces maximum 19.67% increase in compressive strength than control concrete. Even this combination secures an increase of 3.35% when compared with first series. Also it was assessed that in all cases crushed sand addition resulted better strength than natural aggregate concrete.
- Flexural strength also reached highest value with 5% ESP and 35% CS replacement. There was 8.9 % increase in strength for Second series beams comparing control concrete whereas for First Series beams ultimate strength increased 14.35%. Results have shown slightly lower but gradual increment in flexural strength when crushed sand is added with river sand in all cases.
- Over all we can establish that 35% crushed sand is optimum level of replacement of sand with 5% egg shell powder as it creases compressive and flexural strengths throughout all experiments in this research work. Both of this waste material is available abundantly and through suitable design both can be used in different concrete grades. Thus way the construction industry can become slight ecofriendly with increased strength option.

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