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An Experimental Study on Flexural behaviour of Reinforced Concrete Beam by Partial Replacement of Fine aggregate with Coal based Brick-Kiln-Ash

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Abstract - *Concrete is an extensively used material in the world. Production of constituents of concrete leads to the depletion of the natural resources as well as it leads to the environmental pollution. Brick-Kiln-Ash is considered as a waste material in the Brick industries. In this study, Brick-Kiln-Ash is used for the partial replacement of Fine aggregate. Fine aggregate is replaced with Brick-Kiln-Ash by 15%, 20%, 25% and 30% by weight and compared with the control mix without any replacement of Brick-Kiln-Ash. M30 grade of concrete was designed and constant water-cement ratio of 0.45 was used. Super Plasticizer was used to increase the workability. Mechanical properties of concrete such as Compression and Split tensile strength were evaluated. Results showed increase in strength till 25%, and then it got reduced for 30%. So, 25% replacement of Brick-Kiln-Ash was chosen as optimum value. Further, using the optimum value reinforced concrete beams was casted and results were compared with control beams without Ash for Flexural behavior. And also experimental values were compared with the theoretical values as per IS: 456-2000.*

Key Words: Brick-Kiln-Ash, Workability, Flexural behavior, Compression strength, Split tensile Strength.

1. INTRODUCTION

Concrete is one of the most important construction material is being used all over the world. It is a compound material composed of fine and coarse aggregate (filler material) nested in a hard matrix of cement (binders) that fills the space among the fine and coarse aggregate particles and bind them together. Concrete's versatility, economy and durability have made the concrete world's most utilized construction material. The cement production adds to pollution environment is a well-known fact to Environmentalists and civil Engineers. The production of cement in large-scale is posing environmental problems on one side and unconditional reduction of natural resources on the other side. Each tonne of ordinary Portland cement production leads to the emission of one tonne CO_2 into the environment.

The objective of this research is to study the feasibility of utilizing the Brick-kiln-Ash produced by Brick industries in India as a replacement for Fine aggregate in concrete. Brick-Kiln-Ash is a by-product which is produced after firing of brick using coal as a fuel. It is having Cementitious property but its physical properties are similar to sand that is used in this study. Indian brick industry is utilizing 15-20 million tons of coal per year. Indian brick industry is the 3rd largest utilize of coal in India after thermal power plants and steel industries. After China, India is the second largest producer of bricks.

This Brick Kiln Ash is dumped as a waste material and which causes environmental pollution. Brick Kiln-Ash can be used as an alternative to natural sand. Hence the use of Brick Kiln Ash in concrete as fine aggregate will reduce not only the demand of natural sand but also the environmental pollution and burden. Moreover the incorporation of Brick-Kiln-Ash will considerably reduce the production cost of concrete. In brief the effective utilization of Brick-Kiln-Ash will turn waste material into a valuable resource for the concrete production.

2. LITERATURE REVIEW

Govindarajan D et al. (2014) [1] studied the effect of coal bottom ash as partial replacement of sand in concrete. Compressive strength of concrete was studied with different replacement level and at different curing age. Coal bottom ash was replaced with sand from 0 to 100% with the increment of 10% and cured for 7, 14 and 28 days. It was found that bottom ash absorbs more water and this can be overthrown by utilizing super plasticizer. Further, strength development of higher replacement wasn't good but for lower replacement levels strength development was significant. This makes it economical for bigger construction. It was found that bottom ash as the property to absorb moisture even after the construction. This property of the ash leads to use of waterproofing coat on the structure.

Jaylina Rana et al. (2014) [2] studied the effect of the coal bottom ash obtained from combustion boiler on the compressive strength, workability, water absorption and resistance to sulphate attack of the concrete. Bottom ash

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was replaced by weight of coarse aggregate in varying percentages (25%, 50%, 75% and 100%) and grade 15 was designed. The research work concluded that only the coal bottom ash concrete with 25% replacement meets Compressive strength, workability and durability requirements. It was concluded from this study that 25% of coal bottom ash can effectively be used in low strength concrete applications.

Remya Raju et al. (2014) [3] studied the effect of bottom ash as a partial replacement of fine aggregate (M-sand) in various percentages (0 – 30%) with the increment of 5%, on properties of concrete such as compressive strength, split tensile strength, flexural strength and modulus of elasticity. Also in this study, micro silica was replaced for the optimum bottom ash concrete in percentage of 4%, 6%, 8%, 12% and 15%. Results of workability, flexural strength, and modulus of elasticity were decreased and compressive strength and split tensile strength was increased. For micro silica concrete mixes 10% bottom ash concrete was selected as control mix. Similar results were obtained for the micro silica concrete.

M.P.Kadam and Y.D. Patil (2014) [4] studied the effect of fine aggregate replaced with coal bottom ash by 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% by weight. Compressive strength, Split tensile strength, flexural strength and permeability were studied. Coal bottom ash was taken from thermal power plant for this study. The compressive strength for 7, 28, 56 and 112 days were increased up to 20% replacement level and after that it were decreased. The split tensile strength was increased at 7, 28, 56 and 112 days for 10% to 30% replacement. The flexural strength was increased for 10 % to 30% replacement and after that it was decreased. It is found that the permeability up to 20 % replacement was decreased and after that permeability was increased from 30 % to 100 % replacement.

Rafat Siddique and Malkit Singh (2014) [5] studied compressive strength and durability aspects of concrete such as drying shrinkage, chloride ion penetrability, resistance to external attack of sulphate and sulphuric acid by performing laboratory test. Compressive strength after 90 days was better for bottom ash concrete. It showed slightly better resistance to sulphuric acid attack as compared to conventional concrete. Performance of bottom ash concrete under sulphate attack was almost identical to that by control concrete and this was conducted by the SEM image and XRD spectrum. Bottom ash concrete mixtures showed better resistance to chloride ion penetration. Dry shrinkage of bottom ash concrete mixtures decreased with the increase in coal bottom ash content in concrete.

3. EXPERMENTAL PROGRAMME

3.1 Materials

For this experimental study, Ordinary Portland cement of 53 grade was used. Natural sand and angular aggregates were used as a fine and coarse aggregate. The Basic tests were conducted as per Indian standards. Brick-Kiln-Ash was brought from Venkateshwara Bricks & Tiles, Bengaluru. Potable water supplied in the campus is used for this study. The physical and chemical properties of the materials used are given in Table 1, 2 and 3.

TABLE 1: Physical Properties of Aggregate

Particular	Fine aggregate	Brick-Kiln-Ash	Coarse aggregate
Specific Gravity	2.61	2.395	2.615
Water absorption (%)	1.67	20.48	0.4
Bulk density (g/cc)	1.51	1.39	-
Percentage of voids (%)	42.14	41.96	-
Zone	III	III	-
Fineness Modulus	2.07	2.31	-

TABLE 2: Physical Properties of Cement

Particular	Test Results
Fineness (%)	7
Normal consistency (%)	30
Initial Setting time (Minutes)	120
Final setting time (Minutes)	285
Specific Gravity	3.15

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TABLE 3: Chemical properties of Brick-Kiln-Ash

Sl No	Parameter	Brick Kiln Ash (% By Mass)
1	Silicon Dioxide (SiO_2)	56.44
2	Calcium Oxide (CaO)	4.77
3	Magnesium Oxide (MgO)	0.1
4	Alumina (Al_2O_3)	21.16
5	Ferric Oxide (Fe_2O_3)	4.31
6	Sulphur Anhydride (SO_3)	1.87
7	Chloride (Cl)	0.028
8	Loss On Ignition (LOI)	3.1
9	Insoluble Residue (Ir)	76.6

3.2 Mix Design of concrete

M30 grade was designed as per IS: 10262-2009. Mix proportion obtained for this study was 1:1.61:2.99. Mix proportion of M30 grade concrete for 1 cubic meter is given in the table 4. Sand was replaced 15%, 20%, 25% and 30% by Brick-Kiln-Ash by weight.

TABLE 4: Mix proportion for M30 grade of concrete for one m^3

Particulars	Quantity
Cement	394 kg
Water	177 kg
Fine aggregate	634 kg
Coarse aggregate	1180 kg
Admixture	4.72 kg
Water cement ratio	0.45

3.3 Workability

Slump test was conducted to know the workability of the mix. As the percentage of Brick-Kiln-Ash increased Workability decreased for fixed water cement ratio and super plasticizer. This nature is due to increase in fine content which requires more water to wet the surface and it may also due to the higher water absorption of Brick-Kiln-Ash. Chart 1 gives the variation of slump values for different Mix proportions.

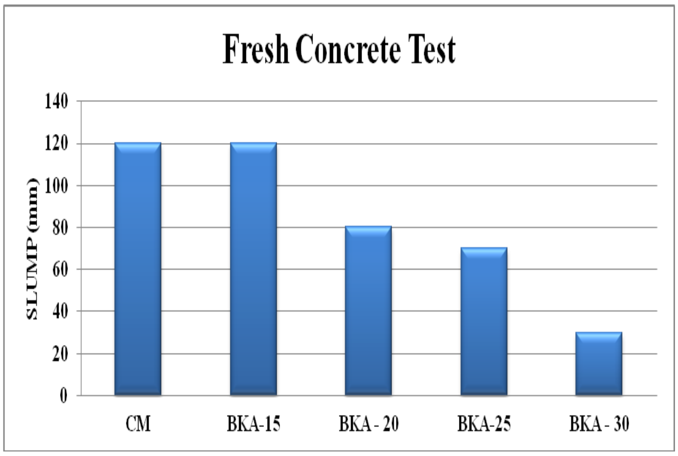

CHART 1: Slump Values for Different Mix Proportions

3.4 Compression strength of Concrete

Compressive strength was carried out for different mixes by varying the percentage of Brick-Kiln-Ash by 15%, 20%, 25% and 30% and also by keeping all other parameters constant. Standard cubes of size 150X150X150 mm were used to cast 45 cubes to check the strength at 7, 14 and 28 days. Test was conducted as per IS: 516-1959. The maximum strength was obtained for 25% replacement. This may be due to the proper densification of concrete at that level. After 25%, strength got reduced due to the increase of pores in the concrete.

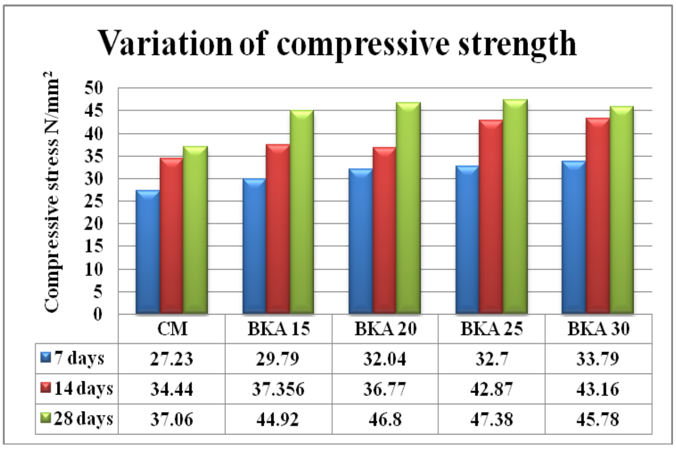

CHART 2: Avg. Compression strength of concrete

3.5 Splitting tensile strength of Concrete

Standard cylinder of diameter 150mm and height 300 mm was used to cast the cylinders. The test was conducted as per IS: 5816-1999. This test gives the load at which crack first starts. From the results, it is cleared that for 25% replacement level is having better cracking load capacity than others.

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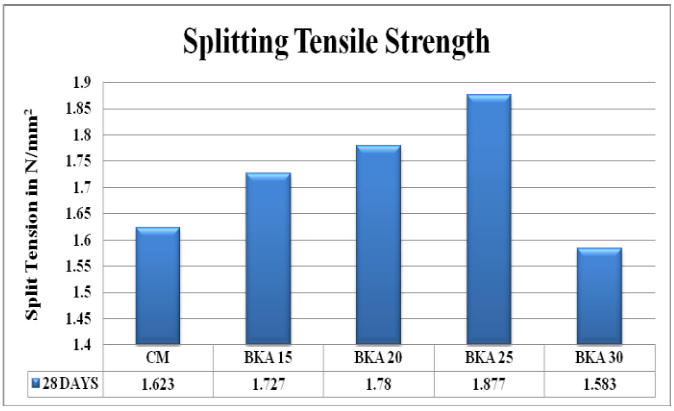

CHART 3: Avg. Splitting tensile strength of concrete at 28 days

3.6 Flexural behaviour of Reinforced Concrete beam

Due to the better compression and split tensile strength of 25% replaced concrete, it was chosen as optimum. In the present study 6 beams were casted, 3 were control and 3 were optimum percentage replacement concrete. All the beams were designed as under reinforced beams. Effective length was1600mm, Clear cover was 25mm, f_y is 500 N/mm² and f_{ck} is 30 N/mm². Other details are shown in the Fig 1.

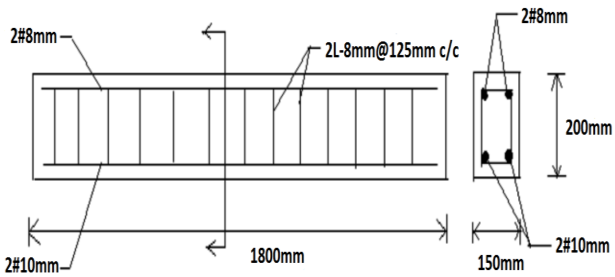

FIG 4: Reinforcement details of Test beams

White washing was done in order to aid marking of cracks. After white washing on the beam, the markings were made to indicate the loading points, support points, points to measure surface strains and also centre of beams. Then the beam was placed on the supports in the loading frame. Small adjustments are made to coincide exactly with the lines marked on the two supports so that there is no eccentricity. Then two steel rollers were kept on the beam at the loading point and eccentricity is checked. Then Rectangular tubular section was rested on the rollers and the hydraulic jack was placed central on the channel. Hydraulic jack was used to apply load at a regular interval of 2kN till the beam fails. The deflection and strains also measured for every 2kN loading. The surface strain reading was noted till the maximum possible value that is indicated in the Demec gauge. The cracks were marked immediately as they appeared and maximum crack width was noted down at cracking load, Expected service load and at ultimate load and their propagations were marked. Crack load and ultimate load were noted and also the pattern of crack was marked along the length of the beam. The loading was continued till the test beam failed.

FIG 5: Test set up on loading frame

4. RESULT AND DISCUSSION

4.1 Mode of failure and crack pattern

In all the beams cracks were started from the bottom of the beam and at failure it propagates till the compression face of the beam. Flexural failure was the mode of failure in all the beams. There was no bonding failure because there were no horizontal crack at the level of reinforcement and also no crushing of concrete at the top.

4.2 Experimental Results

In this section, Load v/s deflection curves, Cracking moment, Cracking load (P_{cr}), Ultimate moment, Ultimate load (P_u), Deflections(Δ), Crack width(W), Strain were presented.

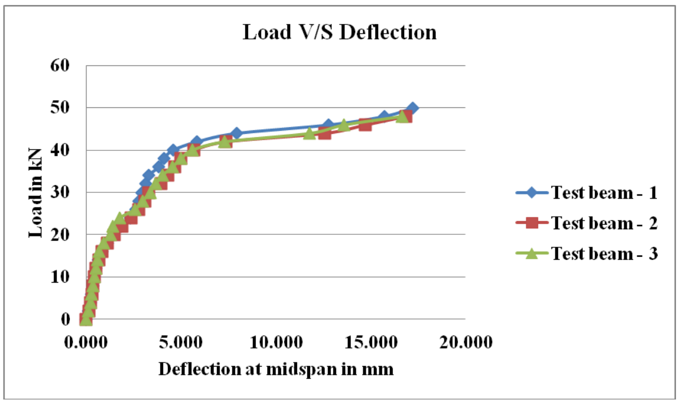

CHART 4: Load V/S Deflection curve of Test beam 1, 2 & 3

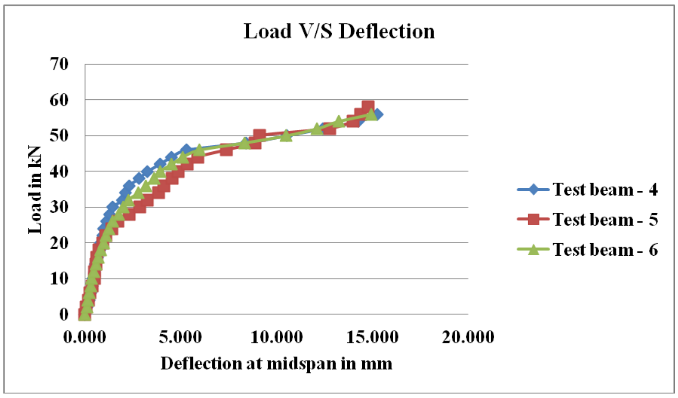

CHART 5: Load V/S Deflection curve of Test beam 4, 5 & 6

TABLE 5: Experimental Results of Cracking Load and Ultimate Load with their Respective Deflections and Crack Width

Beam Desig-nation	A_{st} (%)	Experimental test results					
		P_{cr} kN	Δ_{cr} mm	W_{cr} mm	P_u kN	Δ_u mm	W_u mm
TB - 1	0.62	24	2.319	0.1	50	17.239	0.35
TB - 2		24	2.369	0.15	48	16.842	0.4
TB - 3		22	1.401	0.15	48	16.648	0.4
TB - 4	0.62	24	0.974	0.1	56	15.263	0.3
TB - 5		26	1.733	0.1	58	14.798	0.35
TB - 6		26	1.432	0.1	56	14.932	0.3

TABLE 6: Experimental Results of Surface Strain, Cracking Moment and Ultimate Moment

Beam Designation	Maximum Surface Strain		Avg. Cracking Moment (kNm)	Avg. Ultimate Moment (kNm)
	Compression	Tension		
TB - 1	-1.20E-04	2.83E-04	6.218	12.978
TB - 2	-1.84E-04	2.94E-04		
TB - 3	-1.71E-04	2.94E-04		
TB - 4	-2.10E-04	2.90E-04	6.751	15.111
TB - 5	-2.11E-04	2.83E-04		
TB - 6	-2.10E-04	3.05E-04		

5. CONCLUSIONS

From the results of Experimental investigation following conclusion were made.

- The basic material test results showed the similarities between fine aggregate and Brick-Kiln-Ash and it can be used as Fine aggregate.
- The workability of fresh concrete decreases with increase in the replacement of brick kiln ash content for the same dosage of super-plasticizer. This was attributed to high water absorption of brick kiln ash.
- The 28 days average compressive strength obtained for 25% brick kiln ash mix concrete shows 21.78% increase in compressive strength when compared to control mix concrete.
- The 28 days average split tensile strength obtained for 25% brick kiln ash mix concrete shows 13.53% increase in split tensile strength when compared to control mix concrete.
- The optimum level of replacement of brick kiln ash was found to be 25% and the results were better than that of control mix.
- The experimental results showed that the maximum strain in the entire test beams were well within the limit of 0.0035 as per IS: 456-2000.
- Cracking moment and Ultimate moment of replaced concrete beam was greater than control beam.
- Crack widths are also well within the permissible limit of 0.3mm for moderate exposure level.
- Since, Concrete with 25% Brick-Kiln-Ash shows good mechanical properties as well as flexural behaviour and it can be effectively utilized as alternative to natural sand.

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