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Flexural Behaviour of RC Beam by Partial Replacement of Fine-Aggregate with Coal Based Brick-Kiln-Ash

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ABSTRACT
One of the main materials used in construction is concrete, due to its durability, concrete is a widely used material. Composites from waste material have emerged as an important solution to compensate for the reduction in natural resources. This study aims to partially replace sand with brick kiln ash at different percentage of15%, 20%, 25% and 30% according to the weight of the fine aggregate. M30 grade concrete was casted with the replacement material along with the control mix for the comparison. To increase the efficiency super plasticizer used. The RC beams are cast using the optimum percentage of 25% brick-kiln-ash and is compared with control beam. Properties such as deflection, initial load, ultimate load and crack width was found and compared. Theoretical and experimental results are contrasted with the guidelines outlined in IS:456-2000.

KEYWORDS: Brick-Kiln-Ash, Workability, Slump, split-tensile strength, crack pattern and width.

I. INTRODUCTION

Utilization of concrete as building material is prevalent in construction that consists of fine and coarse-aggregates, which are bound together by cement. Concrete's durability and versatility are the factors Suitable forits popularityHowever, production of cement results in significant environmental pollution and resource depletion. Each tonne of OPC produced leads to emission of one tonne of CO2.

This study exploresfeasibility of using Brick-kiln-Ash (BKA) as replacement to fine-aggregate in concrete. BKA by-product of brick production using coal as fuel, and it possesses cementitious properties. In India, the brick industry is the third-largest consumer of coal, and BKA is often discarded as waste, leading to environmental pollution. Incorporating BKA into concrete as fine-aggregate doesn't just decrease demandof natural sand butreduces environmental pollution and production costs.Therefore, this research aims to turn BKA from a waste-material into resource for concrete production.

[1] The study aimed to investigate impact of using bottom ash on strength under compression, split tensile, flexure, and elastic modulus. Fine-aggregate, in form of M-sand, was partially substituted for bottom ash, replacement levels ranging 0% to 30% in increments of 5%. Additionally, micro silica replace the optimal bottom-ash in varying levels of 4%, 6%, 8%, 12%, and 15%. Results of the study shows an increase both strength under compression and split tensile,decrease in the strength under flexure and elastic-modulus.

[2] The study investigated feasibility of utilizing bottom-ash as replacement for aggregates in concrete. The fine-aggregatereplaced with varying percentages of bottom ash, ranging 0% to 100%. Furthermore, water loss and workability of fresh concrete were also evaluated. The findings demonstrated that addition of bottom ash reduced water loss in concrete. Strength under compression did not vary much at lower curing ages, it was better for 90 days curing.

[3] The study investigated effects of substituting fine-aggregate with bottom-ash and incorporating glass fibers to enhance strength character of M30 grade concrete. Various replacement levels, ranging

from 0% -100% of fine-aggregatewith bottom ash with 0.3% glass fiber by cement weight, were used to prepare the mix. Properties of concretecompared with conventional-mix, and discovered that the optimal combination was 50% bottom ash (coal) and 0.3% glass fiber. Results revealed that theres no reduction in strength under flexure as the content of bottom-ash increased.

[4] The study was to explore the potential utilization of bottom ash, obtained from power plants, as coarse&fine-aggregates in high-strength structural concrete with compressive-strength60-80 MPa. The study conducted experiments by replacing the natural sand and coarse-aggregate with coarse & fine bottom ash with varying volume fractions ranging 0% to 100% in increments of 25%. The strength under compression of the replaced concrete was not significantly varied, the strength under flexurelinearly decreased with increase the ash content.

[5] The study investigated the suitability of using coal-bottom-ash generated from a thermal power plant. The researchers replaced cement with coal-bottom-ash in increments of 5% up to maximum of 25%. Results of compressive strength and C-S-H fibers increased with a 10% replacement level, as confirmed by SEM micrographs.

II. EXPERIMENTAL PROGRAMME

2.1 MATERIALS

In this study, 53 grade OPC was utilized, while natural sand and angular aggregates were taken as fine and coarse aggregate, respectively. The materials underwent basic tests as per Indian standards, and Brick-Kiln-Ash was obtained from Venkateshwara Bricks & Tiles located in Bengaluru. Potable water provided within the research campus was used.To increase workability of freshly prepare concrete Conplast SP 430 was used and it is provided by FOSROC chemicals, 1.2% to 1.5% (max 2%) quantity was used to raise the concrete workability. and the physical& chemical properties of the materials used are detailed in Tables 1, 2, and 3.

Particular	**Fine-aggregate**	**Brick-Kiln-Ash**	**Coarse-aggregate**
SpecificGravity	2.61	2.395	2.615
Waterabsorption-(%)	1.67	20.48	0.4
Percentage ofvoids(%)	42.14	41.96	-
Bulk density(g/cc)	1.51	1.39	-
FinenessModulus	2.07	2.31	-
Zone	III	III	-

TABLE-1: Physical-properties of aggregate

Particular	**TestResults**
Normalconsistency(%)	30
Fineness(%)	7
SpecificGravity	3.15
InitialSetting-time(Minutes)	120
Finalsetting-time(Minutes)	285

TABLE-2: Physical-properties of cement

Parameter	**BrickKilnAsh (%ByMass)**
SiliconDioxide(SiO_2)	56.44
CalciumOxide-(CaO)	4.77
MagnesiumOxide-(MgO)	0.1
Alumina(Al_2O_3)	21.16
FerricOxide(Fe_2O_3)	4.31
SulphurAnhydride(SO_3)	1.87
Chloride(Cl)	0.028
LossOnIgnition(LOI)	3.1
InsolubleResidue(Ir)	76.6

TABLE-3: Chemical-properties of Brick-kiln-ash

2.2 MIX DESIGN

M30 grade is designed as per IS: 10262-2009. Proportion for this study is 1:1.6:3. Proportion of M30-grade concrete for 1 cubic meter is given in the table-4. Fine-aggregate is replaced 15%, 20%, 25% and 30% by Brick-Kiln-Ash by weight.

Particulars	Quantity
Cement	394kg
Water	177kg
Fine-aggregate	631kg
Coarse-aggregate	1182kg
Admixture	4.72kg
Watercementratio	0.45

TABLE-4: Mix proportion for M30-grade concrete for 1m^3.

2.3 WORKABILITY

Workability of concrete mix is determined by the slump test was conducted. Results showed as percentage of Brick-kiln-ash increased, workability of mix decreased, despite keeping the water-cement ratio and super plasticizers constant. This decrease can be due to higher fine content which necessitates more water to wet the surface, and also to the high-water absorption of Brick-kiln-ash. There was a variation in the slump values observed for different percentages of Brick-kiln-ash is given in chart1.

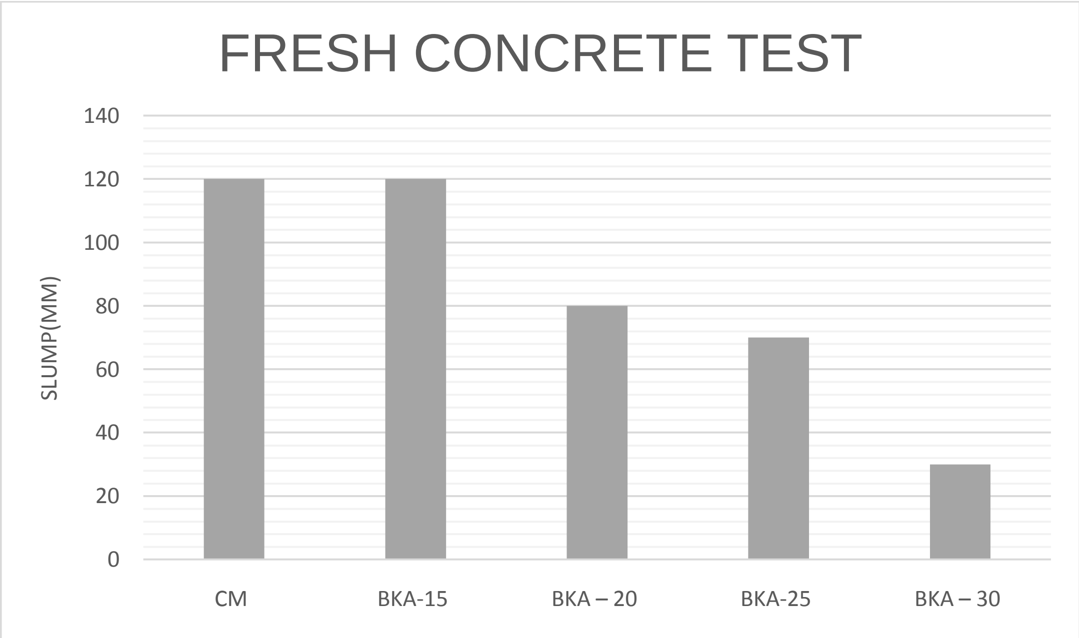

CHART1: Slump values of different mix proportions

2.4 COMPRESSION STRENGTH

Compressive-strength of various concrete mixes by altering percentage of Brick-Kiln-Ash in increments of 15%, 20%, 25%, and 30% while maintaining other parameters constant. Standard cubes measuring 150 x 150 x 150 mm were casted&tested their strength after 7, 14, and 28 days, as per IS: 516-1959. The highest strength was seen with a 25% replacement level, which may be due to densification of concrete at that level. However, the strength decreased after 25%, possibly due to increase of pores in the concrete.

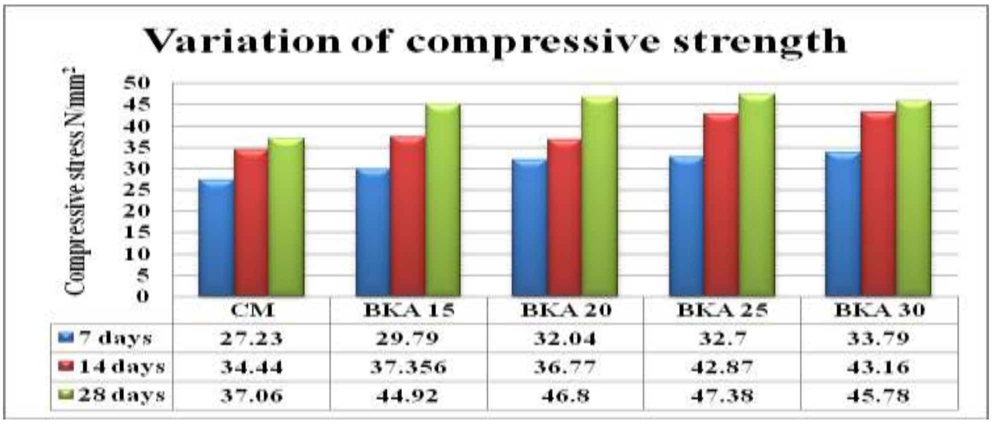

CHART 2: Avg. compression strength

2.5 SPLIT-TENSILE STRENGTH

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

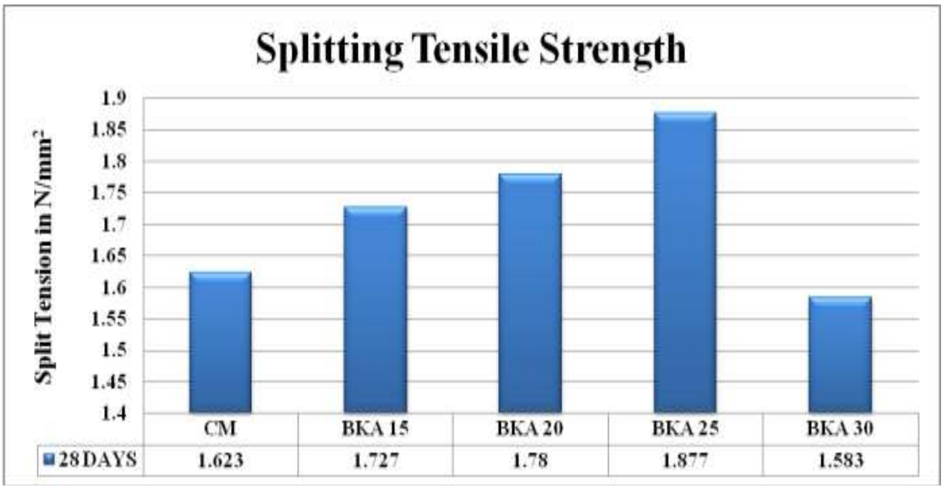

CHART 3: Avg. Split-tensile strength

2.6 FLEXURAL-BEHAVIOUR OF RC-BEAM

As the concrete with 25% replacement showed superior compression and split-tensile strength, it was considered as the most suitable optimum percentage. The study involved casting six beams, out of which three were control and the remaining three were made of concrete with the optimal percentage of replacement. The beams were designed as under-reinforced beams with a clear cover of 25mm, effective length of 1600mm, fy of 500 N/mm2, and fck of 30 N/mm2. Further details are provided in Figure 1.

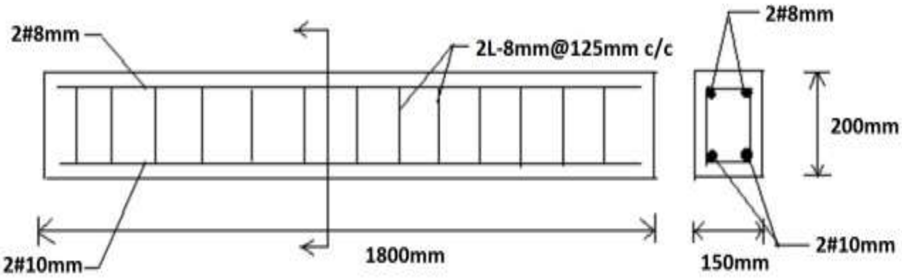

FIG 1: Reinforcement details of test beams

In order to facilitate crack detection, the beam is coated with white paint. The markings were then made on beam to indicate the loading points, support points, points for measuring surface strains, and center of the beam. The beam was then positioned on the supports of the loading frame, with small adjustments made to ensure there was no eccentricity. Two steel rollers are placed on the loading point of the beamthe eccentricity was checked. A rectangular tubular section was then placed on the rollers, and a hydraulic jack was centered on the channel. The hydraulic jack is used to apply load at regular intervals of 2kN, and the deflection and strains were measured for every 2kN of loading. Surface strain readings were recorded up to the maximum value indicated on the Demec gauge. The appearance of cracks was immediately marked, and the maximum crack width was noted at the cracking load, the expected service load, and ultimate load. The pattern of crack propagation along the length ofbeam was also marked. The loading was continued until thebeam failed, and the crack-load and the ultimate-load were noted.

FIG 2: Test set up on loading frame

III. RESULTS AND DISCUSSION

In this section, Load v/s deflection curves, Cracking moment, Cracking load (Pcr), Ultimate moment, Ultimate load (Pu), Deflections(Δ), Crack width(W), Strain were presented.

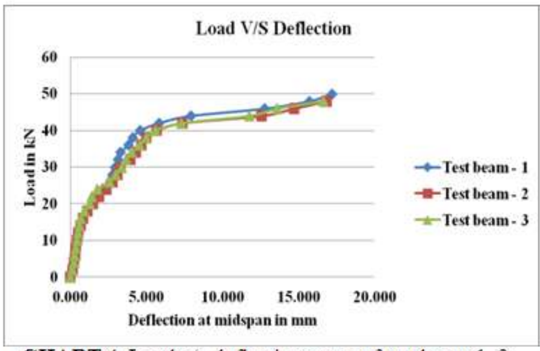

CHART 4: Load v/s deflection curve of test beam 1, 2 & 3

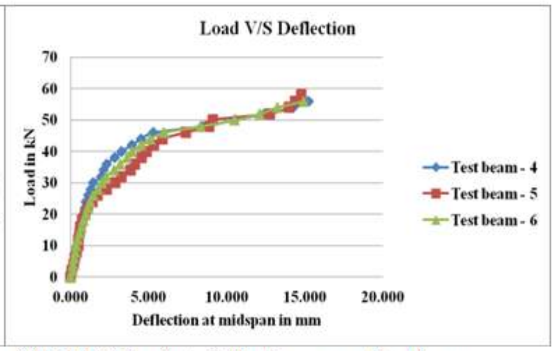

CHART 5: Load v/s deflection curve of test beam 4, 5 & 6

BeamDesig-nation	Ast(%)	Experimentaltestresults					
		PcrkN	Δcr mm	Wcrmm	PukN	Δu mm	Wumm
TB-1		24	2.319	0.1	50	17.239	0.35
TB-2		24	2.369	0.15	48	16.842	0.4
TB-3	0.62	22	1.401	0.15	48	16.648	0.4
TB-4		24	0.974	0.1	56	15.263	0.3
TB-5		26	1.733	0.1	58	14.798	0.35
TB-6	0.62	26	1.432	0.1	56	14.932	0.3

TABLE 5: Experimental values of cracking-load and ultimate-load with respective deflections and crack width.

BeamDesignation	MaximumSurface Strain		Avg.CrackingMoment(kNm)	Avg.UltimateMoment(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		

TABLE 6: Experimental values of surface strain, cracking moment and ultimate moment.

IV. CONCLUSION

From the results the following conclusion were made.

- The basic material tests results indicated that fine-aggregate and Brick-Kiln-Ash share similar properties and can be employed as substitutes for each other.
- The replacement of brick kiln ash content increased for the same amount of super-plasticizer, workability of fresh concrete reduced. Its due to the high-water absorption of brick kiln ash.
- A 25% brick-kiln-ash mix concrete exhibited an average increase in compressive-strength of 21.78% at 28 day.
- The 25% brick kiln ash mix concrete had an average increase in split-tensile strength of 13.53% at 28 day.
- The optimum level of replacement of brick-kiln-ash found to be 25%.
- Results showed that the maximum strain in the entire test beams were well within limit of 0.0035 as per IS: 456- 2000.
- Cracking moment and Ultimate moment of replaced concrete beam was greater than the control beam.
- Crack widths are also well within permissible limit of 0.3mm for moderate exposure level.
- Since, Concrete with 25% Brick-Kiln-Ash shows good mechanical properties as well flexural behaviour and it can effectively utilized as alternative to fine aggregate.

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