

A Study on Strength Characteristics of Concrete with Varying Percentage of Boiler Ash

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Abstract - Many industries and power plants generate a lot of waste as a by product during their combustion process. The waste generated in large quantity is a major problem faced by many countries. In order to save natural resources and to minimize material cost these industries wastes should be effectively utilized. The infusion of boiler ash with concrete is to utilise the boiler ash which is a waste product in many of the industries. The development and advancement in this type of concrete is to reduce the effect of hazardous human activities on the environment and an effort to minimize carbon footprint. Thus making use of these wastes in construction is cost saving and environment friendly hence we have chosen this topic of "A Study on strength characteristics of concrete with varying percentage of Boiler ash", where the boiler ash is effectively utilized and also helps to solve landfill problems. In this project concrete infused with boiler ash along with appropriate admixture to different percentage to study their mechanical properties such as compressive strength and flexural for various curing periods of concrete i.e., 7, 14 and 28 days.

1. INTRODUCTION

The pivotal thrust of utilizing waste materials into road construction field is diminishing the detrimental repercussion of processing natural materials on environment, to alleviate burden on authorities in both developing and developed countries in providing landfills and setting provisions for such waste and to reaffirm the commitment of the industry towards better road services and driving quality. Many pieces of research have proven a success in reusing and recycling of some compositions of these waste materials in pavement structures.

Boiler ash is non-combustible residue of combustion in the boilers or furnace. It is traditionally referred to as coal combustion and comprises traces of combustibles embedded in clinkers & sticking to hot side walls of boiler during its operation.

Boiler ash (coal ash) is major component of the nation's industrial waste stream. Boiler ash may be used as alternative raw material, replacing earth or sand or aggregates, for example in road construction and in cement kilns.

1.1 CONCRETE USAGE IN CONSTRUCTION OF RIGID PAVEMENTS

Concrete is considered very important factor for different type construction. It is the second most used material on earth. It mainly makes use or utilizes ordinary Portland cement as its main elements. The demand for cement as construction material is accelerating day by day enormously. Cement manufacturing industries expel CO₂ in large quantities and are considered as green house gas causes global warming. Cement industries produce about 6% of greenhouse gases. In order to overcome this environmental problem, many researchers have been conducting works in cement incorporating naturally available waste and by-product of different industries such as saw dust, rice husk ash, GGBS, silica fumes, fly ash etc... As a result the need of the hour is to find a solution for growing cement demand is an alternate material to replace cement usage.

1.2 FRC [FIBER REINFORCED CONCRETE]

It is the concrete containing fibrous material which increases the structural. This technology has given its superiority over traditional steel reinforcement. These materials possess high strength capacity and corrosion resistance and can be employed as the main reinforcement in combination with adhesives and anchorages to strengthen reinforced concrete (RC) beam members. RC beams are designed to provide resistance against flexure, shear, torsion, fatigue, impact and blast loading. The strength and ductility of RC beam can be improved via FRP composites RC beams can be improved via FRP composites in RC beams is controlled by fiber type, configuration, and materials and strengthening technique. Contains short discrete fibres that are uniformly distributed and randomly oriented. Fiber reinforced polymer composites are extensively used in advanced concrete.

1.3 SSC [SELF COMPACTING CONCRETE]

It is the fresh concrete that flows under its own weight and does not require external vibrations to undergo compaction. Self compacting concrete is a highly flow able type of concrete that spreads into the form without the need for the mechanical vibration. Self compacting concrete is a non segregating concrete that is placed by means of its own weight the importance of SCC is that maintains all concrete durability and characteristics meeting expected performance requirements.

2. LITERATURE REVIEW

Poly vinyl alcohol modified pavement concrete using recycled cement aggregates; [Journal of material in civil engineering, volume 30, issue 4]

The optimum p/c ratio tended increase with an increase in w/c ratio being 0.5, 1 & 1.5 for w/c ratio of 0.3, 0.4, 0.5 & 0.6. The optimum p/c ratio tended to increase with an increase in w/c ratio being 0.5, 1, & 1.5 for w/c ratio of 0.3, 0.4, 0.5, & 0.6. Based on requirements of Dept. of Highways, Thailand, p/c < 1 at w/c < 0.5 was found to be suitable for developing RCA-PVA concrete for rigid pavements.

Study and analysis of rigid pavements using boiler ash (By VALLABUNI KALYAN, P.SANDEEP CHANDRA & MOHAMMAD IBRAHIM);

In this study, cement replacement levels by fly ash were 0, 20, 30, 40, 50 & 60% for analysis. Compressive strength of cubes at ages of 3, 7 & 28 days were determined. This study concluded that fly ash can be suitable substituent for cement and M40 grade concrete with maximum replacement of 30 % boiler ash may be recommended.

Compressive stress-strain relationship for boiler ash concrete (KUNJIE FAN, LONG YUAN LI cement & concrete composites 2019):

The tests were carried out on an apparatus specially designed for studying 'hot' mechanical properties of concrete materials; the results include Compressive strength, strain @ peak stress point young modulus. It was found that 25% replacement of OPC with boiler ash in concrete would yield less decrease of compressive strength.

Mechanical properties of concrete using steel slag aggregates by J. SARAVANAN ETAL (2016)

In this paper the study was made on comparing natural aggregate concrete with a concrete made of steel slag. The material used are cement of OPC 43 grade, locally available coarse aggregates, steel slag and natural river sand as fine aggregates, concrete of grade M40 is used. Different tests like compression, split tensile, flexure and modulus of elasticity tests were performed. Test results showed that particle density method for conventional coarse aggregates gave 6% higher compressive strength than the control mix and also 100% replacement of steel slag with conventional aggregates was not found to give good strength. Split tensile strength of steel slag concrete increases in 28% compared to the conventional coarse aggregate concrete.

A review on fly ash characteristics towards promoting high volume utilization in developing sustainable concrete:

In view of increase in the level of fly ash replacement in cement to minimize the carbon foot print firstly, the current state of fly ash application in concrete by considering about 200 papers published since 1980 to till date. Secondly, the analysis of form structure property of fly ash reported in

various literature and its co-relation with strength and durability characteristics. Thirdly, the contradictions reported in literature regarding the performance of fly ash particularly in the context of shrinkage, high temperature curing, water demand etc. This study concluded that facilitating a higher replacement of cement possibly up to 60% in a scientific way rather than by trial and error basis.

Flexural Behaviour of Basalt Chopped Strands Fiber Reinforced Concrete Beams, R SINGARAVADIVELAN ET AL(2013)

Studied on strengthening of RC beam and its behavior by making use of fibers made of basalt chopped strands. The proportions of fibers added to the concrete are 0%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%. The grade of concrete used for casting beams is M-20. The materials used for concrete are PPC cement, river sand as fine aggregates and granite stone as coarse aggregates. The flexural strength test was conducted on basalt chopped strands fibers concrete (BCSFC) for this rectangular beams of size 150mm*200mm*2100mm with reinforcements are casted. The two pint loading method is made used in order to achieve pure bending. Finally from test results they have concluded that there is a increase of ultimate load capacity of BCSFC beams by 6.08% w.r.t control beam, also the deflection of BCSFC beams is reduced upto 20.17% w.r.t control beam and the crack width in BCSFC beams is less compared to control beam.

Mechanical characterisation of basalt fibre reinforced plastic, V. LOPRESTO ET AL (2011) Studied different mechanical tests in order to find a possibility to replace a glass fibers with a basalt fibers in a concrete. Here Basalt and glass fiber reinforced plastic laminates with 300 mm *300 mm in plane dimensions are made. Different mechanical tests were carried out, on both composites: such as tensile, compression, flexural, shear and low velocity impact test. Result showed that the basalt composite showed better results than glass fiber reinforced composites. In terms of modulus of elasticity basalt fibers showed 35-42% higher values when compared to the glass. And also commercially available basalt fiber showed 16% higher modulus compared to E-glass fiber. But hen it comes to ultimate strength basalt fibers showed lesser tensile strength compared to glass fibers. Failure by bending was due to compression for glass fibers and tensile for basalt fibers. Finally they have concluded that use of basalt fiber reinforced composites are very useful in new perspectives and in field of construction industry.

Basalt Fiber Reinforced Concrete, NAYAN RATHOD ET AL(2013)

In this paper study was made on relative use of basalt fibers. Uses, characteristics of basalt fibers were also studied. Compressive strength and flexural strength test were done

for concrete with basalt fibers and without adding basalt fibers by preparing cubes and prisms.

Various properties and applications of basalt fibers were also studied. They have concluded that BFRC can be effectively used as an alternative material for construction, with good resistance to heat and corrosion.

Effect of Basalt Fibre on Mechanical Properties of Concrete Containing Fly Ash and METAKAOLIN, ELBA HELEN GEORGE ET AL (2014)

This studies shows the effect of basalt fibre on properties of concrete. Basalt fibres were used as reinforcement to enhance concrete toughness either partially or totally to the conventional reinforcement. Basalt fibre of size 13 micron meter diameter and length 12 mm was used in the experiment. They have also used metakaolin and 2.5 % of fly ash, which enhances the efficiency of packing. M20 grade of concrete is selected and respected cubes, cylinders and beams for both conventional and for replacement were casted. Tests such as compression, split tensile and flexural tests were done on these specimen to know the mechanical properties of the concrete. The results showed that the compressive strength decreased on increase in the percentage of fly ash. And for split tensile test for increasing the percentage of fibre to conventional concrete split tensile strength increased significantly. The flexural strength increases when fibres were added and it decreased when fly ash was added.

Strength and Durability of Concrete Using Steel Slag as a Partial Replacement of Coarse Aggregate in Concrete K.THANGASELVI ET AL(2015)

The study was on the replacement of coarse aggregate by steel slag for various proportions i.e 0%, 20%, 40%, 60%, 80%. Different tests like compressive strength, split tensile strength, flexural strength for 7 days and 28 days were done. Grade of concrete used are M40 and W/C was 0.40. The test results concluded that the study successfully disposes steel slag, the flexural strength, compressive strength and split tensile strength of a concrete is increased with the replacement of steel slag with coarse aggregates, steel slags optimum % was found to be 60%. Higher resistance to sulphate and acid attack is possible with increase in percentage of steel slag and by using this optimum value production of concrete is possible with high strength and durability than a conventional concrete and saves the cost of a material upto 10%.

Use of Basalt fibers for concrete structures, CORY HIGH ET AL (2015) in this studies the basalt fibers were used as reinforcement and additive to enhance the mechanical properties of concrete. This showed that the use of chopped basalt fibers had negligible effect on the compressive strength of the concrete. And it also enhances the flexural strength of the concrete. The research was mainly comprised of two studies. The first study showed the behavior of

flexural strength when basalt fibers were added and second study showed the use of chopped basalt fibers to enhance the mechanical properties. Different specimens were casted and test were done. The test results showed that compressive strength of concrete when flyash and admixtures were added increased slightly for 28 days. It was also showed flexural strength of the concrete when fly-ash, admixtures were added with low water-cement ratio.

Mechanical Properties of Concrete Using Steel Slag Aggregate, J. SARAVANAN ET AL(2016)

In this paper the study was made on comparing natural aggregate concrete with a concrete made of steel slag. The materials used are cement of OPC 43 grade, locally available coarse aggregates, steel slag and natural river sand as fine aggregates. Concrete of grade M40 is used. Different tests like compressive, split tensile, flexure and modulus of elasticity tests were performed. Test results showed that Particle density method for conventional coarse aggregate gave 6% higher compressive strength than the control mix. And also 100% replacement of steel slag with conventional aggregate was not found to give good strength. On the basis of aggregate packing analysis, good strength results was obtained in both cases of conventional and LD slag aggregates Compressive strength of steel slag concrete increases in 6 % compared to the conventional coarse aggregate concrete. Split tensile strength of steel slag concrete increases in 28 % compared to the conventional coarse aggregate concrete. The flexural strength in LD slag concrete is increased by 34% when compared to conventional concrete.

Experimental investigation of concrete with basalt fibre, N.GOPI ET AL(2016)

Studied the effect of different proportions of fibres in the concrete and find out optimum percentage of fibres with maximum strength criteria. The specimens were casted for M20 Grade concrete with locally available materials. They have used Basalt fibres of different percentages 0.20%, 0.25%, 0.30% are being replaced for the total volume of concrete. Different tests such as compression test, flexural test and modulus of elasticity test were carried out. Results showed that compressive strength of concrete is increased upto 25% for 0.25% fibers and gradually decreased for 0.3% and flexural strength increased upto 40% for 0.25% of fibers and decreased gradually for 0.3%. They have concluded that workability of concrete is not affected by addition of basalt fibers it remains same as the normal concrete so there is no need of use of super plasticizers. The compressive strength of basalt fiber reinforced concrete was found to be 22% more than the conventional concrete. The tensile strength of bfrc was 45% more than conventional one.

3. METHODOLOGY

The methodology adopted is explained below;

- The first step involved is collecting different materials such as cement, fine aggregates, coarse aggregates, boiler ash and preliminary steps were conducted.
- Cement used is OPC 53 grade, fine aggregates used is M-sand from local quarry, coarse aggregates passing through 16mm sieve and retained in 12 mm sieve.
- Boiler ash is procured from AMRIT DISTILLARIES, BENGALURU.
- Cubes of size (150*150*150mm) are to be casted for specimens with varying percentage of boiler ash (10, 20, 30, &40%) and cured for 28 days.
- Specimens after curing are tested and results are compared to the control specimens & conclusions are made.

3.1 CEMENT

Table: Physical properties of cement

Properties	Obtained values	Requirement as per IS 8112-1989
Specific gravity	3.126	----
Initial setting time	120	Not less than 30 minutes
Final setting time	210	Not more than 600 minutes

3.2 FINE AGGREGATES

Table: Sieve analysis of M-Sand

Sieve size	Weight of empty sieve (gm)	Weight of sieve+sand retained	% of sand	Cumulative %	% finer
4.75	313	322	0.9	0.9	99.1
2.36	226	408	18.2	19.1	80.9
1.18	396	693	29.7	48.8	51.2
750	279	727	44.8	93.6	6.4
600	285	287	0.2	93.6	6.2
300	285	287	0.2	94	6
150	303	305	0.2	94.2	5.8
75	345	385	4	98.2	1.8
PAN	238	256	1.8	100	0

3.3 COARSE AGGREGATE

Table: Coarse aggregate physical properties

Properties	Results	Standard results
specific gravity	2.72	2.5-3
Water absorption	0.2	<0.6
Abrasion value	22.12	<30%
Impact value	26.71	<30%
Crushing strength value	18.31	<30%

3.4 BOILER ASH

Table : Physical properties of boiler ash

SL no	Properties	Values
1	specific gravity	2.65

3.5 WATER

Portable water confirming to IS 456:2000 is used

4. RESULTS AND DISCUSSION



Figure: Compressive strength Machine

TESTS RESULTS OF COMPRESSIVE STRENGTH

Table: Compressive strength results of M40 grade concrete for 28 days

Specimen	Load, kN	Area	Compressive Strength, N/mm ²	Avg compressive strength N/mm ²
Conventional	1020	150*150	45.33	43.86
	1087		48.31	
	987		43.87	
	925		41.11	
	915.6		40.69	
10% boiler ash	1087	150*150	48.31	47.73
	1098		48.80	
	1054		46.84	
	1086		48.27	
	1045		46.44	
20% boiler ash	1097	150*150	48.76	49.03
	1086		48.27	
	1154		51.29	
	1067		47.42	
	1112		49.42	
30% boiler ash	1231	150*150	54.71	51.40
	1119		49.73	
	1149		51.07	
	1085		48.22	
	1198		53.24	

TESTS RESULTS OF FLEXURAL STRENGTH TEST

Table: Flexural strength test results of M40 Grade concrete

Specimen	Area	Flexural strength	Avg flexural strength N/mm ²
Conventional	100*100*500	3.98	4.08
		4.12	
		3.94	
		4.03	
		4.34	
10% boiler ash	100*100*500	4.21	4.21
		4.19	
		4.01	
		4.30	
		4.34	
20% boiler ash	100*100*500	4.75	4.54
		4.61	
		4.52	
		4.30	
		4.53	
30% boiler ash	100*100*500	4.81	4.76
		4.69	
		4.88	
		4.79	
		4.63	



Figure: FLEXURAL STRENGTH TEST

5. CONCLUSION

- The infusion of industrial wastes such as boiler ash in concrete products with various percentages has been assessed for structural and integral purposes to large scale employment of such a technology in the zonal region of industries. Wastes collected from industry to ensure appropriate proportions for waste mix to incorporate into concrete matrix.
- The compressive strength of thus formed boiler ash concrete was formed within permissible limits in accordance with the IS Codes and guidelines.
- Boiler ash can be a suitable substituent for the cement.
- The required compressive strength of any concrete mix can be obtained with boiler ash resolving the conventional concrete to an extent.

- High compressive strength above the normal required strength of concrete with boiler ash replacement is noticed.
- Replacement of about 10% boiler ash with cement, resulted in decreased strength as compared to target strength.
- For 20% and 30% replacement of boiler ash with cement, we have seen a noticeable increase in the strength of concrete when compared to the target strength and also strength development for a period of 7,14 and 28 days for boiler ash concrete can be observed by this study.
- Thus, by this study, M40 Grade concrete with the maximum replacement of 30% boiler ash with cement can be recommended.

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7. FUTURE SCOPE OF WORK

The design can be extended for various other concrete grades using boiler ash replacement to get the required strength values and suitable proportions can be derived and practiced.

8. REFERENCES

Waste water engineering (including air pollution)

By **B.C Punmia**

Use of sludge generated a WWTP in the production of cement mortar and concrete

By **Drazen Vouk, Domagoj Nakic**

Use of waste water sludge in concrete mixes

By **Dr. Mohammed Arafia and Dr. Maoun AL-Quedra**

Reuse of industrial sludge as pelletized aggregate for concrete

By **Joo- hwa Tay, Sze-Yunn Hong**

Bureau of Indian standards(BIS)

IS4764:1963 Tolerance limits for sewage effluent discharged into inland surface waters.

Use of sludge ash in cementitious material

By **D Vouk, D Nakic, N Strimer**

Environmental impact of sewage sludge ash assessed through leaching

By **Drazen vouk, Damagoj Nakic, Shane Donatello**

Compressive strength of concrete with sludge ash(SSA)

By **Thevaneyan Krishta David and Srinivasan Karan Nair 2018**

Eric R Berg, John Neal, "concrete masonry unit mix design using municipal solid waste bottom ash", journal 95(4), 470-479,1998.

Nilo Cesar Consoli, Jim Graham, "loading tests on compacted, bottom ash and lime layers", proceedings of the institution of civil engineering 161(1),29-38-2008.

Bureau of Indian standards(BIS) – IS4764-1973 Tolerance limits for sewage effluent discharged into inland surface waters.

Characterization and demonstration of reuse applications on sludge ash

By Brett Q Tempest and Miguel A pondo

Ecological and economical balance for sludge management options

By Jermy Hall, Dr. Ing Diester O'Reimann

T. Bakoshi, K kohno "Strength and durability of concrete", material publication 179, 159-172,1992

N Ghafoori, Jeffrey Buchole, "Properties of bottom ash for structural concrete" material 94(2), 90-101-1997, volume 94, issue2

Nader Ghafoori, YuzhengCai, "RCC containing dry bottom ash: journal 95(2), 121-130-1998

Eric R Berg, John Neal, " concrete masonry unit mix design using munciple solid waste bottom ash", journal 95(4), 470-479,1998.

Nilo Cesar Consoli, Jim Graham, " loading taests on compacted, bottom ash and lme layers", proceedings of the institution of civil engineering 161(1),29-38-2008.

Bureau of indiuan standards(BIS) – IS4764-1973 Tolrance limits for sewage effluent dischargrd into inland surface waters.

Khanna S K and Justo CEG (2001) Highway Engineering, Nem Chand and BROS., Rourke.

Marta Kosior-Kazberuk (2007) Strength Development of concrete with fly ash addition, Journal of Civil Engineering and Management, ISSN1822-3605 online

Murlidharrao (2007) Utilization of fly ash at Rancher Thermal power station of Karnataka power Corporation Ltd, FAUACE.

Pachauri R K and P.V. Shidehara (1998) Looking back to Think ahead, TERI Publication New Delhi.

Ramiro S (2007) Fly ash based alternate for partial replacement of Portland cement, FAUACE.

Santhakumar A R (2008) Concrete Technology, Oxford University Press, New Delhi. Shetty M S(2003) Concrete Technology, S Chand and Company Ltd, New Delhi.

District Schedule of rates (2008), published by PWD Department, Government of India Publication.

ACI Committee 226 (1988) Use of fly Ash in Concrete

S K Kaushik "Quality of Concrete using Fly ash contents "International Conference on Engineering Materials, 1998

N P Raja mane j Annie Peter and S Gopala Krishna "Performance of admixture produce using as a mineral Admixture in Concrete, "Cement and Concrete Research (2000)

M M Prasad "strength Development of Concrete with fly ash and silica furnace "Cement & Concrete mixture "Cementand concrete Research 2004

Concrete Technology by N. KRISHANA RAJU. CODE BOOKS

IS 456-2000

IS 10262-2009

WEBSITES

www.indiaspend.com

www.google.co.in

www.sciencedirect.com