Experimental Analysis of Waste Foundry Sand and Bottom Ash in Partial Replacement of Fine Aggregate in Concrete

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Abstract: In this thesis an attempt is made to present a state-of the- art review of papers on replacement of natural sand by by-products and recyclable materials. This paper aims to deal with the current and future trends of research on the use of Manufactured Fine Aggregate (MFA) in Portland cement concrete. With natural sand deposits the world over drying up, there is an acute need for a product that matches the properties of natural sand in concrete. In the last 15 years, it has become clear that the availability of good quality natural sand is decreasing. With a few local exceptions, it seems to be a global trend. Existing natural sand deposits are being emptied at the same rate as urbanization and new deposits are located either underground, too close to already built-up areas or too far away from the areas where it is needed, that is the towns and cities where the manufacturers of concrete are located. Environmental concerns are also being raised against uncontrolled extraction of natural sand. The arguments are mostly in regards to protecting riverbeds against erosion and the importance of having natural sand as a filter for ground water. The above concerns, combined with issues of preserving areas of beauty, recreational value and biodiversity are an integral part of the process of most local government agencies granting permission to aggregate producers across the world. This is the situation for the construction industry today and most will agree that it will not change dramatically in the foreseeable future. Crushed aggregate, bottom ash, foundry sand and various by-products are replacing natural sand and gravel in most countries. This paper emphasizes on the use of material to be replaced by natural sand with bottom ash and foundry sand in Mix design with M30 and M40 the cement will be replacement of 0%, 10%, 20%, 30% and 40% with foundry sand and bottom ash, compressive strength, split tensile strength, flexural strength and durability were compared. This will give new dimension in concrete mix design and if applied on large scale would revolutionize the construction industry by economizing the construction cost and enable us to conserve natural resources.

Key Words: **Replacement, Natural sand, Concrete, Manufactured Fine Aggregate (MFA) Urbanization.**

I.INTRODUCTION

Cement, sand and aggregate are essential needs for any construction industry. Sand is a major material used for preparation of mortar and concrete and plays a most important role in mix design. In general consumption of natural sand is high, due to the large use of concrete and mortar. Hence the demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. The developing country like India facing shortage of good quality natural sand and particularly in India, natural sand deposits are being used up and causing serious threat to environment as well as the society. Rapid extraction of sand from river bed causing so many problems like losing water retaining soil strata, deepening of the river beds and causing bank slides, loss of vegetation on the bank of rivers, disturbs the aquatic life as well as disturbs agriculture due to lowering the water table in the well etc are some of the examples.

Bottom Ash

Bottom ash is a by-product of burning coal at thermal power plants. Bottom ash particles are much coarser than the fly ash. It is a coarse, angular material of porous surface texture predominantly sand-sized. This material is composed of silica, alumina, and iron with small amounts of calcium, magnesium, and sulfate Grain size typically ranges from fine sand to gravel in size. Chemical composition of bottom ash is similar to the fly ash but typically contain greater quantity of carbon. Bottom ash exhibits high shear strength and low compressibility. These engineering properties make bottom ash an ideal material in design construction of dam and for other civil engineering applications.

Bottom ash is the coarse, granular, incombustible by-product of coal combustion that is collected from the bottom of furnaces. Most bottom ash is produced at coal-fired power plants. Below is a comparison of fly ash and bottom ash, to show the size difference of the particles and the difference in texture.

Bottom Ash

Advantages of Bottom Ash

Ash has been investigated for its suitability for utilization in major areas as building material and other civil engineering sectors. The areas mentioned below have tremendous scope of large scale use of Bottom ash.

Building bricks and block. Road construction, Drainage media and Sound insulating walls. It is used in mining mortar in such application as rock stabilization or filling of cavities. It is used as a construction material for highway and pavement It is used for pressure grouting in concrete highways and for other purposes viz, tunnel lining. It is used as mineral filler in asphalt roads to minimize void content and increase the stability of bituminous wearing course during road construction. It is used as a light weight synthetic aggregate in block and concrete. It is used along with bottom ash as a growing media for plants In concrete, bottom ash is used as replacement of fine aggregate in which concrete has advantageous properties like improved workability, resistance to chemical attack.

Foundry Sand

The Foundry industry in India has been growing steadily over the T past several years despite economic slowdown dented its demand from the end user industry i.e. engineering and auto component sectors. The Indian Metal Casting (Foundry Industry) is well established & producing estimated 9.99 Million MT of various grades of castings as per International standards. There are approx. 4500 units out of which 85% can be classified as Small Scale units & 10% as Medium & 5% as Large Scale units. Approx. 800 units are having International Quality Accreditation. Apart from the registered 4550 units there are several unregistered units, which according to various sources range approximately from 1500 to 5000 units.

Foundry sand is clean, uniformly sized, high quality silica sand, used in foundry casting processes. The sand is bonded to form molds or patterns used for ferrous (iron and steel) and non-ferrous (copper, aluminum, brass) metal castings. Shake-out sand from completed metal casting are often reclaimed back into the foundry sand process.

Foundry Sand

Objective of the study

The main objectives for this research are:

- To determine the optimum content of bottom ash as a substitute for fine aggregate (sand) in concrete;
- To evaluate the mechanical properties (compressive strength) of concrete containing bottom ash from power plant as sand replacement in concrete;
- To study the physical properties of concrete materials.
- To arrive a mix design summary for concrete using IS code method. To study the workability of fresh concrete such as slump.
- To study the various strength of hardened concrete such as compressive strength of concrete cubes at 28 days and Split tensile strength of cylinder at 28 days and Flexural strength of prism at 28 days .
- To compare the workability and various strength for different percentage of partial replacement of sand with Bottom ash, and foundry sand.

II.LITERATURE REVIEW

Shyam Prakash Koganti1 , Kommineni Hemanthraja2 , Satish Sajja3 et all, (2017) Cement concrete paving blocks are precast hard products complete out of cement concrete. The product is made in various sizes and shapes like square, round and rectangular blocks of different dimensions with designs for interlocking of adjacent tiles blocks. Several Research Works have been carried out in the past to study the possibility of utilizing waste materials and industrial byproducts in the manufacturing of paver blocks. Various industrial waste materials like quarry dust, glass powder, ceramic dust and coal dust are used as partial replacement of fine aggregate and assessed the strength parameters and compared the profit percentages after replacement with waste materials. Quarry dust can be replaced by 20% and beyond that the difference in strength is not much higher but considering cost we can replace up to 40% so that we can get a profit of almost 10%. Similarly we can replace glass powder and ceramic dust by 20% only beyond that there is decrement in strength and even with 20% replacement we can get 1.34 % and 2.42% of profit. Coal dust is not suitable for alternative material as fine aggregate as it reduces the strength. By results of specific gravity it was clear that ceramic dust, quarry dust, glass powder have somehow similar specific gravity as normal sand in the range of 2.3 to 3 but coal powder had low specific gravity as 0.8 to 1.4 which is very low among all the materials. Another result was about particle size distribution, glass powder, ceramic dust, quarry dust, coal dust have similar particle size distribution curve when compared to nominal sand as simple ‘S’ curve By replacing with quarry dust by 20% its compressive strength is about 28.5N/mm2 i.e., an increment of 51.92 % and further there is no appreciable increment, whereas for glass powder it is observed that there is gradual decrease in compressive strength when replaced. Even though there is higher profit percentage at 40% CrD it cannot be used beyond 20% because of decrement in strength of concrete. Considering the strength there is no appreciable increment in strength when QD % is increased beyond 20% but the profit percentage is higher so QD% can be replaced up to 40% when considering both strength and cost parameters.

Huang et al. (1990) He investigated the shear strength of Indiana bottom ash and boiler slag compacted to different densities using direct shear testing. The reported friction angles varied in a wide range from 35 to 55% depending on the density.

Seals etal. (1972) He presented data obtained from West Virginia bottom ash. The standard Proctor maximum densities varied between 11.6 and 18.4 kN/m3; the optimum water content ranged from 12 to 34%. They also performed a series of one-dimensional compression tests on West Virginia bottom ash. They showed that, at low stress levels, the compressibility of bottom ash was comparable to natural granular soils placed at the same relative density.

III.COLLECTION OF MATERIALS

1.CEMENT AND ITS PROPERTIES

The cement is an important constitute of concrete. The cement is a binder can bind other materials together. The word cement derived from the Romans. Different brands of cement have been found to possess different strength development characteristics and behavior due to the variations in the compound composition and fineness.

For the present investigation, Ordinary Portland Cement of 53 Grade conforming to IS 269-1986 was used. The cement sample was tested as per the procedure given in IS: 4031- 1988 and IS: 4032-1985.

OPC 53 GRADE CEMENT

2. AGGREGATESAND ITS PROPERTIES

The most popular use of aggregates is to form Portland cement concrete. Approximately three-fourths of the volume of Portland cement concrete is occupied by aggregate. Aggregates typically make up 70-80% of the volume of Portland cement concretes and over 90% of asphalt concretes. Thus, their properties play important roles in determining the properties of the composite materials in which they are to be used. Knowledge of relative density/specific gravity, absorption, unit weight and voids content are necessary for the proper design of both Portland cement and bituminous concretes.

FINE AGGREGATES, AND COARSE AGGREGATES

3.WATER

Water is one of the important ingredients in construction but in present day quality of water is not given such big importance. during construction work. The quality and quantity of water plays a major role in determining the strength of mortar and cement concrete in construction work.

4. BOTTOM ASH

Bottom ash [normally recognized as coal combustion residues (CCRs) from pulverized fuel power stations] has been categorized as solid garbage. But, CCRs are increasingly being regarded as a useful substitute material resource. They had an appearance similar to dark gray coarse sand, and its particles are clusters of micron sized granules, up to 10mm in diameter (60%-70% smaller than 2 mm. and l0%-20% smaller than 75 microns).

5.FOUNDRY SAND

Most of the metal industries prefer sand casting system. In this system mould made of uniform sized, clean, high silica sand is used. After casting process foundries recycle and reuse the sand several times but after sometime it is discarded from the foundries known as waste foundry sand. The application of waste foundry sand to various engineering sector can solve the problems of its disposal and harmful effect to environment. Foundry sand is clean, uniformly sized, high-quality silica sand that is bounded to form moulds for ferrous (iron and steel) and non-ferrous (copper, aluminum, brass) metals. Type of foundry sand depends on the casting process in foundries. Foundry sand is generally of two types: Green sand, chemically bounded sand. Additive in sand depends on type of metal casting. Use of waste foundry sand as full or partial replacement by fine aggregate helps to achieve different properties or behavior of concrete.

6. MIX DESIGN

6.1 TRAIL MIX OF M30 GRADE OF CONCRETE

Final trial mix for M30 grade concrete is 1:1.64:2.55 at w/c of 0.45

S.no	Cement	Fine aggregate	Bottom Ash	Foundry sand	Coarse aggregate	water
1	292 kgs	360	47.645	47.645	742	132
Addition of 10 %	321.20 kgs	396	52.41	52.41	816.20	145.20

6.2 TRAIL MIX OF M40 GRADE OF CONCRETE

Final trial mix for M40 grade concrete 1: 1.65: 2.92 @ 0.40 W/C

S.no	Cement	Fine aggregate	Bottom Ash	Foundry sand	Coarse aggregate	admixture	water
1	269 kgs	356	44.33	44.33	785	0.900	119
Addition of 10 %	295.90 kgs	391.60	48.763	48.763	863.50	0.99	130.90

IV. RESULTS

1 . MATERIAL PROPERTIES

CEMENT

Sl.No	Test	Results	IS code used	Acceptable limit
1	Specific gravity of cement	3.150	IS:2386:1963	3 to 3.2
2	Standard consistency of cement	7mm at 34% w/c	IS:4031:1996	w/c ratio 28%-35%
3	Initial and final setting time	55 mins and 10 hours	IS:4031:1988	Minimum 30mins and should not more than 10 hours
4	Fineness of cement	5.00%	IS:4031:1988	<10%

COARSE AGGREGATES

Sl.No	Test	Results	Is code used	Acceptable limit
1	Fineness modulus	7	IS:2386:1963	6.0 to 8.0mm
2	Specific gravity	2.95	IS:2386:1963	2 to 3.1mm
3	Porosity	48.83%	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.8955	IS:2386:1963	Any value
5	Bulk density	1.52g/cc	IS:2386:1963	-
6	Aggregate impact value	39.5	IS:2386:1963	Less than 45%
7	Aggregate crushing value	28.6%	IS:2386:1963	Less than 45%

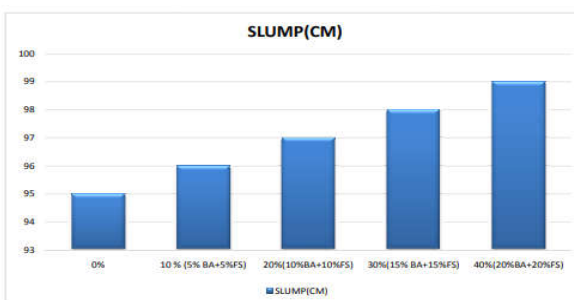
FINE AGGREGATES

Sl.No	Test	Result	Is code used	Acceptable limits
1	Fineness modulus	3.507	IS:2386:1963	Not more than 3.2 mm
2	Specific gravity	2.68	IS:2386:1963	2.0 to 3.1
3	Porosity	38.6%	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.59	IS:2386:1963	Any value
5	Bulk density	1.98	IS:2386:1963	-
6	Bulking of sand	6.0%	IS:2386:1963	Less than 10%

TRAIL I (MIX DESIGN OF M30)

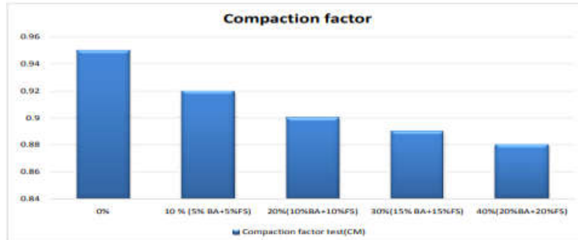
SLUMP CONE TEST

Sl.No	Material	SLUMP(CM)
1	0%	95
2	10 % (5% BA+5%FS)	96
3	20%(10%BA+10%FS)	97
3	30%(15% BA+15%FS)	98
4	40%(20%BA+20%FS)	99



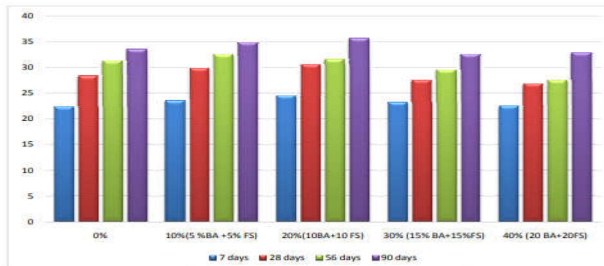
COMPACTION FACTOR TEST

Sl.No	Material	Compaction factor test
1	0%	0.95
2	10 % (5% BA+5%FS)	0.92
3	20%(10%BA+10%FS)	0.90
3	30%(15% BA+15%FS)	0.89
4	40%(20%BA+20%FS)	0.88



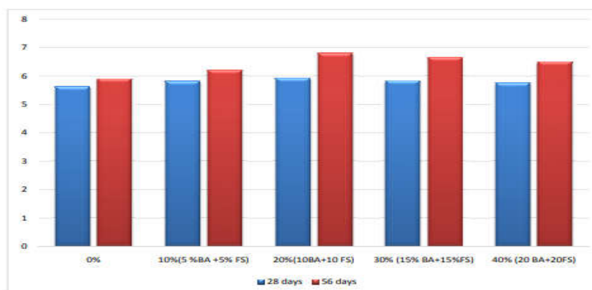
COMPRESSIVE STRENGTH

Sl.No	% of replacement of fine aggregate	Compressive Strength kN/mm^2			
		7 days	28 days	56 days	90 days
1	0%	22.35	28.3	31.25	33.45
2	10%(5 %BA +5% FS)	23.5	29.8	32.5	34.8
3	20%(10BA+10 FS)	24.5	30.52	31.55	35.6
4	30% (15% BA+15%FS)	23.2	27.5	29.5	32.5
5	40% (20 BA+20FS)	22.5	26.8	27.5	32.8



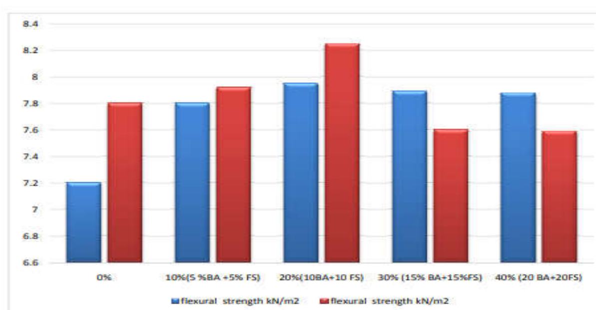
SPLIT TENSILE STRENGTH

Sl.No	% Of replacement of fine aggregate	Split Tensile Strength kN/mm^2	
		28 days	56 days
1	0%	5.62	5.90
2	10%(5 %BA +5% FS)	5.81	6.20
3	20%(10BA+10 FS)	5.95	6.85
4	30% (15% BA+15%FS)	5.83	6.65
5	40% (20 BA+20FS)	5.75	6.50



FLEXURAL STRENGTH

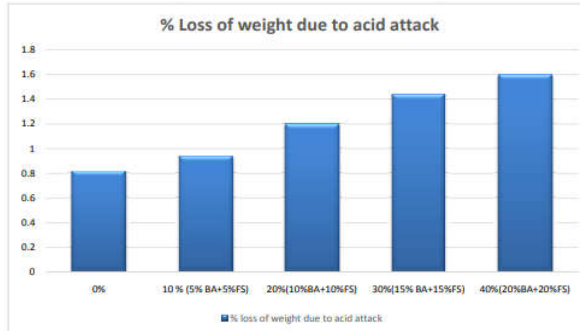
Sl.No	% of replacement of fine aggregate	Flexural Strength kN/m^2	
		28 days	56 days
1	0%	7.20	7.80
2	10%(5 %BA +5% FS)	7.80	7.92
3	20%(10BA+10 FS)	7.95	8.25
4	30% (15% BA+15%FS)	7.89	7.60
5	40% (20 BA+20FS)	7.88	7.59

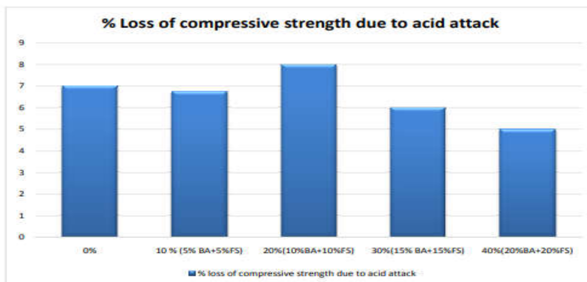


DURABILITY TEST

ACID ATTACK

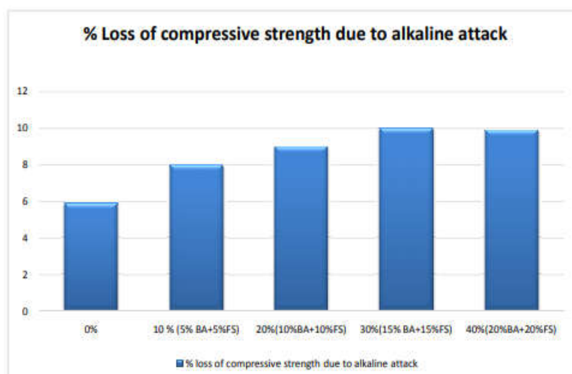
Sl. No	%replacement	Initial weight of cubes after 28days curing in grams	Final weight of cubes after 90days curing in grams	% loss of weight due to acid attack	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	% loss of compressive strength due to acid attack
1	0%	2261	2242	**0.82**	40.52	33.5	**7.02**
2	10 % (5% BA+5%FS)	2340	2318	**0.94**	38.25	31.5	**6.75**
3	20%(10%BA+10 %FS)	2351	2323	**1.2**	38.5	30.5	**8.00**
4	30%(15% BA+15%FS)	2234	2202	**1.44**	37.5	31.5	**6.00**
5	40%(20%BA+20 %FS)	2394	2356	**1.6**	37.5	32.5	**5.00**

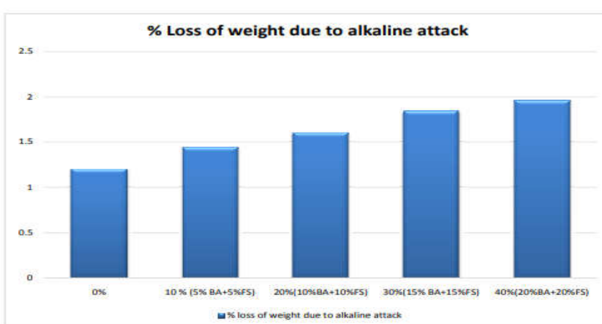




ALKALINE ATTACK

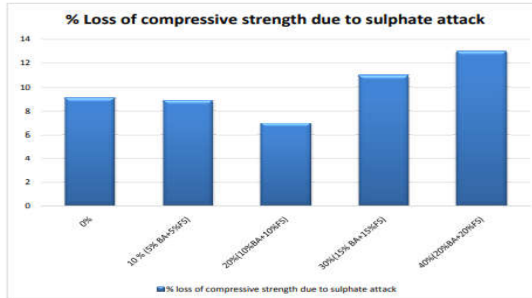
Sl. No	% replacement	Initial weight of cube after 28days curing in grams	Final weight of cubes after 90days curing in grams	% loss of weight due to alkaline attack	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	% loss of compressive strength due to alkaline attack
1	0%	2286	2259	**1.2**	41.5	35.6	**5.90**
2	10 % (5% BA+5%FS)	2340	2306	**1.44**	39.5	31.5	**8.00**
3	20%(10%BA+ 10%FS)	2280	2244	**1.6**	38.5	29.5	**9.00**
4	30%(15% BA+15%FS)	2310	2268	**1.84**	39.5	29.5	**10.00**
5	40%(20%BA+ 20%FS)	2296	2251	**1.96**	34.5	24.6	**9.90**





SULPHATE ATTACK TEST

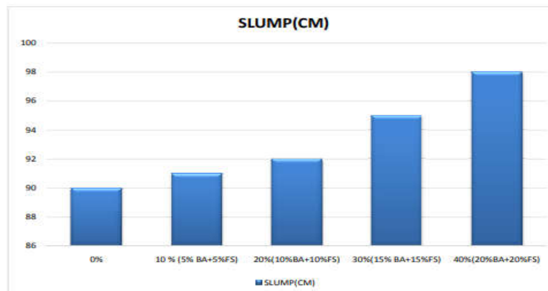
Sl.No	% replacement	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	% loss of compressive strength due to Sulphate attack
1	0%	39.6	30.5	9.10
2	10 % (5% BA+5%FS)	42.5	33.6	8.90
3	20%(10%BA+10%FS)	41.5	34.5	7.00
4	30%(15% BA+15%FS)	36.5	25.5	11.00
5	40%(20%BA+20%FS)	34.5	21.5	13.00



TRAIL II (MIX DESIGN OF M40)

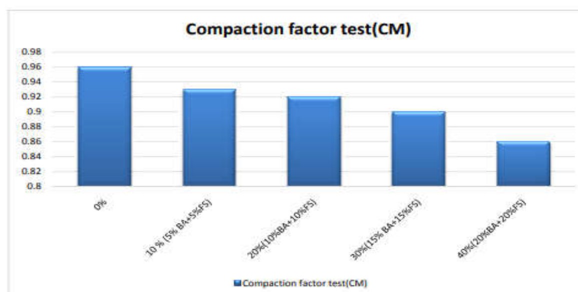
SLUMP CONE TEST

Sl.No	Material	SLUMP (CM)
1	0%	90
2	10 % (5% BA+5%FS)	91
3	20%(10%BA+10%FS)	92
3	30%(15% BA+15%FS)	95
4	40%(20%BA+20%FS)	98



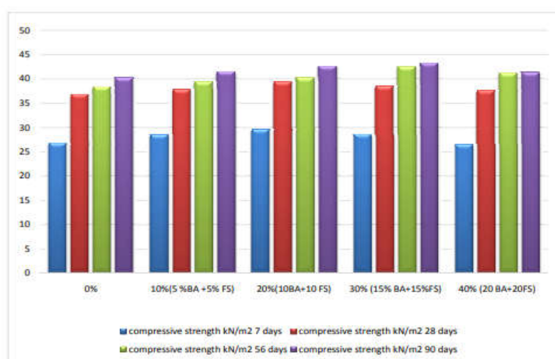
COMPACTION FACTOR TEST

Sl.No	Material	Compaction factor test (CM)
1	0%	0.96
2	10 % (5% BA+5%FS)	0.93
3	20%(10%BA+10%FS)	0.92
3	30%(15% BA+15%FS)	0.9
4	40%(20%BA+20%FS)	0.86



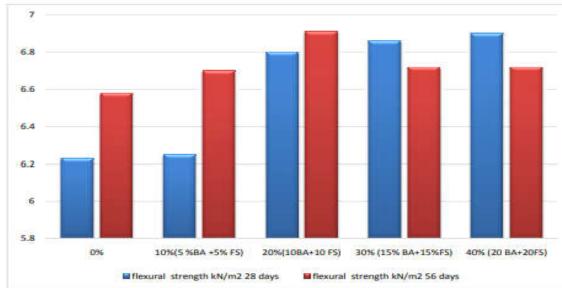
COMPRESSIVE STRENGTH

Sl.No	% of replacement of fine aggregate	Compressive strength kN/m^2			
		7 days	28 days	56 days	90 days
1	0%	26.8	36.8	38.4	40.21
2	10%(5 %BA +5% FS)	28.5	37.8	39.4	41.5
3	20%(10BA+10 FS)	29.6	39.4	40.25	42.6
4	30% (15% BA+15%FS)	28.6	38.5	42.5	43.26
5	40% (20 BA+20FS)	26.5	37.6	41.2	41.3



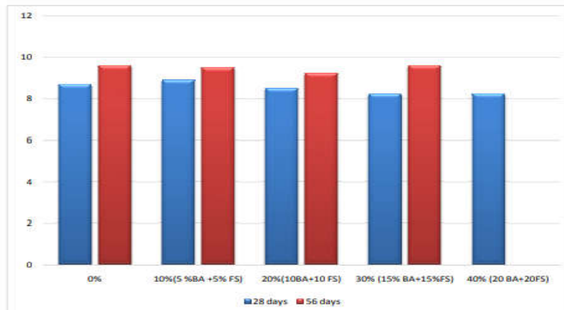
FLEXURAL STRENGTH

Sl.No	% of replacement of fine aggregate	Flexural Strength kN/m^2	
		28 days	56 days
1	0%	6.23	6.58
2	10%(5 %BA +5% FS)	6.25	6.7
3	20%(10BA+10 FS)	6.8	6.91
4	30% (15% BA+15%FS)	6.86	6.72
5	40% (20 BA+20FS)	6.9	6.72



SPLIT TENSILE STRENGTH

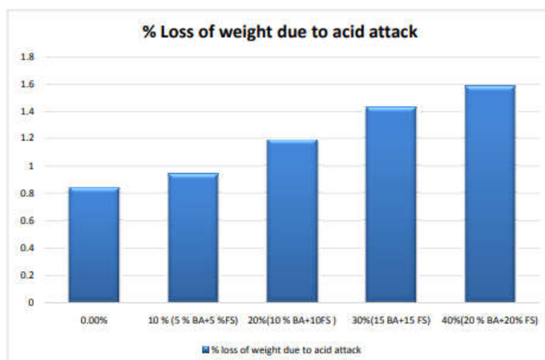
Sl.No	% of replacement of fine aggregate	Split Tensile Strength kN/m^2	
		28 days	56 days
1	0%	8.69	9.6
2	10%(5 %BA +5% FS)	8.9	9.5
3	20%(10BA+10 FS)	8.5	9.23
4	30% (15% BA+15%FS)	8.23	9.6
5	40% (20 BA+20FS)	8.24	'9.75

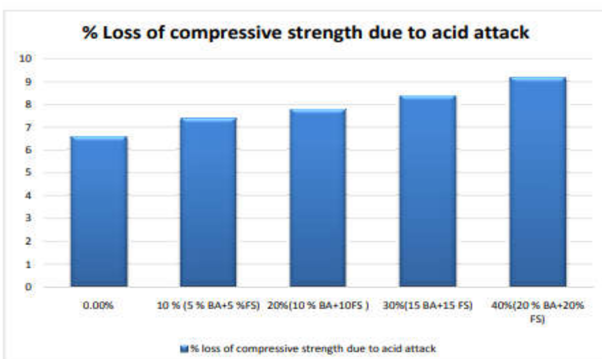


DURABILITY TEST

ACID TEST

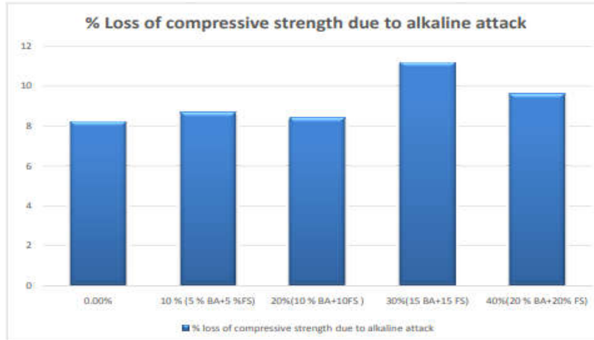
Sl.No	% replacement *Of fine aggregates*	Initial weight of cube after 28days curing in grams	Final weight of cubes after 90days curing in grams	% loss of weight due to acid attack	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	% loss of compressive strength due to acid attack
1	0.00%	2261	2242	**0.84**	29.55	27.6	**6.6**
2	10 % (5 % BA+5 %FS)	2340	2318	**0.94**	31.19	28.88	**7.4**
3	20%(10 % BA+10FS)	2351	2323	**1.19**	32.016	29.52	**7.8**
4	30%(15 BA+15 FS)	2234	2202	**1.433**	30.47	27.91	**8.4**
5	40%(20 % BA+20% FS)	2394	2356	**1.587**	29.84	27.1	**9.2**

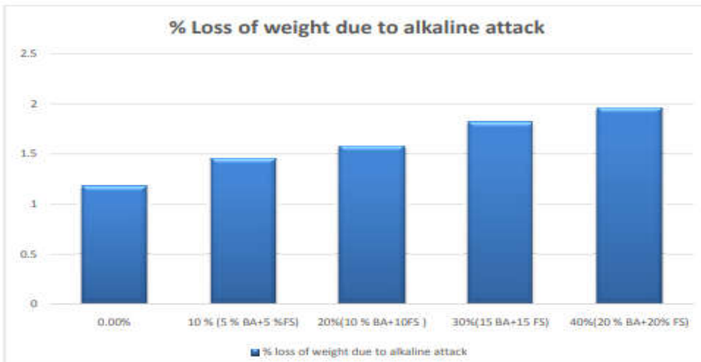




ALKALINE ATTACK

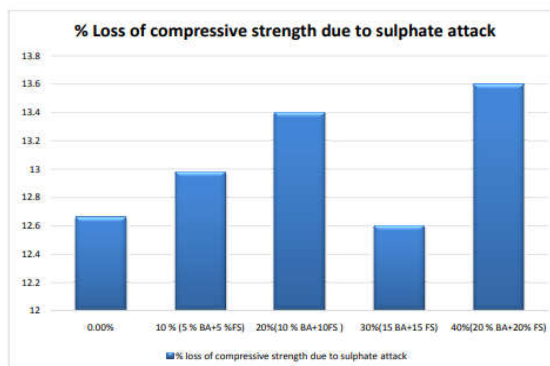
Sl. No	% replacement *Of fine aggregates*	Initial weight of cube after 28days curing in grams	Final weight of cubes after 90days curing in grams	% loss of weight due to alkaline attack	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	% loss of compressive strength due to alkaline attack
1	0.00%	2286	2259	**1.181**	29.55	27.12	**8.223**
2	10 % (5 % BA+5 %FS)	2340	2306	**1.452**	31.19	28.48	**8.688**
3	20%(10 % BA+10FS)	2280	2244	**1.578**	32.016	29.32	**8.42**
4	30%(15 BA+15 FS)	2310	2268	**1.818**	30.47	27.06	**11.191**
5	40%(20 % BA+20% FS)	2296	2251	**1.959**	29.84	26.97	**9.617**





SULPHATE ATTACK

Sl.no	% replacement *Fine aggregates*	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	% loss of compressive strength due to Sulphate attack
1	0.00%	29.55	25.8	12.66
2	10 % (5 % BA+5 %FS)	31.19	27.14	12.98
3	20%(10 % BA+10FS)	32.016	27.73	13.4
4	30%(15 BA+15 FS)	30.47	26.63	12.6
5	40%(20 % BA+20% FS)	29.84	25.78	13.6



V.CONCLUSIONS

The present investigation was carried out to evaluate the suitability of utilizing bottom ash as a partial replacement of fine aggregates in M30 and M40 grade concrete. The study also investigated the effect of micro silica in optimum bottom ash concrete mix. Test results indicate that bottom ash from Hindustan Newsprint Limited is a suitable material to be used as fine aggregate in partial replacement of fine aggregate along with micro silica in production of structural concrete. Based on the analysis of test results and discussions following conclusions can be drawn.

The present investigation was carried out to evaluate the suitability of utilizing bottom ash as a partial replacement of fine aggregates in M30 and M40 grade concrete. The study also investigated the effect of micro silica in optimum bottom ash concrete mix. Test results indicate that bottom ash from Hindustan Newsprint Limited is a suitable material to be used as fine aggregate in partial replacement of fine aggregate along with micro silica in production of structural concrete. Based on the analysis of test results and discussions following conclusions can be drawn.

SCOPE OF THEFUTURE WORK

he project can be implemented to the further grades of the cement concrete with different grades of the replacement of the bottom ash and foundry sand, This project is limited to the distractive tests can be implemented by conducting NON DISTRACTIVE TESTS.

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