An Experimental Investigation in to Partial Replacement of Fine Aggregate with Bagasse Ash in Concrete

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ABSTRACT:

High demand for sand in construction leads to environmental strain due to depletion of natural resources. Proposal to address this issue by using bagasse ash, a waste material from the sugarcane industry, as a partial replacement for sand in concrete. Experimental study conducted to assess suitability of bagasse ash for sand replacement. Tests performed on M30 grade concrete with sand replaced by bagasse ash in increments from 0% to 30%. Properties studied include workability, compressive strength, split tensile strength, and durability. Results indicate that bagasse ash can effectively replace sand in concrete up to 10% without significant loss in strength characteristics.

KEYWORDS:

Environmental strain, BagasseAsh, Concrete, Partial Replacement,Experimental study of M30 concrete.

1. INTRODUCTION:

India being an agricultural based country, a lot of Agro Industries have come up. The sugar and paper industries are generating a huge quantity of bagasse ash as waste, creating ecological problems because of dumping in open places causing environmental pollution.The bagasse ash obtained from sugar factory normally contains calcium carbonate and small amount of free lime. Hence bagasse ash can be utilized in concrete and in construction industry.In this project work, it has been planned to use it in concrete with the partial replacement of sand by using bagasse ash added as an additional ingredient in different proportions to enhance the binding property of concrete.The experimental studies are conducted for workability characteristics of fresh concrete and mechanical properties of hardened concrete with bagasse ash. From the results the optimum replacement of bagasse ash is determined and durability studies also carried out to check the viability.

2. SUGAR MANUFACTURING:

Prepared cane is transferred to mills through rake type carrier and the extracted juice is screened and juice is pumped to the process house and is weighed, added Phosphoric acid for better juice clarification. The juice is pumped to Vapour line juice heater and Dynamic juice heater to heat about 70oC thereby achieve maximum steam economy. The partially heated juice is subjected to simultaneous liming and sulphitation to precipitate colloidal and fine suspended impurities.The treated juice from secondary juice heater is passed to juice clarifier where the precipitated impurities (bagasse ash) which settle at the clarifier is collected.

2.1 CAPACITYOF SUGAR MANUFACTURE

Sugarcane crushing	=	7000 tons / day
Sugar produced	=	660 tons / day
Bagasse produced	=	2100 tons / day
Lime consumed	=	0.25% on cane
	=	17.5 tons / day
Bagasse ash produced	=	2 tons /day

Bagasse ash which essentially contains calcium carbonate with varying amounts of free lime is a waste product from sugar, paper, fertilizer and calcium carbide industries. The annual production of bagasse ash is approximately 4.8mt. The utilities bagasse ash for the manufacture of cement and lime have been investigated for commercial exploitation. The bagasse ash is a solid residue obtained from sugar factory. Free lime is being added in sugar processing for cleaning the juice. Fig-2.4 shows the feeding of raw lime to sulphitation process. The residue obtained along with some soil and cane pith is called bagasse ash. It contains a small percentage of free lime which has binding property. This can be utilized with some aggregate for making concrete or building blocks. In this project work we have obtained the bagasse ash from Sakthi Sugars Ltd., Sakthi Nagar.Manufacturing of plantation white sugar involves some mechanical means like

- Cane preparation device
- Mills
- DSM screen
- Juice collection tank
- Juice weighing scale
- Raw juice heaters
- Juice sulphitation unit
- Ssecondary juice heaters
- Formation of Bagasse ash

3. METHODOLOGY:

The methodology diagram of partial replacement of fine aggregate by using bagasse ash in concreteis shown in Figure 1.1.

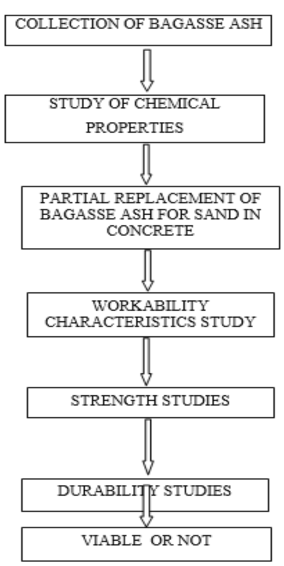


Figure 1.1Methodology of partial replacement of fine aggregate by using bagasse ash in concrete

4. CHARACTERISTICS OF BAGASSE ASH

4.1 PHYSICAL PROPERTIES

Presence Of Sio_2 and Al_2o_3

- Inert Materials
- Impart Strength
- Impart Workability
- Acts as a Filler Material
- Acidic in Nature
- Presence of Ca O
- Imparts Strength
- Increases Strength with Age
- Easily Combines with Basic Oxides To Form Various Silicates
- Basic in Nature

4.2 CHEMICAL PROPERTIES

Presence of Al_2o_3

- Oxidizing Agent (Trivalent Oxide)
- Supplies Oxygen to Metals
- Refractive Material
- Withstand High Temperature
- In Portland Cement 5% To 10 % Available

Presence of Sio_2

- Hard solid with high melting, boiling point andstable solid
- Role in the manufacturing of industrial products likeGlass, Cement and Abrasives
- Acidic Oxide (Tetravalent Oxide)
- In Portland Cement 20% To 25% Available

Presence of CaO

- Easily combines with basic oxides to form various silicates
- Silicate is a very important material named as cement, glass, abrasive refractories and slag
- In Portland cement 50% to 60% available

Presence Of MgO

- Insoluble in water
- Highly instable in nature

5.LITERATURE SURVEY

1.S.Gopalakrishnan et al(19) said that reinforced concrete is the most extensively used material for construction worldwide. A particle substitution of cement by an industrial waste such as fly ash is not only economical but also improves the properties on fresh and hardened concrete and enhances the durability characteristics. The reactive silica component present in them companies with the free calcium hydroxide , liberated during hydration of cement, to form additional calcium-silicate-hydrate (CSH), which otherwise would have leached out and increasing the porosity of the cement matrix. The additional CSH increases the denseness of the matrix and refines the pore structure. Hence the use of supplementary cementitious materials in concrete can lead to enhanced durability characteristics. It also improves the rheology of the fresh mixes, enhances the strength of concrete, and reduces the cost.

2. A.K.Mullick (20) describes the characteristics of cementitious system required to meet the diverse requirements of strength and durability of concrete and high lights the advantages of part replacement of OPC by fly ash, graduated slag either singly or in combination in ternary blends.

3. Dr.Perumal (18)in his research study, the movement of ions in a porous medium under a concentration gradient is called diffusion. It is often necessary to ascertain the impermeability of concrete to chloride ions as a quality control measure and also for assessment of improvements effected in properties of new concretes. Measurement of chloride diffusion co-efficient requires a long time for establishment of steady state conditions. Therefore, a direct current (DC) potential is usually applied to accelerate migration of ions.

4. Prof.M.S.Shetty(7) has mentioned that the durability deals with fundamental considerations of volume change and cracks in concrete, leading to permeability, in an unconventional manner. Latest methods of Mix Design as per ACI methods and British methods (DOE method) have been pointed out.Thechemical property of bagasse ash comparative with ordinary cement test reports is shown in Figure 5.1.

	BAGASSE ASH	ORDINARY CEMENT
Silicon dioxide (SiO_2)	21.1	20
Aluminum oxide (Al_2O_3)	10.6	06
Ferric oxide (Fe_2O_3)	1.5	03
Calcium oxide (CaO)	43.0	63
Magnesium oxide (MgO)	1.0	1.5
Loss of Ignition	20.8	less than 5

all values are in %

Figure 5.1Chemical composition of bagasse ash

6. EXPERIMENTAL INVESTIGATIONS

6.1 MATERIAL USED

6.1.1 BAGASSE ASH

The bagasse ash is a solid residue obtained from sugar factory. Free lime is being added in sugar processing for cleaning the juice. The residue obtained along with some soil and cane pith is called bagasse ash. It contains a small percentage of free lime which has binding property. This can be utilized with some aggregate for making concrete or building blocks. In this project work we have obtained the bagasse ash from Sakthi Sugars Ltd. Sakthi Nagar.

Figure 6.1Collection of bagasse ash

6.1.2 FINE AGGREGATE

M Sand is either round or angular grains and is often found mixed in various gradation of fineness. A brick made from sand consisting of rounded grains is as good as that in which the grains are angular. The river or pit sand should be used and not sea sand as it contains salt and other impurities which will after the structure. In this project work, M Sand has been usedthe

Figure 6.2M Sand

6.1.3 WATER

In general, for mixing of ingredients water is used. Excess of acidity or alkalinity in water is to be avoided. Potable water from Bhavani River is used for this work.

6.1.4 CEMENT

Cement is a binding material in concrete which is used in all building elements. Ordinary Portland Cement 53(OPC) grade is used for casting the cubes.

Figure 6.3Cement

6.1.5 AGGREGATES

These are the inert or chemically inactive materials which form the bulk ofcement concrete. The aggregates are bound together by means of cement. The aggregates to be used for cement concrete work should be hard, durable, and clean and free from lumps of clay, organic and vegetable matter, fine dust, etc. The presence of all such debris prevents adhesion of aggregates and hence, reduces the strength of concrete. A good quality of aggregates with adequate particle distribution, from Uttuguli area is used for this project work.

Figure 6.4Coarse Aggregate

7.PROPERTIES OF MATERIALS:

7.1 CEMENT:

The cement used for the manufacture of concrete cubes is of 53 grade ordinary cement. The properties of Cement like consistency, Initial setting time, final setting time and fineness modulus are tested for the samples and the results are given below.

S.NO	DESCRIPTION	TEST RESULT
1	Specific gravity of cement	3.15
2	Fineness of cement	2.0
3	Standard consistency of cement	48%
4	Setting time Initial setting time Final setting time	 68min 338 min
5	Soundness of cement	2.2mm

Result 7.1Cement

7.2FINE AGGREGATE:

The fine aggregate is one of the most important constituents of the concrete. The properties fine aggregate is listed below.

S.NO	DESCRIPTION	TEST RESULT
1	Specific gravity of fine aggregate	2.65
2	Fineness modules of fine aggregate	1.97
3	Water absorption	0.7
4	Density of fine aggregate Loose bulk density Rodded bulk density	 1480 Kg/m^3 1597 Kg/m^3

Result 7.2Fine Aggregate

7.3COARSE AGGREGATE

A good quality of aggregates with adequate particle distribution, from Uttuguli area is used for this project work.

S.NO	DESCRIPTION	TEST RESULT
1	Specific gravity	2.72
2	fineness modules	6.99
3	water absorption	0.5
4	Impact value	7.143
5	Crushing value	39.05
6	Density of coarse aggregate Loose bulk density Rodded bulk density	 1449 Kg/m^3 1535 Kg/m^3

Result 7.3Coarse Aggregate

7.4 SPECIFIC GRAVITY OFBAGASSE ASH AND SAND

Identification	Ratio of Sand with Bagasse ash	Specific Gravity
A	95% Sand + 5% Bagasse ash	2.652
B	90% Sand + 10% Bagasse ash	2.625
C	85% Sand + 15% Bagasse ash	2.604
D	80% Sand + 20% Bagasse ash	2.594
E	75% Sand + 25% Bagasse ash	2.545
F	70% Sand + 30% Bagasse ash	2.521

Result 7.4Specific Gravity of Bagasse Ash and Sand

7.5 WATER

The water is one of the most important constituents of the concrete. Water is responsible for setting of cement by the process of hydration. The water used in concrete should be portable water.

Alkalinity

- Alkalinity due to OH_ = 95 mg / lit
- Alkalinity due to CO3 = 190 mg / lit
- Alkalinity due to HCO3 = 480 mg / lit

The amount of chlorides present in given sample =144.95 mg / lit

The hardness of the given sample = 615 mg / lit

Ph value of a given sample = 7.1 PPM.

8. MIX DESIGN OF CONCRETE

- As per IS code IS 10262:2019 & IS 456:2000

8.1 MIXDESIGN (GRADE M30)

DESIGN STIPULATIONS:

Characteristic compressive strength required in the field at 28 days = 30 Mpa

Max nominal size of aggregate =20mm

Degree of workability=0.90

(Compacting factor)

Degree of Quality control = Good

Type of exposure= Modern

8.1 MIX PROPORTION (GRADE M30)

Cement : 370 kg/ m3

Water : 148 kg/ m3

Fine aggregate : 779.1 kg/ m3

Coarse aggregate : 1199.52 kg/ m3

Water	Cement	Fine Aggregate	Coarse Aggregate
148 liters	370 Kg	779.1 Kg / m³	1199.52 Kg / m³
0.4	1	2.10	3.24

8.2 SCHEDULE OF CASTING

CASTING OF CUBES

- Take Bagasse ash as partial replacement of sand by - 0%,5%,10%,15%,20%,25%,30%
- Adopt water cement ratio - 0.40.
- Period of curing - 28 days
- Size of moulds (150mm x 150mm x 150mm)

8.3 EXPERIMENTAL PROGRAM

TESTS CONDUCTED

1. Slump Test and Compaction Factor Test
2. Compressive Strength Test
3. Split Tensile Strength Test

8.3.1 SLUMP TEST

- Slump test as per IS code IS 456 - 2000
- A concrete mix of M30 with 0% to 30% partial replacement of bagasse ash is filled in three layers compacted with tamping rod.
- Top surface is levelled, and mould is raised vertically.
- The slump which is the difference in height between the top of the mould and the highest point on the subsided concrete is measured.

Figure 8.1Slump Test

8.3.2 COMPACTION FACTOR TEST

- Compaction factor test as per IS code IS 10262:2019
- A concrete mix of M30 with 0% to 30% partial replacement of bagasse ash is filled in upper hopper of compaction factor apparatus.
- The trap door is opened so that the concrete falls into the lower hopper and bottom hopper.
- The excess concrete is removed and find the weight of concrete placed in cylinder.
- The cylinder is again refilled with full compaction and find the weight of concrete.
- The compaction factor is the ratio between partial and full compaction concrete.

8.3.3 COMPRESSION TEST

- Compression test as per IS code clause 6.2 of IS 456-2000
- The required quantity of ingredients was weighed and were prepared cubes with the help of moulds and cured for 7 days, 14 days and 28 days.
- At the end of curing period, the cube was placed in between the compression plates of the Universal Testing Machine and apply load gradually.
- The reading was noted at the time of first crack and at the time of failure .
- The compressive strength can be calculated by ratio of compressive load and area of the cube.

Figure 8.2 Compression Test

8.3.4 SPLIT TENSILE TEST

- The required quantity of ingredients was weighed and were prepared cylinders with the help of moulds and cured for 7 days, 14 days and 28 days.
- At the end of curing period, the cylinders were placed in between the compression plates of the Universal Testing Machine and apply load gradually.
- The reading was noted at the time of first crack and at the time of failure .

- The tensile strength can be calculated by using formula Tensile strength = 2P/3.14xD x L N/mm2

Where,

P-compressive load,
D-Dia of cylinder mould,
L-Length of cylinder

Figure 8.3 Split Tensile test

9.RESULT:

The discussions about slump value and compaction factor provide further insights into the effects of incorporating bagasse ash into concrete:

Mix Designation	A 0%	B 5%	C 10%	D 15%	E 20%	F 25%	G 30%
Slump (in mm)	20	19	18	16	14	11	11
Compaction Factor	0.90	0.86	0.85	0.83	0.78	0.75	0.70

TABLE 4.1 Results of Slump and Compaction factor test

9.1 SLUMP VALUE:

- As the percentage of bagasse ash increases, the slump value decreases. This reduction is attributed to the higher powder content of bagasse ash, which absorbs water in the concrete mixture.
- This reduction in slump indicates a decrease in the workability of the concrete mixture, making it less fluid and more difficult to shape and place.
- One potential strategy to mitigate this reduction in slump is to reduce the amount of fine aggregate in the mixture by substituting it with bagasse ash as a filler material. This adjustment could help maintain the desired slump while still incorporating bagasse ash into the mixture.

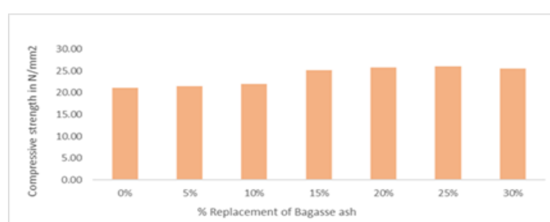
9.2 COMPACTION FACTOR VALUE:

- Similar to the slump value, the compaction factor decreases with increasing percentages of bagasse ash. This decrease is due to the higher powder content of bagasse ash, which requires more compaction to achieve the desired density.
- A reduction in compaction factor indicates that more effort is needed to compact the concrete mixture effectively, leading to potential challenges during construction.
- Like with the slump value, one approach to address this decrease in compaction factor is to reduce the amount of fine aggregate in the mixture by using bagasse ash as a filler material. This adjustment could help improve the compaction properties of the concrete mixture while incorporating bagasse ash.

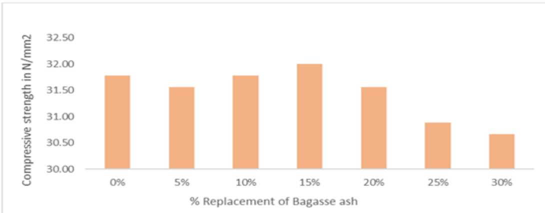
Overall, these discussions highlight the importance of considering the impact of bagasse ash on both the workability and compaction properties of concrete mixtures. Adjusting the mixture proportions and incorporating bagasse ash as a filler material can help mitigate these effects and optimize the performance of the concrete mixture for construction applications.

9.3 COMPRESSION TEST:

The test results reveal key insights into the strength development of concrete with bagasse ash at various curing periods:

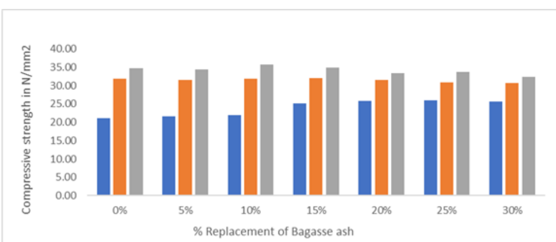


7 Days Curing: 25% bagasse ash replacement shows the highest strength initially, but strength decreases with higher replacements. This suggests a limit to bagasse ash's early strength benefits.



14 Days Curing: Surprisingly, 15% replacement yields peak strength, differing from the 7-day results. Again, strength decreases with higher bagasse ash replacements.

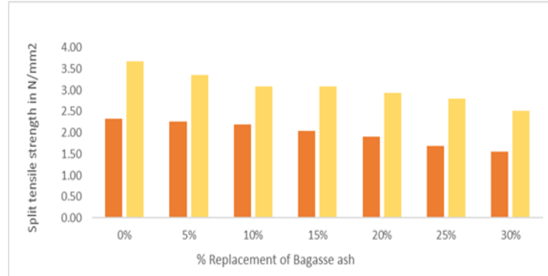
28 Days Curing: Strength peaks at 10% replacement, indicating ongoing strength development. Calcium carbonate in bagasse ash may enhance strength, hinting at potential mineral admixture benefits. Despite slow pozzolanic reaction, significant strength gain occurs at 28 days.



Overall, these findings underscore the intricate interplay between bagasse ash content and concrete strength across curing periods. Strategic replacement levels can balance strength and durability, with potential for further optimization through mineral admixture inclusion.

9.4 SPLIT TENSILE TEST:

The discussion highlights the impact of bagasse ash on tensile strength:



Tensile Strength Reduction: The tensile strength decreases as the percentage of bagasse ash in the concrete mix increases. This trend is attributed to the brittle nature of lime present in bagasse ash, which inherently reduces the tensile strength of the concrete.

Increase in Powder Content: Additionally, the increase in powder content due to the addition of bagasse ash contributes to the cumulative effect on reducing tensile strength. The higher powder content alters the composition and behavior of the concrete mixture, resulting in decreased tensile strength.

Overall, these observations underscore the importance of considering not only the compressive strength but also the tensile strength when evaluating the effectiveness of bagasse ash as a supplementary material in concrete construction.

10.CONCLUSION:

COMPRESSIVE STRENGTH:the addition of bagasse ash to concrete initially increases compressive strength, with the optimum replacement level being 10%. Beyond this level, there's a decrease in strength.

COST-EFFECTIVENESS: bagasse ash is cost-effective as it's a byproduct of the sugar industry and can significantly reduce construction costs compared to using fly ash or clay bricks.

EFFECT ON STRENGTH: higher percentages of bagasse ash reduce concrete strength due to increased calcium oxide content.

VERSATILITY: bagasse ash can also substitute for lime in weathering courses, further reducing construction costs.

DURABILITY: durability tests demonstrate no significant variation in durability when bagasse ash is added to concrete, making it suitable for various construction applications.

WORKABILITY: while the addition of bagasse ash reduces workability, the increase in compressive strength compensates for this drawback up to 10% replacement.

RESISTANCE TO ACID AND CHLORIDE PENETRATION: durability tests show that concrete with 10% bagasse ash replacement is not significantly affected by acid and chloride penetrations compared to normal concrete.

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