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EFFICIENCY ANALYSIS OF BANANA STEM ASH AS A SUPPLEMENTARY CEMENTITIOUS MATERIAL IN CONCRETE

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Abstract - *Cement is a core binding material used for the production of concrete. The cement manufacturing industry is one of the major contributors of global greenhouse gas emissions. The best solution is the optimum usages of cement in concrete without compromising on quality. There are different materials are available for the partial replacement of cement in concrete and a number of researches are going in this field. The main aspect for the development of a sustainable concrete is the selection of its constitutive materials to reduce the negative impacts on the environment. Use of natural supplementary cementitious materials from new sources is gaining importance in modern construction practices due to their superior performance and benefits. Banana stem ash is a natural supplementary cementitious material with prominent pozzolanic properties. The use of agricultural products in concrete makes it more economical and protects the environment by reduced waste generation. The optimum replacement of cement in concrete can helps to reduce the CO_2 emissions from its production. This study includes the efficiency analysis of M 30 grade banana stem ash concrete in terms of strength and durability properties. Banana stem ash is used as partial replacement for cement. The percentage variation of cement replacement by banana stem ash is 0%, 5%, 10%, 15% and 20%. Fresh and hardened properties of concrete are determined for the analysis. Workability of the fresh concrete is measured by using slump test. Compression strength test, flexural strength test and split tensile strength tests are used for the strength analysis of different concrete mixes. Durability properties are analyzed using water absorption test and chloride attack test.*

Key Words: **Banana stem ash, Cement, Concrete, CO_2 emissions, Durability, Supplementary cementitious materials, Strength.**

1. INTRODUCTION

Supplementary cementitious materials are useful for improved concrete performance in both fresh and hardened stages of concrete. These materials mainly used for improved workability, durability and strength development. Their use minimizes the consumption of conventional cement per unit volume of concrete. The conventional cement has high-energy consumption and emissions associated with its manufacture. The availability of conventional supplementary cementitious materials such as fly ash, blast furnace slag, silica fume, etc. has expected to decrease in the future and these materials are not easily available everywhere. The ashes of natural fibres have excellent physical and mechanical properties useful for the production of sustainable concrete. The implementation of natural fibre ashes in concrete as a partial replacement for cement can provide high strength, high load bearing capacity and good crack sealing property. In this project, banana stem ash has used as a supplementary cementitious material for the production of sustainable concrete. The optimum usage of banana stem ash in concrete as partial cement replacement provides reduced water demand for a given workability. Banana stem ash is easy to use and it can be added directly to the cement. The cost reduction is possible with the use of banana stem ash as a cement replacement material in all grades of concrete. It can impart early strength gain and high impermeability to the concrete and make it more durable. The replacement of cement with banana stem ash will reduce the unit water content required to obtain the same slump of conventional concrete. The surface configuration and particle shape of supplementary cementitious materials is being different from cement particles. They have a high potential for pozzolanic reaction and enhance the hydration properties of the cement paste. The use of supplementary cementitious materials in concrete production utilizes cement more efficiently during the hydration process and improves the resistance of concrete to aggressive environmental agents.

1.1 Scope and Objectives of the Study

The large emissions come from cement production, necessitates the optimum usage of cement in concrete. Use of natural supplementary cementitious materials such as banana stem ash can partially replace the cement economically. The high procurement cost of various ingredients of concrete is creating problems in rural and underdeveloped countries. The best immediate option is to use simple and relatively cost effective and point of use technologies to improve the performance of concrete.

The main objectives of the study are:

- To analyze the efficiency of using banana stem ash as a supplementary cementitious material in the production of concrete
- Development of an efficient, sustainable concrete at low cost by using natural replacement of cement

- To find the optimum dosages of banana stem ash at which appreciable results for the sustainable concrete will be obtained
- To analyze the strength properties of concrete using the compression strength test, flexural strength test and split tensile strength test
- To study the durability properties of concrete using water absorption test and chloride attack test
- To reduce the negative impacts of concrete on the environment in an efficient and economical manner

2. MTERIALS USED FOR THE STUDY

The important materials used for the production of concrete include cement, fine aggregate, coarse aggregate and banana stem ash. The testing of the materials has carried out in the laboratory for the determination of their properties and suitability.

2.1 Cement

Ordinary Portland cement of grade 53 is used for the experimental analysis. Testing on OPC 53 is carried out as per the recommendations of IS 12269:2013 and IS 4031:1988.

Table -1: Properties of Cement

Sl.No.	Properties	Results
1	Specific gravity	3.15
2	Standard consistency	33%
3	Fineness	1%
4	Initial setting time	30 minutes
5	Final setting time	160 minutes

2.2 Fine Aggregate

Manufactured sand (Zone II) is used for this experimental investigation. IS 383:1970 and IS 2386:1963 are the relevant codes used for the testing of fine aggregate.

Table -2: Properties of Fine Aggregate

Sl.No.	Properties	Results
1	Specific gravity	2.62
2	Water absorption	1%
3	Fineness modulus	2.60

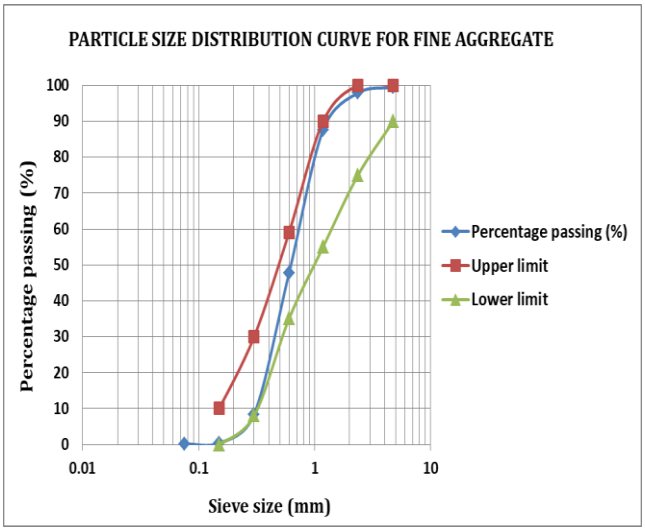

Chart -1: Particle size distribution curve for fine aggregate

2.3 Coarse Aggregate

The maximum size of coarse aggregate used in this study is 20 mm. Testing of coarse aggregate is carried out as per the recommendations of IS 2386:1963 and IS 383:1970.

Table -3: Properties of Coarse Aggregate

Sl.No.	Properties	Results
1	Specific gravity	2.7
2	Water absorption	0.6%
3	Fineness modulus	3.69

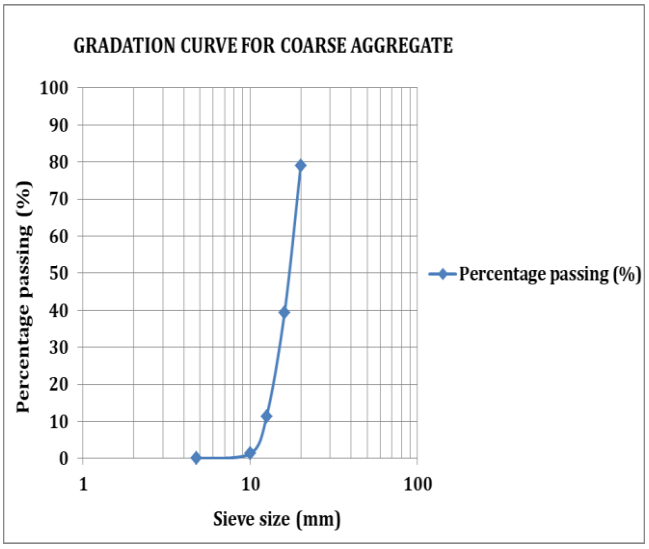

Chart -2: Gradation curve for coarse aggregate

2.4 Banana Stem Ash (BSA)

The banana stems are collected from banana cultivation fields after the season of harvesting. The collected banana stems are washed and cleaned with potable water to remove dirt and other types of impurities. Then the samples are cut into small uniform pieces and dried for over one week under sunlight. The dried samples have kept in an oven at 150°C for 24 hours to convert the organic material to an inorganic matter. Then the samples have grounded by a milling machine. The grounded samples are passed through a sieve of size 150 micron. The powdered samples passing through 150 micron sieve have used for the partial replacement of cement. The specific gravity of banana stem ash is obtained as 2.50. Banana stem ash is added to the concrete at different percentages such as 0%, 5%, 10%, 15% and 20%.

Fig -1: Banana stem ash (BSA)

3. MIX PROPORTION OF M 30 CONCRETE

Mix design is done according to IS 10262:2009 for M 30 concrete. Mix design of M 30 grade concrete has carried out using the results obtained from the laboratory testing of materials. The obtained mix proportion for M 30 grade concrete is 1: 1.46: 2.57: 0.45.

Table -4: Mix Proportion of M 30 Concrete

Sl.No.	Name of material	Quantity
1	Cement	438.13 kg/m^3
2	Fine aggregate	643.68 kg/m^3
3	Coarse Aggregate	1129.46 kg/m^3
4	Water	197.16 kg/m^3

4. EXPERIMENTAL ANALYSIS

Experimental analysis includes different tests to determine the workability, strength and durability properties of the conventional M 30 and banana stem ash concrete. After estimating the quantities of materials required, the casting of cubes, beams and cylinder samples have carried out. Three samples have cast for each type of concrete mixes and their average test results has noted. The compression strength test has conducted for cubes after 7 and 28 days of curing. The 28 days flexural strength and split tensile strength tests are conducted for beams and cylinders respectively. The durability tests include water absorption test and chloride attack test and conducting after 28 days of curing.

4.1 Determination of Workability

For analyzing the workability properties of fresh concrete mix, the slump test has conducted. The various percentages of banana stem ash used for the tests include 0%, 5%, 10%, 15% and 20%. An increase of 5% in slump value is achieved with 10% cement replacement by banana stem ash.

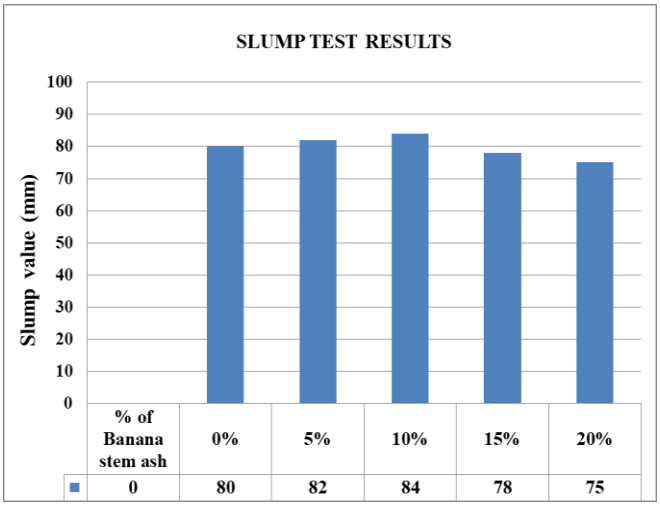

Chart -3: Slump test results of banana stem ash concrete

4.2 Compression Strength Test

For compression strength test, 150 mm x 150 mm x 150 mm sized cube samples after 7 and 28 days of curing are used. The varying percentages of banana stem ash used for the test include 0%, 5%, 10%, 15% and 20%.

Table -5: Average compression strength results (N/mm^2)

Percentages of banana stem ash	Compressive strength	
	7 Days	28 Days
0%	24.11	30.55
5%	26.10	32.14
10%	28.33	35.03
15%	22.73	29.16
20%	20.88	28.26

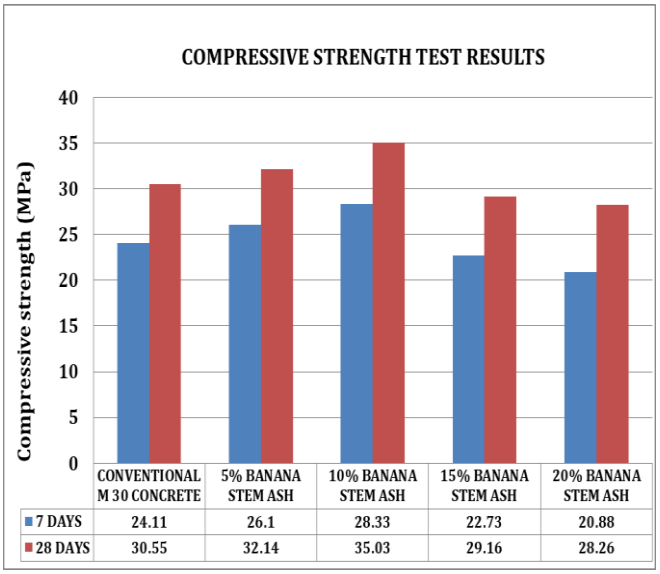

Chart -4: Comparison of compression strength results

The optimum dosage of 10% replacement of cement by banana stem ash in M 30 concrete gives maximum value of compressive strength after 7 and 28 days of curing.

4.3 Flexural Strength Test

Beam specimens of size 500 mm x 100 mm x 100 mm are used for the testing of flexural strength after 28 days of curing. The different percentages of banana stem ash used for the test include 0%, 5%, 10%, 15% and 20%. The optimum dosage of banana stem ash is 10% and gives higher value of flexural strength.

Table -6: Average flexural strength results (N/mm²)

Percentages of banana stem ash	Flexural strength 28 Days
0%	5.44
5%	5.63
10%	6.21
15%	5.31
20%	4.79

4.4 Split Tensile Strength Test

Cylinder specimens of size 300 mm x 150 mm are used for the split tensile strength test. This test is conducted after 28 days of curing in the water tank. The percentage variation of banana stem ash used for the test is 0%, 5%, 10%, 15% and 20%. Maximum value of split tensile strength is at 10% optimum dosage of banana stem ash in concrete.

Table -7: Average split tensile strength results (N/mm²)

Percentages of banana stem ash	Split Tensile Strength 28 Days
0%	2.42
5%	2.48
10%	2.78
15%	2.22
20%	2.16

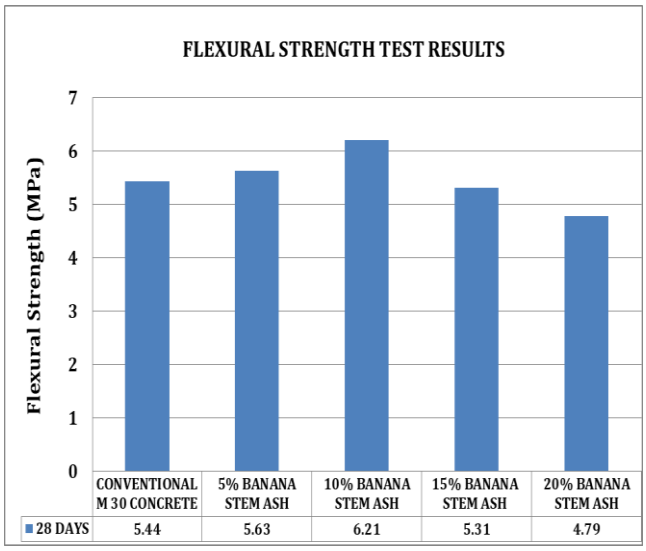

Chart -5: Comparison of flexural strength results

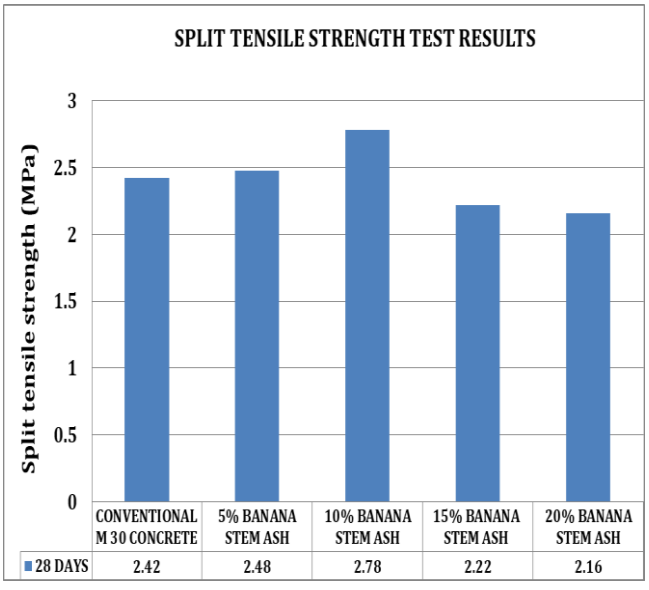

Chart -6: Comparison of split tensile strength results

4.5 Water Absorption Test

The water absorption test is conducted after 28 days of curing for 150 mm x 150 mm x 150 mm sized cube samples. It is an important durability test based on the water absorption properties of concrete. The specimens are oven dried at a temperature of 100°C to 110°C for one day. Then the specimens removed from the oven are cooled to room temperature for the determination of dry weight. After the determination of dry weight and wet weight of the samples, percentage of weight loss is calculated. The wet weights are calculated after the 48 hours immersion of samples in water. By using initial and final weights, percentage weight loss of the cube samples is determined. The water absorption test is mainly conducted for conventional concrete samples and for optimum dosage of banana stem ash (10%).

Table -8: Water absorption test results

Type of mix		Water absorption (%)	Average
Conventional M 30 mix	Sample 1	2.13%	1.8%
	Sample 2	1.12%	
	Sample 3	2.13%	
BSA = 10%	Sample 1	1.45%	1.37%
	Sample 2	1.23%	
	Sample 3	1.45%	

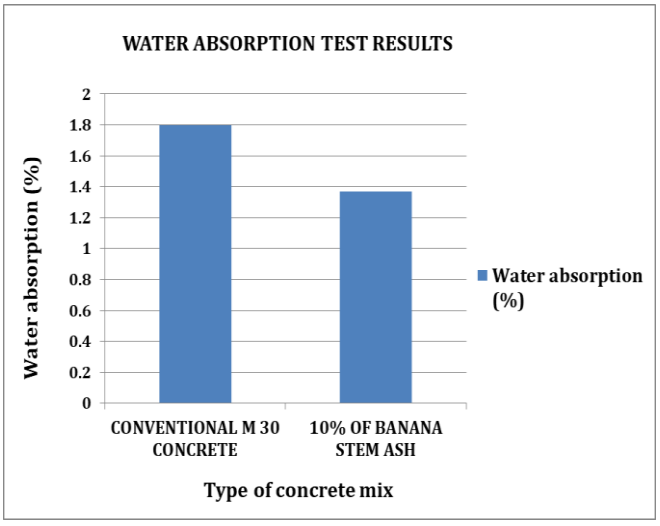

Chart -7: Comparison of water absorption results

The water absorption percentage of banana stem ash concrete at optimum dosage is less than that of conventional concrete. Hence, the banana stem ash concrete has good durability in terms of water absorption.

4.6 Chloride Attack Test

A durable concrete should have good resistance against chloride attack. The chloride attack test is mainly conducted for conventional M 30 grade concrete and banana stem ash concrete samples having optimum dosage of 10%. Chloride attack test is conducted after 28 days of curing for 150 mm x 150 mm x 150 mm sized cube samples. The dry weight of the cube specimens is calculated. The specimens are allowed to immerse in sodium chloride (NaCl) solution for a period of 7 days. Then the final weights are noted. Percentage weight loss and strength reductions are calculated from the test to assess the durability properties.

Table -9: Average weight loss due to chloride attack

Type of mix	Weight loss	
	Initial weight (kg)	Final weight (kg)
Conventional M 30 mix	8.70	7.92
BSA = 10%	8.82	8.12

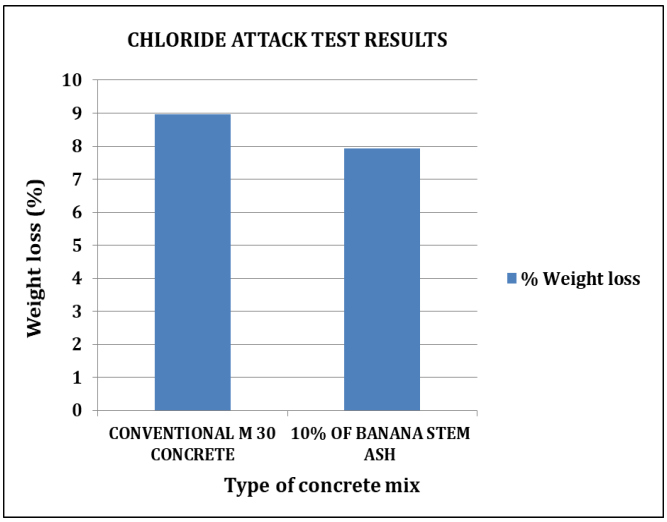

Chart -8: Percentage weight loss due to chloride attack

The percentage weight loss of banana stem ash concrete at optimum dosage of 10% is comparatively less than that of conventional M 30 grade concrete. So the banana stem ash concrete has good resistance against chloride attack in terms of percentage weight loss.

The compressive strength of conventional M 30 concrete and BSA concrete (10%) is determined after the chloride attack test. The reduction in compressive strength due to chloride attack has used as another parameter to draw conclusions about the chloride attack resistance of the concrete samples. After the determination of compressive strength values at 28 days of curing in the water tank, compressive strength at 7

days immersion in NaCl solution is noted. The percentage loss of compressive strength is taken as a measure of chloride attack resistance of the tested samples.

Table -10: Average compressive strength values

Type of mix	Compressive strength (N/mm²)	
	Initial strength	Final strength
Conventional M 30 mix	30.55	23.25
BSA = 10%	35.03	28.41

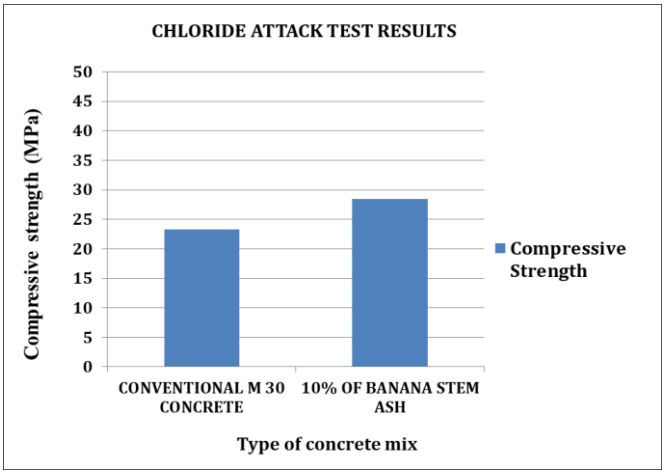

Chart -9: Compressive strength after chloride attack test

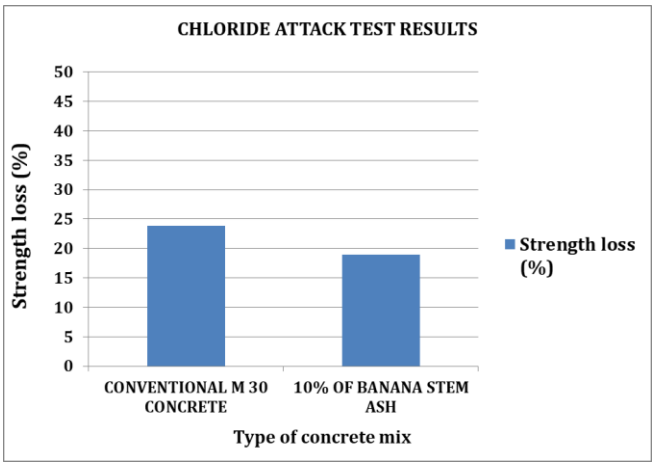

Chart -10: Percentage strength loss due to chloride attack

The percentage strength loss is higher for conventional M 30 grade concrete. For the 10% optimum dosage of banana stem ash in concrete, the strength loss is lesser than that of conventional concrete. The banana stem ash concrete has good resistance against strength loss due to chloride attack.

5. CONCLUSIONS

The percentage replacements of cement by banana stem ash for the tests include 0%, 5%, 10%, 15% and 20%. Slump test, compression strength test, flexural strength test, split tensile strength test, water absorption test and chloride attack test are used for the performance evaluation of banana stem ash concrete in comparison with the conventional M 30 grade concrete. The optimum percentage of banana stem ash for cement replacement in concrete is obtained as 10%.

At the same water cement ratio of conventional M 30 grade concrete, the 10% optimum dosage of banana stem ash in concrete attained 5% more workability with reduced water demand.

The 10% optimum replacement of banana stem ash in concrete shows 17.50% increase in 7 days compressive strength and 14.66% increase in 28 days compressive strength than the conventional concrete.

The optimum dosage of banana stem ash in concrete gives 14.15% increase in 28 days flexural strength in comparison to the conventional concrete.

An increase of 14.87% in 28 days split tensile strength has achieved with 10% optimum dosage of banana stem ash in concrete than the conventional M 30 concrete.

There is a decrease in the water absorption percentage for optimum dosage of banana stem ash than the conventional M 30 concrete. Percentage water absorption of conventional concrete has obtained as 1.8% and that of banana stem ash concrete with the optimum dosage (10%) of cement replacement is 1.37%. The water absorption percentage of banana stem ash concrete is 1.31 times lesser than that of conventional concrete.

Banana stem ash in concrete at optimum dosage (10%) gives hopeful results regarding its chloride attack résistance. Percentage weight loss of conventional M 30 concrete is 8.96%. The weight loss percentage of banana stem ash concrete at optimum dosage is 7.93%. The percentage weight loss of banana stem ash concrete is 1.129 times lesser than that of conventional concrete.

The percentage strength loss of conventional M 30 concrete after 7 days in NaCl solution is 23.89%. The strength loss percentage of banana stem ash concrete at optimum dosage due to chloride attack is 18.89%. The percentage strength loss of banana stem ash concrete is 1.264 times lesser than that of conventional concrete. The strength reduction is comparatively less for optimum dosage of BSA concrete and it has good chloride resistance.

The banana stem ash incorporated concrete with optimum cement replacement shows superior mechanical and durability properties. The use of natural supplementary

cementitious materials having good pozzolanic properties in concrete is efficient and economical.

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