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Design of low Volume Traffic Pavements Using Bagasse Ash

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Abstract - *There is a high demand of natural resources due to rapid urbanization. Moreover, the massive constructions release enormous amount of pollutants to the atmosphere and studies reveal that the pollutants from the construction industry are more harmful than the pollutants from any other segment. On the other hand, there is also a large production of agricultural wastes as Agricultural Industry is one of the largest industries in India as more than 70% of Indian Population is dependent on agriculture. Many agricultural waste materials are already used in concrete as replacement alternatives for cement, fine aggregate, coarse aggregate and reinforcing materials. Moreover, the various processes for the production and processing of cement, bitumen, tar, fine and coarse aggregate requires a lot of energy and production of harmful gaseous and chemical wastes into the environment.*
Thus In view of the above Problems, an attempt is made to study, to reduce the pollution from cement and other materials used in the construction process with a view to create and develop greener methods of construction. In the experimental study, bagasse ash is used in the manufacturing of paver blocks for low volume traffic road which can serve us for the development of road pavements for Village roads, Other District roads or City street roads . Paver blocks as per the geometric dimensions were casted with the different trial mixes and tested as per the BIS and IRC standards. Findings: As we know that one of the greatest features of a pavement is the compressive strength. The compressive strength for cube and paver block was determined as per BIS and it shows the uniform results. A flexible pavement for low volume traffic road was designed and compared with SCBAPB road. Even the thickness of bagasse ash paver block is 70mm more than the conventional road; it shows the economical benefit in terms of construction and maintenance cost. The usage of bagasse ash in manufacturing of paver block leads to lesser environmental hazards than conventional concrete, which leads to reduce the pollution and global warming. In addition, it shows the economical benefit in terms of construction and maintenance cost by replacing cement with bagasse ash in concrete paver blocks.

Key Words: Bagasse Ash, Compressive Strength, Bitumen, Paver Blocks, Pavement

1.INTRODUCTION

DUE to limited availability of natural resources and rapid urbanization, there is a shortfall of conventional building construction materials. On the other hand, energy consumed for the production of conventional building construction materials pollutes the air, water and land. Accumulation of unmanaged agro-waste, especially from the developing countries, has an increased environmental concern. Therefore, development of new technologies to recycle and convert waste materials into reusable materials is important for the protection of the environment and sustainable development of the society.

The fibrous residue of sugarcane after crushing and

Figure- Bagasse

extraction of its juice, known as 'bagasse', is one of the largest agriculture wastes in the world.

Figure- Sugar Cane Wastes (Bagasse)

The Use of these materials as biofuel or burnt in open fields especially in Haryana, Punjab and UP has posed a great environmental threat of polluting air ,water, etc. Even after strict restrictions by the government of respective states, there is no end to field fires as people want to get rid-off this bulky and huge wastes. During rains these wastes begin producing highly offensive gases, thereby again causing nuisance. The smoke produced also causes invisibility.The utilization of these waste materials in the manufacture of concrete provides a satisfactory solution to some of the environmental concerns and problems associated with waste management. Like other

Agro wastes such as rice husk ash, wheat straw ash, hazel nutshell, and cork, sugarcane bagasse ash is also used as pozzolanic materials for the development of blended cements. It can also be used as a fine aggregate in concrete mix design. Many studies have been reported on the use of bagasse ash as partial cement replacement material in respect of cement mortars. In this Case, the effects of bagasse ash as partial replacement of cement on Compressive strength and durability properties of hardened concrete paver blocks are studied and analysed.

1.1 Advantages of SCBA as binding material

As we know that Ordinary Portland Cement (OPC) is being considered as a major construction material throughout the world. Researchers all over the world today are focusing on ways of utilizing either industrial or agricultural waste as a source of raw materials for construction industry. This waste utilization would not only be economical, but may also result in foreign exchange earnings and environmental pollution control. Industrial wastes, such as blast furnace slag, fly-ash and silica fume are being used as supplementary cement replacement materials. Therefore it is possible to use sugarcane bagasse ash as cement replacement material to improve the quality of concrete and reduce the cost of construction materials such as mortar, concrete pavers, concrete roof tiles and soil cement interlocking block.

There are wide ranges of paving options that can be used. In this project, the major construction material "cement" is being replaced with a readily available and cheaper material from the sugar industry wastes called "bagasse ash". By using this, there is also scope for an effective wastes reduction technique and it also improves the strength property of normal concrete blocks. Also the surface tends to be more durable and allows a year-round mobility to all types of low volume traffic. The pavement constructed using bagasse ash paver blocks (SCBAPB) is also found to be economic with good aesthetics.

A few studies have been carried out on the ashes obtained directly from the industries to study pozzolanic activity and their suitability as binders partially replacing cement and the results proved to be beneficial. The test results indicate that bagasse ash is an effective mineral admixture, with 20% as optimal replacement ratio of cement. When pozzolanic materials are added to cement, the silica present in these materials reacts with free lime released during the hydration of cement and forms additional calcium silicate hydrate as new hydration products, which improves the mechanical properties of concrete formulation. Partial replacement of cement by sugarcane bagasse ash increases workability of fresh concrete as being bulky, therefore use of super plasticizer is not necessary. The density of concrete decreases with increase in sugarcane bagasse ash content, therefore low weight concrete is produced with waste materials. The rate of bleeding is reduced. Improved long term strength and durability performance is observed by replacing cement partially with bagasse ash. Lower shrinkage, lower porosity, lower permeability, better resistance to chloride ingress and sulphate attack and lower heat of hydration in thick sections are some of the advantages for using bagasse ash in concrete paver blocks. Adding sugar cane bagasse ash as a replacement for cement may provide additional enhancements in a sustainability perspective. The compressive strength tends resistance to chloride ion penetration and water-proofing properties. Reduced alkali silica reactivity is studied by partially replacing cement with sugarcane bagasse ash. The chemical composition of bagasse ash indicates that there is zero lime content and reduced carbon content. The use of sugar cane bagasse ash as a partial replacement of cement has a beneficial effect to protect the steel bars from corrosion because it reduced the pore size in the cement paste, which minimized the ingress of aggressive ions into concrete. Another advantage of using this material is the fact that India, especially Uttar Pradesh and Haryana (UP called as sugar bowl of India) already has a well-established and growing sugarcane ethanol industry. It also places a significant advantage on the environment, particularly, as the pollution caused due to the manufacturing of cement continues to be criticized from to be less at the early stage but increases at later stages, meaning that the bagasse ash can be used as an effective replacement material for cement.

1.2 Experimental Investigation

The materials used in this project are cement, fine aggregate, coarse aggregate and bagasse ash. Laboratory tests were conducted as per IS code provisions on these materials to determine their properties. Various tests on soil were conducted to study the properties of soil, to design the flexible pavement and low volume traffic road pavement using bagasse ash interlocking paver blocks. The paver blocks with and without bagasse ash were casted based upon the mix design arrived, to obtain the required strength. The specific gravity and sieve analysis test results of various materials are as tabulated in I & II.

Table I. Specific gravity of materials

Materials	Specific gravity
Cement	3.20
Fine aggregate	2.80
Finer coarse aggregate	2.68
Bagasse ash	2.31
Soil	2.33

Table II. Sieve analysis test

Description	Uniformity Coefficient	Curvature Coefficient	Effective size (mm)
Fine Aggregate	0.28	3.21	0.74
Finer Coarse	3.1	2.31	1.22
Bagasse Ash	0.079	2.89	1.11

1.3 Other Tests Results

On sieving cement, around 1.13% of residue was found to be retained on 90 micron IS sieve and the rest of the cement particles passed through the sieve. Since being less than 10%, the cement is found to be suitable. The initial setting time turned out to be less than 30 minutes while the final setting time turns out to be more than 10 hours. The grading of sand was found to fall in Zone II and it was classified as poorly graded Sand (SP). Moreover, the Bulking of sand was calculated as 27.6%. The chemical composition analysis of bagasse ash showed that it contained over 70% Silica, which is the highest constituent and is responsible for imparting strength to cement. Since it prolongs the setting time, the composite has a slow rate of strength gain.

The Atterberg limits like liquid limit, plastic limit and shrinkage limit of the sub-grade soil were found to be 60%, 29% and 5% respectively. Since the soil used in this study has a liquid limit of 60%, it is deemed to possess high compressible characteristic. For the liquid limit of 60% and plasticity index of 31%, the soil lies above A-line. Hence the soil is clay. Therefore the soil used in this study is classifie d as Highly compressible Clay (CH).From the standard Proctor -compaction tests conducted, the maximum dry density and the optimum moisture content (OMC) obtained are 1.7g/cc and 17%. For this value of OMC and for 2.5 mm penetration, the California Bearing Ratio (CBR) test was conducted and the value was found out to be 6%. CBR value for the subsoil tested turned out to be 6%, the effective CBR was recalculated from IRC: 37-2012.

2. DESIGN OF PAVEMENTS

2.1 Flexible Pavement Design

The data stipulations and the computation of design traffic to design the flexible pavement are given in Table III. As per IRC: 37-2012, for an effective CBR of sub-grade of 7% and 4 msa traffic, the pavement thickness was arrived from Plate 5 of IRC: 37-2012. The details of the pavement thickness arrived are given in Table IV.

2.2 Design of Bagasse Ash Paver Block Pavements

The design of pavement using bagasse ash paver blocks was done as per IRC: SP: 63-2004. The paver blocks used were supposed to have a minimum compressive strength of 35 N/mm^2 and satisfy the requirements given in IRC: SP: 63-2004. The details of these requirements given in IRC: SP: 63-2004 and the status of fulfillment of the interlocking paver blocks used in this study are shown in Table V. By comparing the properties of paver blocks used in this study with IRC requirements, it was found that it fulfilled all the requirements except thickness and water- cement ratio. However considering the length to thickness ratio and minimum strength requirement parameters, which is found to be more than the specified value of the paver blocks were used to design the pavement. For the design, in-situ CBR of the sub-grade soil was taken as 6% from the CBR soil test results. To design the pavement, the cumulative number of standard axles was calculated as per the guidelines of IRC: 37-2012. The Details of requirements for interlocking paver block used in road as per IRC: SP: 63-2004 are given in Table V.

Table III. Data stipulations and computation of design traffic for flexible pavement

Description	Values
Number of commercial vehicles as per last count (P)	470
Annual growth rate of commercial vehicles (r)	0.07
Number of years between the last count and the year of completion of construc tion (x)	1
Initial traffic in the year of completion in CV/day (A)	503
Type of Road	Two-lane single
Lane Distribution Factor (D)	0.5
Type of terrain	Rolling/Plain
Vehicle damage factor (F)	3.5
Design life in years (n)	10
The cumulative number of standard axles in msa (N)	4

Table IV.Sectional details of pavement designed

Components of flexible pavement	Thickness in mm
Semi Dense Bituminous Course	29
Dense Bituminous Macadam	51
Wet Mix Macadam	242

Gravel Sub-base	165
Total thickness of the flexible pavement	488

Table V. Guidelines for interlocking paver blocks used as per IRC: SP 63 – 2004

Criteria	Requirements as per IRC: SP 63-2004	Values
Bedding sand layer	25-60% shall pass through 600 micron IS sieve	45.01%
Top surface area	5000-60,000 mm^2	27,222 mm^2
Horizontal	Shall not exceed 28 cm	18.2 cm
Thickness	Between 60-140 mm	45 mm
Length/Thickness	Shall be ≥4	5
CBR	Not less than 5%	6.3%
Thickness of base course	250 mm	250 mm
Thickness of sub- base course	250 mm	250 mm
Water-cement ratio	0.34-0.38	0.43
Quantity of cement	380 Kg/m^3 to 425 Kg/m^3	428 Kg/m^3
Aggregate-cement ratio	3:1 to 6:1	3.6 : 1
Minimum compressive strength	30 N/mm^2	38 – 42N/mm^2

For CBR of the sub-grade of 6% and 10 msa traffic, the interpolated pavement thickness was taken from Plate 1 of IRC: SP: 63-2004. The data stipulations and the computation of design traffic used in the bagasse ash pavement design are given in Table VI. The design parameters used are same as that of the flexible pavement design, except for the design life. The design life for the flexible pavement is 10 years but for the paver blocks road, the minimum prescribed design life is 20 years as per IRC codal specifications. The parameters used in the design of bagasse ash paver block road are given in Table VI.

Table VI. Different Parameters used in the design of bagasse ash paver block road

Description	Values
Number of commercial vehicles as per last count	470
Annual growth rate of commercial vehicles (r)	0.07
Number of years between the last count and the year of completion of construction (x)	1
Initial traffic in the year of completion in CV/day (A)	503
Type of Road	Two-lane single carriageway
Lane Distribution Factor (D)	0.5
Type of terrain	Rolling/Plain
Vehicle damage factor (F)	3.5
Design life in years (n)	20
Cumulative number of standard axles in msa (N)	10

For CBR of sub-grade of 6% and 10 Msa traffic, the pavement thickness was arrived from Plate 1 of IRC: 37-2012. The details of the pavement thickness for bagasse ash paver block roads arrived are given in Table VII.

Table VII. Components of pavement using bagasse ash interlocking paver blocks

Components of flexible pavement	Thickness in
Interlocking paver blocks	43
Sand bed	18
Water Bound Macadam/Wet Mix Mac- adam base	255
Granular sub-base	250
Total thickness of the flexible pavement	566

2.3 Mix Design for Paver Blocks

The mix design was prepared as per IS: 10262-200912 and was modified as per the guidelines of IRC: SP: 63-2004, to achieve the characteristic strength of 30 MPa. The mix ratio for the PCC was arrived as 1:1.88:1.78 with water-cement ratio of 0.45 and this was adopted for trial I as per IS: 10262-2009. Trial II was arrived by satisfying the guidelines given in the code IRC: SP: 63-2004, with slight modifications in the ratio arrived as per IS: 10262-2009. The modified ratio was arrived as 1:2.23:2.12 with water-cement ratio of 0.38. Trial III and IV was arrived by replacing the cement with 50% of bagasse ash and the ratio arrived with modification in water-cement ratio is given in Table VIII.

For all the trials I to IV, the cube specimens and concrete paver blocks were casted to determine the compressive strength at the age of 7 and 28 days. Figure 1 shows the geometric dimensions of the paver block that was casted and tested.

Table VIII. Design mix ratio for M30 grade concrete

Trials	I	II	III	IV
Reference Code	As per IS 10262-2009	As per IRCSP 63-2004	As per IS 10262-2009	As per IRC SP 63-2004
Concrete mix	PCC	PCC	PCC+50% Bagasse ash	PCC+50% Bagasse ash
Cement	1	1	0.5	0.5
Bagasse ash	0	0	0.5	0.5
Fine aggregate	1.88	2.23	1.88	2.23
Finer coarse aggregate	1.78	2.12	1.78	2.12
Water Cement ratio	0.45	0.38	0.45	0.38

Figure- Bagasse Ash paver block

3.Results and Discussion

3.1 Cost Estimation of Pavements (Economic Analysis)

As far as the costs are concerned, it was observed that the amount required for per kilometer length of flexible pavement is Rs.90,10,000 and the cost of interlocking bagasse ash paver block road is Rs.68,93,000. The construction of kerb cost shall be varied based on the site condition. The construction of road using bagasse ash paver blocks seems to be more cost effective than the conventional flexible pavement by 23.50%. Moreover, the design life of bagasse ash paver blocks road is high when compared to conventional flexible pavement and also the maintenance of bagasse ash paver blocks road is easy when compared to flexible pavement. The occurrence of damage is less in bagasse ash paver blocks road and it is easy to remove and rectify the road with less amount. Apart from these things, bagasse ash is a readily available waste material and is also an eco-friendly material. The design life of bagasse ash paver blocks road is 20 years, whereas design life of flexible pavement is only 10 years.

Figure-Pavement having SCBAPB Tiles

Figure- Manufacture of Pavement Tiles of different Shapes& Sizes

3.2 Compressive Strength Test Results

The compressive strength (an important parameter of pavement) testing of cubes and paver blocks casted were conducted and analysed. Table IX shows the compressive strength values for concrete cubes and paver blocks for various trials conducted. From the compressive strength test results, the compressive strength values of paver blocks more than the control concrete. Hence the paver block can be deemed a suitable and economically viable replacement for OPC while casting paver blocks. Although the rate of strength gain is slow for Bagasse Ash Paver blocks, it can be easily overlooked in comparison to more strength and as the overall benefits gained outweighs the construction of the same.

Table IX. Compressive strength of concrete cubes and paver blocks

Trials	Curing period in days	Mean compressive strength in	
		Paver blocks	Cube specimen
I		28	26
II		28	27
III	7	28	26
IV		27	25
I	28	45	43
II		42	40
III		42	40
IV		43	41

4. Conclusions

On testing soil, the soil was classified and CBR value was obtained, from which the pavements were designed. The paver blocks using Plain cement concrete as well as for specimens with 50% bagasse ash were casted based upon the mix design calculated and the compressive strength was obtained at the curing age of 7 and 28 days.

Based on the effective CBR value of 7%, the thickness of the flexible pavement was calculated as 488 mm, while for specimens with CBR value of 6%, the paver blocks were casted and the total thickness of road pavement using bagasse ash paver blocks was calculated as 566 mm, i.e., the difference in effective thickness of the pavement was higher by 78 mm, but in effect, was cheaper by 23.50%.

In addition to the reduction in cost, another advantage of using bagasse ash paver block road is the design life. For flexible pavement the design life is only 10 years, whereas the design life is 20 years in case of bagasse ash paver block road.

The maintenance of bagasse ash paver blocks road shall be far easier when compared to conventional flexible pavement, as only the particular damaged block has to be removed and re-laid with a new one. This enormously contributes to the economy factor by reducing the overall investment in pavements in the long run.

The usage of Bagasse ash leads to far lesser environmental hazards than conventional concrete, which leads to reduce the pollution and global warming.

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