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Study on the use of Bagasse Ash Paver Blocks in Low Volume Traffic Road Pavement

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Abstract :

Background/Objectives: The massive constructions releases 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. In this work, the 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. **Method**: In the experimental study, bagasse ash is used in the manufacturing of paver block for low volume traffic road. Paver blocks as per the geometric dimensions were casted with the four trial mixes and tested as per the BIS and IRC standards. **Findings:** The compressive strength for cube and paver block was determined as per BIS and it shows the uniform result. A flexible pavement for low volume traffic road was designed and compared with BAPB 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. **Improvement:** 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.

Keywords: Bagasse Ash, Comressivee Strength, Paver Blocks, Pavement

1. Introduction

The fibrous residue of sugarcane after crushing and extraction of its juice, known as 'bagasse', is one of the largest agriculture residues in the world[1-3]. Literature illustrates the versatility of sugarcane residue usages; through its conversion inclusive but not limited to paper, feed stock and biofuel[1,4].

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. Agro wastes such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash are used as pozzolanic materials for the development of blended cements. Few studies have been reported on the use of bagasse ash as partial cement replacement material in respect of cement mortars. In this project, the effects of bagasse ash as partial replacement of cement on strength and durability properties of hardened concrete paver blocks are studied.

1.1 Effects and Advantages of Sugarcane Bagasse Ash

Ordinary Portland Cement (OPC) is recognized 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

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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 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 (BAPB) is also found to be economic and it also has 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; 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 in the society with waste materials. The rate of bleeding is reduced and better off-shutter finish is possible without affecting the aesthetics. 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[5] Adding sugar cane bagasse ash as a replacement for cement may provide additional enhancements in 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 rebar from corrosion because it reduced the pore size in the cement paste, which minimized the ingress of aggressive ions into concrete[6]. Another advantage of using this material is the fact that India, especially Tamil Nadu, 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 a sustainability perspective. The compressive strength tends to be less at the early stage but increases at later stage, meaning that the bagasse ash can be used as an effective replacement material for cement. In this study the attempt is made to study the use of bagasse ash in production paver block to design the low volume traffic road.

2 Experimental Program

The materials used in this project are cement, fine aggregate, finer coarse aggregate and bagasse ash. Laboratory tests were conducted as per IS codal[7-9] 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 given in Table 1 and 2.

Table 1. Specific gravity of materials used

Materials	Specific gravity
Cement	3.13
Fine aggregate	2.60
Finer coarse aggregate	2.67
Bagasse ash	2.21
Soil	2.30

Table 2. Results of Sieve analysis test

Description	Uniformity Coefficient	Curvature Coefficient	Effective size (mm)
Fine Aggregate	0.28	3.21	0.73
Finer Coarse Aggregate	3	2.3	1.2
Bagasse Ash	0.078	2.95	1.10

2.1 Results of Other Tests

For cement, around 1.23% of residue was found to be retained on 90 micron IS sieve and the rest of the cement particles passed through the sieve. This 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 29.6%. The chemical composition analysis of bagasse ash showed that it contained over 72% 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 classified 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.

3. Design and Cost Estimation of Pavements

3.1 Design of Flexible Pavement

The data stipulations and the computation of design traffic to design the flexible pavement are given in Table 3. As per IRC: 37-2012[10], 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 4.

3.2 Design of Bagasse Ash Paver Block Pavements

The design of pavement using bagasse ash paver blocks was done as per IRC: SP: 63-2004[11]. 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 is shown in Table 5. 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 5.

Table 3. Data stipulations and computation of design traffic for flexible pavement

Description	Values
Number of commercial vehicles as per last count (P)	460
Annual growth rate of commercial vehicles (r)	0.05
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)	483
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)	10
The cumulative number of standard axles in Msa (N)	4

Table 4. Sectional details of pavement designed

Components of flexible pavement	Thickness in mm
Semi Dense Bituminous Course	25
Dense Bituminous Macadam	50
Wet Mix Macadam	245
Gravel Sub-base	170
Total thickness of the flexible pavement	490

Table 5. Requirements for interlocking paver blocks used as per IRC: SP 63 - 2004

Criteria	Requirements as per IRC: SP63-2004	Values
Bedding sand layer	25-60% shall pass through 600 micron IS sieve	44.95%
Top surface area	5000-60,000 mm^2	27,200 mm^2
Horizontal dimension	Shall not exceed 28 cm	16.5 cm
Thickness	Between 60-140 mm	40 mm
Length/Thickness	Shall be ≥4	5
CBR	Not less than 5%	6%
Thickness of base course (min.)	250 mm	250 mm
Thickness of sub-base course (min.)	250 mm	250 mm
Water-cement ratio	0.34-0.38	0.45
Quantity of cement	380 Kg/m^3 to 425 Kg/m^3	462 Kg/m^3
Aggregate-cement ratio	3:1 to 6:1	3.66 : 1
Minimum compressive strength	30 N/mm^2	40 – 45 N/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 6. 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 6.

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 7.

3.3 Mix Design for Paver Blocks

The mix design was done as per IS: 10262-2009[12] 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 8.

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 6. Parameters used in the design of bagasse ash paver block road

Description	Values
Number of commercial vehicles as per last count	460
Annual growth rate of commercial vehicles (r)	0.05
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)	483
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

Table 7. Components of pavement using bagasse ash interlocking paver blocks

Components of flexible pavement	Thickness in mm
Interlocking paver blocks	40
Sand bed	20
Water Bound Macadam/Wet Mix Macadam base	250
Granular sub-base	250
Total thickness of the flexible pavement	560

Table 8. Design mix ratio for M30 grade concrete

Trials	I	II	III	IV
Reference Code	As per IS 10262-2009	As per IRC SP 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

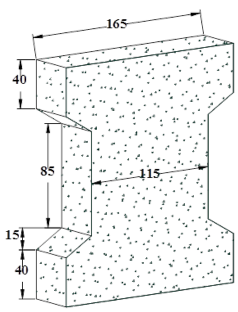

Figure 1. Geometric dimensions (mm) of paver block.

4. Results and Discussion

4.1 Cost Estimation of Pavements

From the analysis of the cost estimation, it was observed that the amount required for per kilometer length of flexible pavement is Rs.77,69,000 and the cost of interlocking bagasse ash paver block road is Rs.58,93,000. 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 24.15%. 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.

4.2 Compressive Strength Test Results

The compressive strength testing of cubes and paver blocks casted were conducted and analysed. Table 9 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 as the overall benefits gained outweighs the construction of the same.

Table 9. Compressive strength of concrete cubes and paver blocks

Trials	Curing period in days	Mean compressive strength in N/mm^2	
		Paver blocks	Cube specimens
I	7	28	27
II		29	28
III		27	26
IV		26	25
I	28	45	43
II		40	40
III		41	39
IV		42	41

5. Conclusions

From the tests on 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 490 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 560 mm, i.e., the difference in effective thickness of the pavement was higher by 70 mm, but in effect, was cheaper by 24.15%.

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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