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Experimental Investigation on the Use of Bagasse Ash in the Construction of Low Volume Traffic Roads

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Abstract: The road transport industry is indeed instrumental in interconnecting all businesses to all major world markets, driving trade, creating employment, ensuring a better distribution of wealth and uniting mankind. The road transport industry's story is sustainable progress. Transport investments within cities and across cities are essential for economic growth, job creation and poverty reduction. Over the last ten years (2002-03 to 2011-12) road transport sector gross domestic production grew at an annual average rate close to 10 per cent compared to an overall annual gross domestic production of 6 per cent.

An efficient road transport system is a pre-requisite for sustained economic development. It is not only the key infrastructural input for the growth process but also plays a significant role in promoting national integration, which is particularly important in India.

In the road transport sector energy planning has a special significance because transport is the second largest consumer of energy. The growth of transport not only leads to pressure on limited availability of non- renewable energy but also gives rise to broader environmental issues. As the demand for transport services rise, it leads to increased use of scarce land resources and contributes to the atmospheric pollution in a big way.

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. On the other hand, 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. 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, 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 by using bagasse ash in the construction of low volume traffic roads by the partial replacement of certain constituent materials. These roads can be constructed in those areas where there is availability of sugarcane bagasse. In Uttar Pradesh and Haryana, there is a large scale cultivation of sugarcane and thus the sugarcane bagasse can be easily procured to be used in the construction of low volume traffic roads.

Keywords: Sugarcane Bagasse Ash, Waste Management, Ordinary Portland Cement, Fine and Coarse Aggregate, Water Bound Maccadam and Wet Mix Maccadam.

I. INTRODUCTION

As we know that the roads are the life-line of every nation. A country's road network should be efficient in order to maximize economic and social benefits. Roads are an integral part of the transport system. They play a significant role in achieving national development and contributing to the overall performance and social functioning of the community. It is acknowledged that roads enhance mobility, taking people out of isolation and therefore poverty. Roads play a very important role in the socio-economic development of the country. The road transport industry is the backbone of strong economies and dynamic societies.

The road transport industry is indeed instrumental in interconnecting all businesses to all major world markets, driving trade, creating employment, ensuring a better distribution of wealth and uniting mankind. It plays a crucial role in the daily economic and social life of industrialized and developing countries alike. An important part of the road transport industry's story is sustainable progress.

Transport investments within cities and across cities are essential for economic growth, job creation and poverty reduction. Beyond simply facilitating cheaper and more efficient movements of goods, people and ideas within cities, transport affects the distribution of economic activity across cities. Road transport is the primary and preferred mode of transport for most of the population and India's road transport system is among the most heavily utilized systems in the world. It plays a pivotal role in the economic development of a nation by increasing the productivity and competitiveness. Over the last ten years (2002-03 to 2011-12) road transport sector GDP grew at an annual average rate close to 10 per cent compared to an overall annual GDP growth of 6 per cent. It contributes in growth of industries whose product requires quick marketing. It helps in increase in the demand for goods. Through it newer customers in newer places can be easily contacted and products can be introduced to them. Today markets have become national or international only because of transport. Transport creates place utility. It bridges the gap between production and consumption centres. It creates time utility also. It helps the product to be distributed in the minimum possible time. It helps in the stabilization of price. It exerts considerable influence upon the stabilization of the prices of several commodities by moving commodities from surplus to deficit areas. The importance of roads in connecting the vast rural areas of India to form the national market and economy cannot be overstated. Connectivity provided by roads is perhaps the single most important determinant of well-being and the quality of life of people living in an urban area. The efficiency of the innumerable government programmes aimed at rural development, employment generation and local industrialization is to large extent determined by the connectivity provided by roads. There is a considerable body of evidence that demonstrates the links between rural road investment, decline in poverty and improvement in the quality of life.

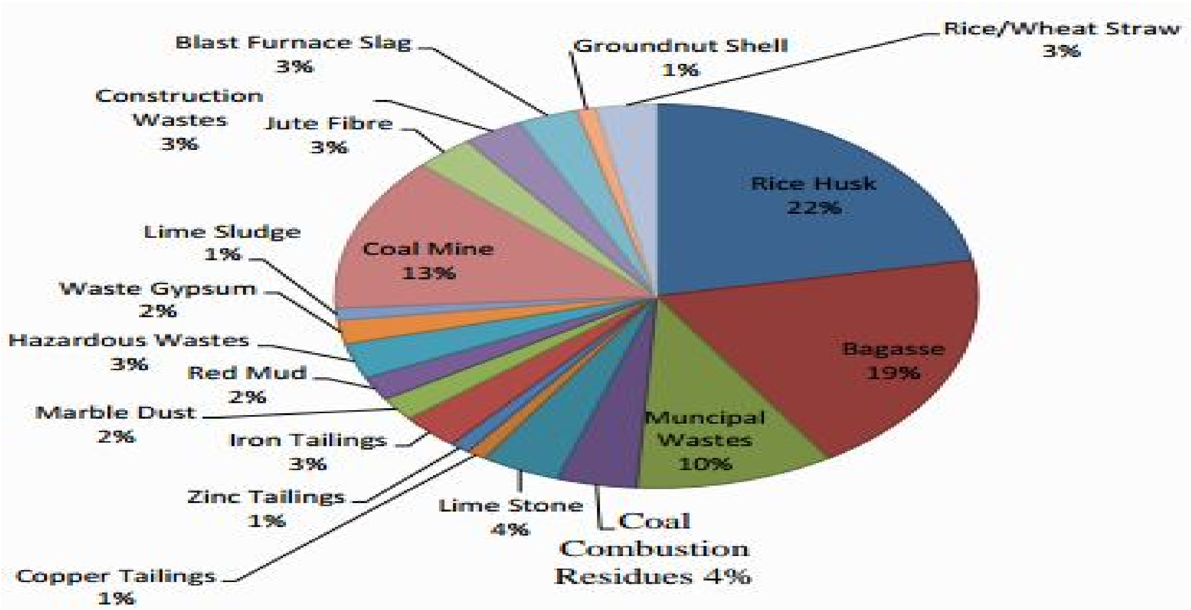
Road investment contributed directly to the growth of agricultural output, increased use of fertilizer and commercial bank expansion. The potential value in improving of rural connectivity especially in the agricultural states is revealed by the large differences between mandi and farm gate prices. Modern businesses, industries, trades, agricultural and general activities depend on transport and transport infrastructure with movement of goods and services from place to place becoming vital and inseparable aspects of global and urban economic survival.

Roads are highly significant for the defence of the country. For the movement of troops, tanks, armoured cars and field guns etc. roads are essential. The great importance given to the construction of border roads is to facilitate the movement of troops for the protection of the borders.

Due to the above mentioned advantages, the road transport has become very popular and its share is constantly increasing. It is therefore legitimate and indispensable to safeguard an industry that is vital to economic growth, social development, prosperity and ultimately peace and which plays a crucial role in everyone's life in industrialized and developing countries alike by meeting the demand for the sustainable mobility of both people and goods.

But very less has been achieved in this sector because in the road transport sector energy planning has a special significance as transport is the second largest consumer of energy. As we know that due to limited availability of natural resources and rapid urbanization, there is a shortfall of conventional building construction materials. Thus the funds required for the construction of roads also increase. These financial constraints hamper the development of a developing nation like India. Also energy consumed for the production of conventional building construction materials pollutes the air, water and land. The growth of transport not only leads to pressure on limited availability of non- renewable energy resources but also gives rise to broader environmental issues. Moreover, the various processes for the production and processing of cement, bitumen, fine and coarse aggregate require a lot of energy and production of harmful gaseous and chemical wastes into the environment. As the demand for transport services rise, it leads to increased use of scarce land resources and contributes to the atmospheric pollution in a big way. 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.

But on the other hand, there is a large production of agricultural wastes such as rice husk ash, wheat straw ash, hazel nutshell, fly ash, cork and sugarcane bagasse ash. Agriculture industry is the largest industry in India as more than 70% of Indian population is dependent on it. It is observed that in India more than 600 MT wastes have been generated from agricultural wastes-(2010).



Sugarcane is largely produced in the states of Punjab, Haryana, Uttar Pradesh and Tamil Nadu. The state of Uttar Pradesh is called the "Sugar Bowl" of India. A large number of sugarcane processing industries are located in these areas. But a large quantity of wastes called as bagasse is produced from these sugarcane processing industries as shown in figure 1.2 (a). As production of sugar cane is more than 1500 million tons in the world and in India about 10 million tons of sugarcane bagasse ash is treated as a waste material

Fig. Sugarcane Bagasse

The fibrous residue (about 40–45%) of sugarcane after crushing and extraction of its juice is known as ‘‘bagasse". The bagasse is reused as fuel in boilers for heat generation which leaves behind 8–10% of ash, known as Sugar Cane Bagasse Ash (SCBA) which is treated as waste and unutilized. Sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicelluloses and 25% of lignin. The use of sugarcane bagasse as bio fuel or burning in open fields has posed a great environmental threat of polluting air, water, etc. Even after strict restrictions by the government of these above said states, there is no end to field fires as people only want to get rid-off these bulky and huge wastes. During rains these wastes begin producing highly offensive gases, thereby again causing nuisance. The smoke produced also causes invisibility. It can therefore be advantageous to use it in the construction of pavements to mitigate the disposal problem as well as to minimize the use of natural aggregate (sand) and binding material (cement, bitumen), so as to construct the low volume economic road pavements.

A. The main objectives of the proposed experimental study is as discussed below-

1) To study the physical properties of SCBA modified concrete.
2) To arrive at a mix design review for modified concrete using IS code method.
3) To study the workability of a fresh sample of this concrete.
4) To study the different strengths of hardened concrete such as compressive strength of concrete samples at 7 and 14 days.
5) To compare the workability and various strengths for different percentage substitutions of cement and sand with sugarcane bagasse ash.
6) Economical design of low volume traffic road pavement tiles of different shapes and sizes by using SCBA.

II. EXPERIMENTAL INVESTIGATION

The various experimental investigations carried out help us in detecting the various physical and chemical properties of the normal and modified concrete mix. The various weathering actions on the specimens at different age groups are also investigated. In the present experimental investigation, bagasse ash modified concrete specimens are tested with varying percentages of cement and fine aggregate replaced with Sugar Cane Bagasse Ash (SCBA). The various percentages of OPC (cement) that are replaced with Sugar Cane Bagasse Ash (SCBA) are 0%, 10%, 15%, 20 and 25%. Similarly the percentages of fine aggregate (sand) replaced with SCBA are 0%, 5%, 10%, 15% and 20%.

The various materials used in the investigational study are binding material (cement), fine aggregate (sand), finer coarse aggregate, sugarcane bagasse ash and water.

Mix design is a process of selecting suitable ingredients for concrete preparation and determining their proportions which would produce the mix as economically as possible, a concrete that satisfies the job requirements. The proportioning of the ingredients of concrete is an important phase of concrete technology as it ensures quality and economy. In pursuit of the goal of obtaining concrete with desired performance characteristics, the selection of component materials is the first step, the next step is a process called mix design by which one arrives at the right combination of the ingredients. The cementitious materials are thoroughly blended and then the aggregate is added and mixed followed by gradual addition of water at mixing. Wet mixing is done until a mixture of uniform colour and consistency is achieved which is then ready for casting. Before casting the specimens, workability of the mixes is found by compaction factor test.

A. Cement Replaced Modified Concrete Specimens (M)

The Sugar Cane Bagasse Ash (SCBA) obtained from the boilers of the industry is sieved. The portion of material passing the 90 micron mesh sieve is collected. This collected sample is used as the partial replacement for Ordinary Portland Cement (OPC).

B. Sand Replaced Modified Concrete Specimens (N)

Similarly the proportion of Sugar Cane Bagasse Ash (SCBA) retained on the 90 micron sieves or above is considered as fine aggregate (sand). Again twenty trial mixes of sand replaced specimens are prepared.

The various concrete samples are cured in normal water and are tested for various physical properties. They are also checked for resistance to various weathering actions. The experimental procedures undertaken in the present study involved several experiments, conducted to obtain various properties. The physical properties tests such as consistency test, setting time test, workability test and soundness test of the mixes are determined. The mechanical properties such as compressive strength, split tensile strength, flexure strength and density is obtained.

1) The various tests conducted on Cement (OPC) and Sugar Cane Bagasse Ash (SCBA) mortar are as listed below:-
   a) Consistency Test

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b) Compaction factor Test
c) Initial Setting Time
d) Final Setting Time
e) Soundness Test
2) The various tests carried out on cement (OPC). coarse aggregate, fine aggregate and SCBA (when certain portion of cement is replaced by SCBA) concrete specimens (M) are as discussed below:-
Compressive strengthAbove given properties of concrete are performed at different water cement ratio and at each water cement ratio the percentage of sugarcane bagasse ash was varied at 0%, 10%, 15%, 20% and 25%.
Similarly, the various tests carried out on (N) specimens containing the constituents of cement (OPC), fine aggregate, coarse aggregate and SCBA (when certain portion of sand is replaced by SCBA) are as discussed below:-
Compressive strengthThe percentage of sugarcane bagasse ash is varied at 0%, 5%, 10%, 15%, and 20%.

C. Characteristics of modified concrete mix (M)
The various important characteristics of modified concrete include compressive strength, split tensile strength, density and flexural strength etc. It is evident that the strength of the modified concrete (M) increases with increase in SCBA percentage up to certain proportion. Also it has been found that the W/C ratio plays an important role. It has been found that an optimum W/C ratio of 0.45 is suitable for M_{30} concrete mix design as the compressive strength is maximum at this ratio. The various results of the above said properties are as tabulated below

D. Comparison of compressive Strength of (M) at 14 and 28 days at W/C ratio of 0.45
As we have found that the concrete mix gains 90% and 99% of its total strength at 14 & 28 days respectively. The various findings that have been revealed are as tabulated below:-

Comparison of compressive strength of (M) at 14 and 28 days

S. No	Percentage of SCBA	Average Compressive Strength after 14 Days (N/mm^2)	Compressive Strength after 28 Days (N/mm^2)
1.	0	34.48	38.28
2.	10	36.98	41.22
3.	15	36.03	40.03
4.	20	34.81	38.66
5.	25	30.65	34.08

E. Characteristics of modified concrete mix (N)
The various important characteristics of modified concrete include compressive strength, split tensile strength, density and flexural strength etc. It is evident that the strength of the modified concrete (N) increases with increase in SCBA percentage up to certain proportion. Also it has been found that the W/C ratio plays an important role. It has been found that an optimum W/C ratio of 0.45 is suitable for M_{30} concrete mix design as the compressive strength is maximum at this ratio. The various results of the above said properties are as tabulated below:-

F. Comparison of compressive Strength of (N) at 07 and 14 days at W/C ratio of 0.45
As we have found that the concrete mix gains 90% and 99% of its total strength at 14 & 28 days respectively. The various findings have been as tabulated below:-

Comparison of compressive strength of (N) at 14 and 28 days

S.No.	Percentage of SCBA	Average Strength after 14 Days (N/mm^2)	Average Strength after 28 Days (N/mm^2)
1.	0	34.47	38.28
2.	10	36.40	40.44
3.	15	35.12	39.01
4.	20	30.68	34.11
5.	25	29.09	32.27

G. Design of Pavements

Initial traffic in each direction on the counting year = N
Construction period since last traffic count = x
Design life of pavement to be constructed = n
Traffic growth rate = r
Vehicle damage factor = F
Lane distribution factor = D

1) Design of flexible pavement

Initial Traffic in each direction in the year of completion of construction

$$A=P(1+r)^x$$

Where,
P= Number of Commercial vehicles as per last count
r= Annual growth rate of commercial vehicles
x= Construction period since last traffic count
Cumulative number of standard axle to be carried during design life in msa

$$N= \frac{365 \times [(1+r)^n-1]}{r} \times A \times D \times F$$

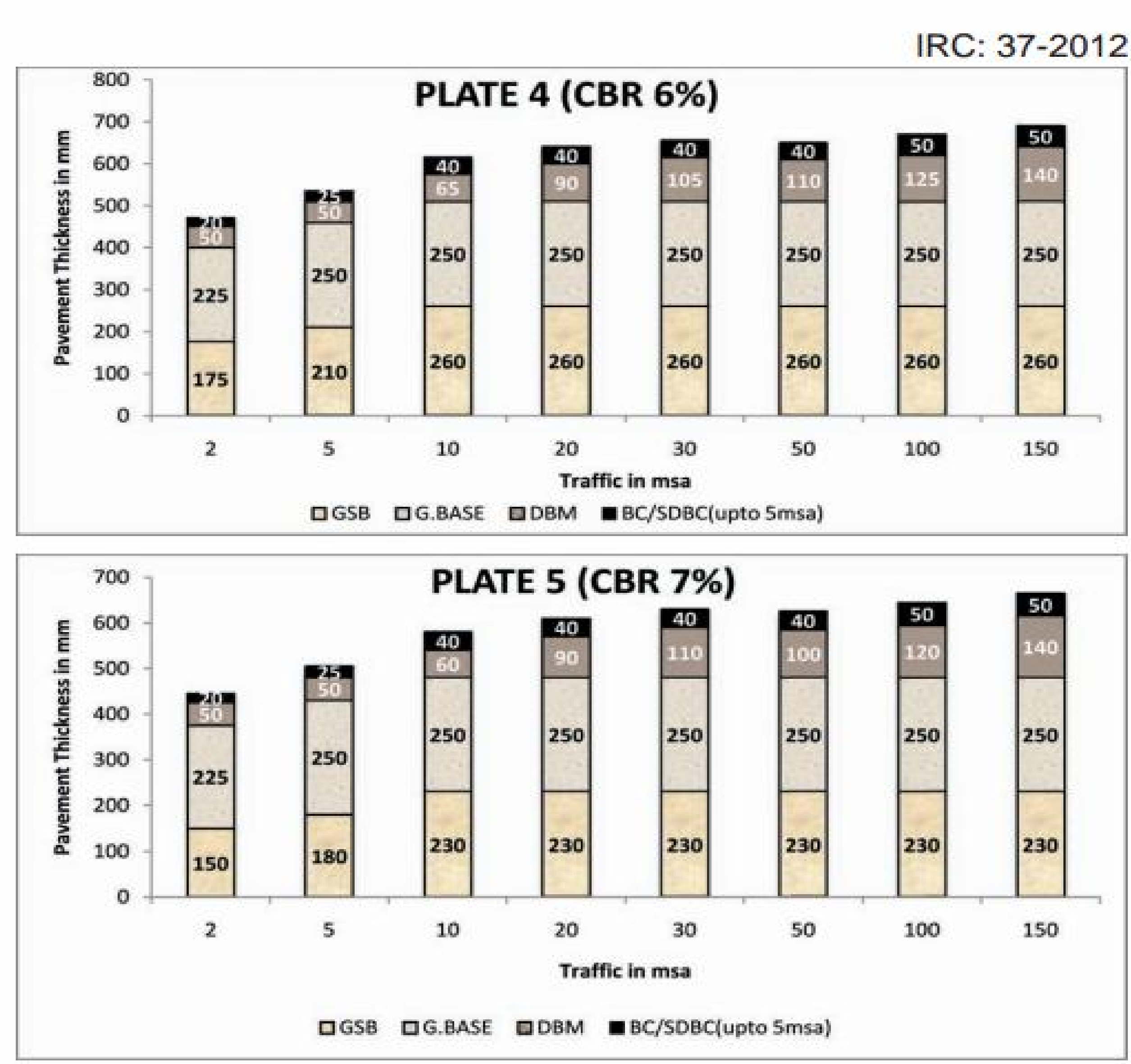
As per IRC: 37-2012, for an effective CBR of sub-grade of 7% and 5 msa traffic, on interpolation the pavement thickness arrived from Plate 5 of IRC: 37-2012 is discussed.

Data stipulations and computation of design traffic for flexible pavement

S.No	Description	Value
1.	Number of commercial vehicles as per last count (P)	450
2.	Annual growth rate of commercial vehicles (r)	0.07
3.	Number of years between the last count and the year of completion of construction (x)	01
4.	Initial traffic in the year of completion in CV/day (A)	482
5.	Type of Road	Two lane
6.	Lane distribution factor (D)	0.5
7.	Type of Terrain	Rolling/Plain
8.	Vehicle damage factor (F)	3.5
9.	Design life in years (n)	10
10.	The cumulative number of standard axles in msa (N)	05

Sectional details of flexible pavement design

S.No	Components of flexible pavement	Thickness (mm)
1.	Semi Dense Bituminous Course Semi Dense Bituminous Course	25
2.	Dense Bituminous Macadam	50
3.	Wet Mix Macadam	250
4.	Gravel Sub-base	210
5.	Total thickness of the flexible pavement	535



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2) Design Of Pavement Withmodified Paver Blocks

The design of pavement using bagasse ash paver blocks is done as per IRC: SP: 63-2004. The paver blocks to be used are to have a minimum compressive strength of 35 N/mm^2 and satisfy the requirements given in IRC: SP: 63-2004. By comparing the properties of paver blocks used in this study with IRC requirements, it is found that it fulfilled all the requirements except thickness and water-cement ratio.

IRC:SP:63-2004

TABLE 1 : DESIGN CATALOGUE FOR PAVEMENT THICKNESS

Traffic and Road Type	Subgrade CBR (%)		
		Above 10	5-10
• Cycle Tracks, Pedestrian Footpaths	Blocks Sand Bed Base	60 20-30 200	60 20-30 200
• Commercial Traffic Axle Load Repetitions less than 10 msa • Residential Streets	Blocks Sand Bed WBM/WMM Base Granular Sub-base	60-80 20-40 250 200	60-80 20-40 250 250
• Commercial traffic Axle Load Repetitions 10-20 msa • Collector Streets, Industrial Streets, Bus and Truck Parking Areas	Blocks Sand Bed WBM/WMM Base Granular Sub-base	80-100 20-40 250 200	80-100 20-40 250 250
• Commercial traffic Axle Load Repetitions 20-50 msa • Arterial Streets	Blocks Sand Bed WBM/WMM Base or WBM/WMM Base and DLC over it* Granular Sub-base	80-100 20-40 250 150 75 200	80-100 20-40 250 150 75 250

Notes :
1. Thickness of layers given above are in mm.
2. Granular sub-base should have at least 150 mm layer at the bottom which is drainable.
3. A typical cross-section is given in Fig. 6.
4. If the subgrade soil has a CBR of less than 5, it should be improved by suitable stabilisation technique to bring the CBR value to 5.
5. msa denotes repetitions in million standard axles

* in case of roads having inadequate drainage or heavy rainfall areas (above 1500 mm per annum)

Parameters used in the design of bagasse ash paver block road

S.No	Description	Value
1.	Number of commercial vehicles as per last count (P)	450
2.	Annual growth rate of commercial vehicles (r)	0.07
3.	Number of years between the last count and the year of completion of construction (x)	01
4.	Initial traffic in the year of completion in CV/day (A)	482
5.	Type of Road	Two lane
6.	Lane distribution factor (D)	0.5
7.	Type of Terrain	Rolling/Plain
8.	Vehicle damage factor (F)	3.5
9.	Design life in years (n)	20
10.	The cumulative number of standard axles in msa (N)	10

Components of pavement using bagasse ash interlocking paver blocks

S.No	Components of flexible pavement with SCBA	Thickness (mm)
1	Interlocking paver blocks	80
2	Sand bed	20
3	Water Bound Macadam/Wet Mix Maccadam Base	250
4	Granular sub-base	250
5	Total thickness of the flexible pavement	600

III.CONCLUSION

Following conclusions have been drawn based on the present study

Sugarcane bagasse ash modified concrete performed better when compared to ordinary concrete up to 20% (finer SCBA) for cement replacement and 10% (less finer SCBA) of sand replacement in ordinary concrete.

Increase of strength in paver blocks is mainly due to presence of high amount of silica in sugarcane bagasse ash.

These pavements are unaffected by the spillage of oil from vehicles and are ideal for bus stops, bus depots and parking areas.

As far as the costs are concerned, it is estimated that the amount required per kilometre length of flexible pavement is Rs.90,10,000 and the cost of interlocking bagasse ash paver blocks road is Rs.68,93,000 per kilometre. The construction of road using bagasse ash paver blocks seems to be more cost effective than the conventional flexible pavement by 23.50%.

Block pavement does not need in-situ curing and so can be opened to traffic soon after completion of construction.

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. The digging and reinstatement of trenches for repairs to utilities is easier in the case of block pavement.

Since the blocks are prepared in the factory, they are of a very high quality, thus avoiding the difficulties encountered in quality control in the field.

Concrete block pavements restrict the speed of vehicles to about 60 km per hour, which is an advantage in city streets and intersections. The block pavements are ideal for intersections where speeds have to be restricted and cornering stresses are high.

Unlike concrete pavements, block pavement does not exhibit very deterioratory effect due to thermal expansion and contraction, and are free from the cracking phenomenon.

Use of permeable block pavement in cities and towns can help replenish depleting underground sources of water, filter pollutants before they reach open water sources, help reduce storm water runoff and decrease the quantum of drainage structures.

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. So utilization of the waste material sugarcane bagasse ash is advantageous as a replacement of cement or fine aggregate in the preparation of concrete paver blocks.

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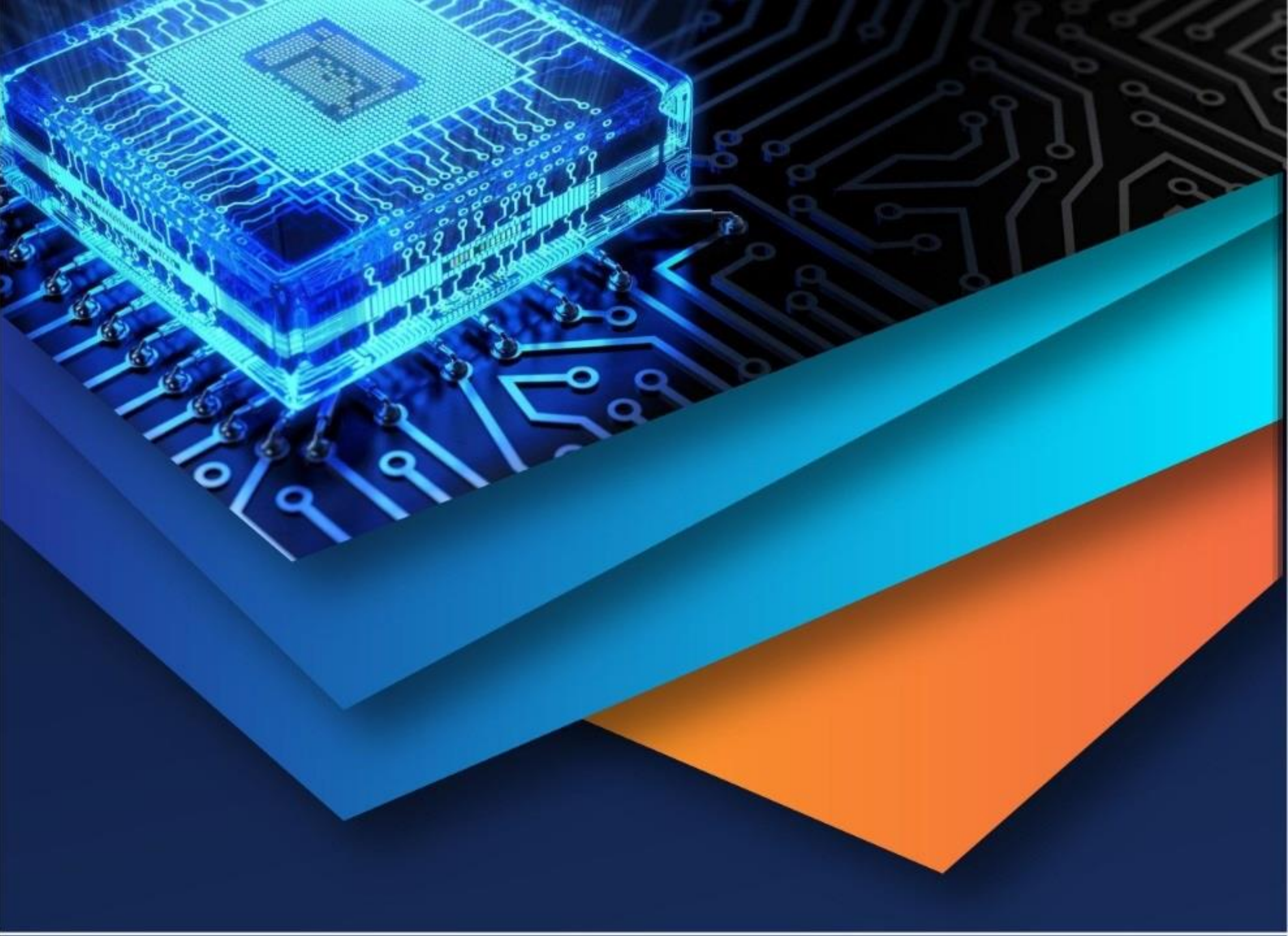

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