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Design of Precast Concrete Blocks for Paving with the use of Cigarette Butts (Cellulose Acetate)

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Abstract: ***Pollution is one of the most important concerns in the 21st century. There are four main types of pollution. They are air pollution, water pollution, soil or land pollution and noise pollution. Litter of cigarette butts contributes significantly in causing soil or land pollution. The remnants of tobacco and harmful toxic chemicals entrapped in these butts leach into soil and waterways contaminating them. These cigarette butts are made up of cellulose acetate which has poor biodegradability and it can take many years for them to break down. Degradation of cigarette butts is a very difficult and costly process. Hence, it is necessary to find a practical solution to reduce the litter of these butts. This study deals with solving the problem of litter of cigarette butts with a practical solution of incorporating them into precast concrete blocks for paving. The precast concrete blocks for paving were tested for different properties such as compressive strength, flexural strength and water absorption in order to find their suitability in construction. The precast concrete blocks for paving were casted and tested as per the specifications given in IS 15658: 2006.***

Keywords: Pollution, Litter, Cigarette butts, Cellulose acetate, Precast concrete blocks, IS 15658:2006.

I. INTRODUCTION

Discarded cigarette butts are one of the most common type of litter found around the world. An estimated 4.5 trillion cigarette butts are littered worldwide every year [1]. The cigarette butts are made from cellulose acetate and are coated with paper. These butts are designed to trap tar and other toxic chemicals before they reach the smoker's lungs. Each butt contains the remnants of tobacco and harmful toxic chemicals. They also contain heavy metals such as arsenic, nickel and cadmium which adds to the existing cocktail of environmental pollution [2]. Cellulose acetate is the acetate ester of cellulose. It is used to make cigarette filters as has low manufacturing cost and good draping qualities [3]. Figure 1 clearly shows the filters in a new and used cigarette. The filter of the used cigarette contains nicotine, tar and other toxic soluble chemicals.

Figure 1: Filters in a new and used cigarette

Degradation of these butts is not an easy process. Since these butts have poor biodegradability, it can take many years for them to break down. Incineration of these butts is not practical as it is a costly process. Hence, it is necessary to find a practical solution to minimise the litter of these butts in order to prevent the pollution caused by them. There are two recorded investigations made prior to this investigation to find a way to solve the world's cigarette butt problem. A research was conducted at the RMIT University, Australia in which the use of these butts in the construction of asphalt concrete roads [4] and in the manufacture of fired clay bricks [5] was done. This investigation deals with the use of cigarette butts in precast concrete blocks for paving.

Precast concrete blocks for paving are used for providing pavements in areas where conventional types of construction are less durable due to many operational and environmental constraints. Paving done with concrete paver blocks is versatile, aesthetically attractive, functional, cost effective and requires less or no maintenance if correctly manufactured and laid. In India, precast concrete blocks for paving are manufactured according to the specifications given in IS 15658: 2006 which is prepared by the Bureau of Indian Standards (BIS) and IRC: SP: 63: 2004 prepared by the Indian Road Congress. There are different grades of paver blocks for different traffic categories. Table 1 shows the recommended grades of paver blocks given in IS 15658: 2006.

TABLE I
RECOMMENDED GRADES OF PAVER BLOCKS FOR DIFFERENT TRAFFIC CATEGORIES

Sr. No.	Grade Designation of Paver Blocks	Specified Compressive Strength of Paver Blocks at 28 days N/mm^2	Traffic Category	Recommended Minimum Paver Block Thickness (mm)	Traffic Examples of Application
1.	M-30	30	Non-traffic	50	Building premises, monument premises, landscapes, public gardens/parks, domestic drives, paths and patios, embankment slopes, sand stabilization area, etc.
2.	M-35	35	Light-traffic	60	Pedestrian plazas, shopping complexes ramps, car parks, office driveways, housing colonies, office complexes, rural roads with low volume traffic, farm houses, beach sites, tourist resorts, local authority footways, residential roads, etc.
3.	M-40	40	Medium-traffic	80	City streets, small and medium market roads, low volume roads, utility cuts on arteria roads, etc.
4.	M-50	50	Heavy-traffic	100	Bus terminals, industrial complexes, mandi houses, roads on expansive soils, factory floor, service stations, industrial pavements, etc.
5.	M-55	55	Very heavy-traffic	120	Container terminals, ports, dockyards, mine access roads, bulk cargo areas, airport pavements, etc.

Precast concrete blocks for paving are available in various shapes in the market. Concrete paver blocks of various shapes can be used as per the requirement on site. According to IRC: SP: 63: 2004, paver blocks can be grouped in three different categories. They are:

A. *Category A:* Dentated units are designed to key into each other on all four faces and which, by their plan geometry when keyed together, resist the widening of the joint. These blocks are generally capable of being laid in herringbone bond pattern (as explained in Section 8).
B. *Category B:* These blocks are dentated on only two sides. Their dimensional accuracy of laying helps in bringing about the interlock effect on other faces. Generally, with some exceptions, these blocks can only be laid in stretcher bond (as explained in Section 8).
C. *Category C:* These are not dentated type but depend on dimensional accuracy for interlocking effect. These blocks can be laid only in stretcher bond.

Figure 2 shows the different categories of paver blocks according to the IRC: SP: 63: 2004.

D. The main Objectives of This Investigation Are

1) To design precast concrete blocks for paving by incorporating them with cigarette butts.
2) To check the properties and practicality of precast concrete blocks for paving incorporated with cigarette butts.
3) To compare the properties of precast concrete blocks for paving with that of precast concrete paver blocks incorporated with cigarette butts.
4) To minimise the litter of cigarette butts by incorporating them in precast concrete blocks for paving.

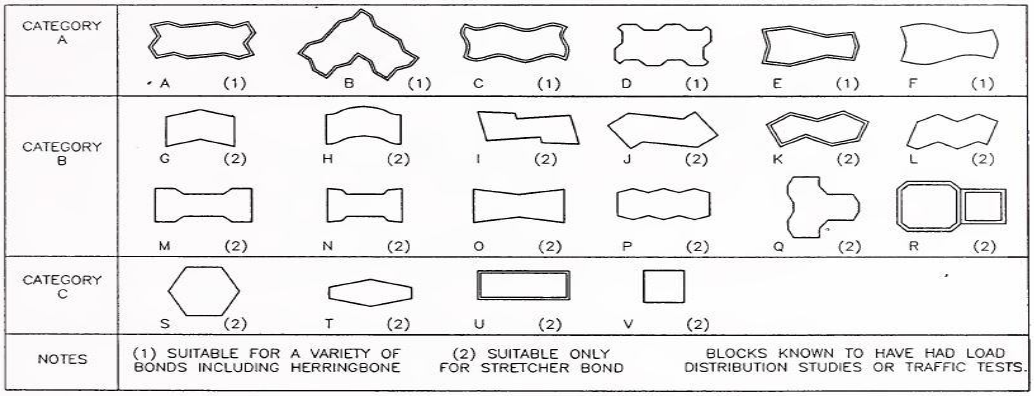

Figure 2: Different categories of paver blocks

II. EXPERIMENTAL INVESTIGATION

A. Materials

1) Cement: Ordinary Portland Cement (OPC) of 53 grade conforming to IS 12269: 2013 is used.
2) Fine Aggregate: Crushed aggregate obtained by crushing rocks from an approved quarry and conforming to the specifications given in IS 383: 1970 is used.
3) Coarse Aggregate: Coarse aggregate obtained from an approved quarry and conforming to the specifications given in IS 383: 1970 is used. The size of the coarse aggregate used is 6 mm.
4) Used Cigarette Butts: Cigarette butts littered on the roads were handpicked. These butts contained remnants of tobacco which was removed. The cigarette butts were then sun dried for 3 continuous days to disinfect them. These butts couldn't be directly mixed with other constituents of concrete as there would have been a possibility of clogging. So, these butts were grinded in a mixer in order to break the compacted filter into smaller fibrous material. Figure 3 shows the sun drying of cigarette butts. Figure 4 illustrates the grinded cigarette butts.
5) Water: Potable water free from acids, alkalis and salts is used.
6) Admixtures: No admixtures are used in the casting of concrete blocks for paving.

Figure 3: Sun drying of cigarette butts

Figure 4: Grinded cigarette butts

B. Mix Proportioning

For the manufacturing of precast concrete blocks for paving, dry and low slump mixes are required. Mix design was carried out to form M30 grade of concrete by using IS 10262: 2009 and specification given by IRC: SP: 63: 2004 and IS 15658: 2006.

C. Casting of Precast Concrete Blocks for Paving

In this investigation, Category A (as per IRC: SP: 63: 2004) Unipaver blocks of thickness 60 mm to 80 mm were casted. The concrete mix considered is M30 i.e., for non-traffic category. Concrete blocks for paving were casted incorporating different percentages of cigarette butts (Cellulose Acetate fibres) i.e., 0%, 0.1% and 0.25% by weight of the mix proportion. Special care was taken while mixing the constituent materials of concrete with the grinded cigarette butts in order to prevent clogging of concrete. Figure 5 shows the mixing of the constituent materials of concrete with grinded cigarette butts. Figure 6 clearly shows how the fine cellulose acetate fibres have mixed with the constituent materials of concrete.

Figure 5: Mixing the constituent materials of concrete with grinded cigarette butts

Figure 6: Cellulose Acetate fibres mixed with the constituent materials of concrete

D. Curing of Precast Concrete Blocks for Paving

Before testing the paving blocks, curing is required. In case of precast concrete blocks for paving, air curing is required. The casted paving blocks were air cured for 28 days.

E. Testing

The precast concrete blocks for paving are tested for a number of properties given in the IS 15658: 2006. Compressive Strength, Flexural Strength and Water Absorption are the three main properties for which the paving blocks are tested.

1) *Water Absorption:* The water absorption of precast concrete blocks for paving is determined in accordance with the specifications given in Annex C of IS 15658: 2006. Water absorption of individual concrete paving block should be less than 7% or maximum 6% by mass (i.e., average of 3 units).
2) *Compressive Strength:* The compressive strength of precast concrete blocks for paving is determined in accordance with the specifications given in Annex D of IS 15658: 2006. Paver block strength shall be specified in terms of 28 days compressive strength. The average 28 days compressive strength of paver blocks shall meet the specified requirement. As per IS 15658: 2006, the minimum average compressive strength of M30 concrete paver blocks should be 30 N/mm^2. The apparent compressive strength of individual block is calculated by dividing the maximum load (in N) by the plan area (in mm^2). The corrected compressive strength is calculated by multiplying the apparent compressive strength by the appropriate correction factor given in Table 5 of IS 15658: 2006. Figure 6 shows the compression test in progress.
3) *Flexural Strength:* The flexural strength of precast concrete blocks for paving is determined in accordance with the specifications given in Annex G of IS 15658: 2006. It is suggested that the minimum flexural strength of a single block should be above 4.5 N/mm^2. Figure 7 shows the flexural test in progress.

The number of blocks tested for each batch as per IS 15658: 2006 is given in Table 2.

TABLE 2 NUMBER OF BLOCKS TESTED AS PER IS15658: 2006

Property	Reference Clause Number	Testing Method	Number of paver blocks for each test
Water Absorption	6.2.4	Annex C	3
Compressive Strength	6.2.5	Annex D	8
Flexural Strength	6.3.2	Annex G	8

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Figure 7: Compression test

Figure 8: Flexural Test

III.RESULTS AND DISCUSSION

A. Water Absorption

The result of the water absorption of precast concrete blocks for paving incorporated with different percentages of cigarette butts i.e., 0%, 0.1% and 0.25% is given in Table 3. It is observed that the water absorption of concrete blocks increases with the increase in the percentage of cigarette butts. The water absorption of concrete paver blocks incorporated with 0.1% and 0.25% cigarette butts is more than 6%. Water repellent admixtures can minimise water movement within the concrete and hence reduce water absorption and efflorescence of the concrete.

TABLE 3
WATER ABSORPTION OF CONCRETE BLOCKS FOR PAVING INCORPORATED WITH DIFFERENT PERCENTAGES OF CIGARETTE BUTTS

Serial Number	Percentage of Cigarette Butts incorporated in Paver Blocks	Water Absorption at 28 days (in %)
1.	0%	5.27
2.	0.1%	6.06
3.	0.25%	6.73

B. Compressive Strength

The compressive strength of concrete paver blocks incorporated with different percentages of cigarette butts is given in Table 4. It is observed that the compressive strength of the concrete paver block decreases with the increase in the percentage of cigarette butts. Higher water-cement ratio leads to increase in the porosity of the mix which is responsible for the decrease in the compressive strength of paver blocks. Hence, adopting the correct water-cement ratio may help to increase the compressive strength. Also, plasticizers and other such admixtures can be used to achieve high early strength of concrete.

TABLE 4
VARIATION OF COMPRESSIVE STRENGTH AT 28 DAYS FOR CONCRETE BLOCKS FOR PAVING INCORPORATED WITH DIFFERENT PERCENTAGES OF CIGARETTE BUTTS

Serial Number	Percentage of Cigarette Butts incorporated in Paver Blocks	Compressive Strength at 28 days (N/mm^2)
1.	0%	30.1
2.	0.1%	29.6
3.	0.25%	26.6

C. Flexural Strength

The flexural strength of concrete paver blocks incorporated with different percentages of cigarette butts is given in Table 5. The flexural strength was found to have increased in paving blocks incorporated with 0.1% cigarette butts. But the flexural strength decreased when the percentage of cigarette butts was increased from 0.1% to 0.25%. It was observed that, in all the three paving blocks with different percentages of cigarette butts viz. 0%, 0.1% and 0.25%, the flexural strength is above 4.5 N/mm^2, which is the minimum required flexural strength as per the IRC: SP:63: 2004.

TABLE 5
VARIATION OF FLEXURAL STRENGTH AT 28 DAYS FOR CONCRETE BLOCKS FOR PAVING INCORPORATED WITH DIFFERENT PERCENTAGES OF CIGARETTE BUTTS

Serial Number	Percentage of Cigarette Butts incorporated in Paver Blocks	Flexural Strength at 28 days (N/mm^2)
1.	0%	11.23
2.	0.1%	12.01
3.	0.25%	9.90

IV. CONCLUSIONS

A. Based on the Experimental Investigation, the Following Observations Were Made

1) The water absorption increased with the increase in percentage of cigarette butts. This can be avoided by using water repellent admixtures as well as by maintaining the appropriate water-cement ratio.

2) There was no significant variation in the compressive strength of paving blocks incorporated with 0% cigarette butts (30.1 N/mm^2) and 0.1% cigarette butts (29.6 N/mm^2). The compressive strength went on to decrease with the increase in percentage of cigarette butts. Hence, cigarette butts can be used in less percentage (up to 0.25%) by weight of the mix proportion to get good quality of paver blocks which will also help us to reduce the world's cigarette butt problem. The compressive strength can

also be increased by maintaining the correct water-cement ratio. Plasticizers and other such admixtures can be used to achieve high early strength of concrete blocks for paving.

3) The flexural strength of concrete paver blocks went on to increase from 11.23 N/mm^2 (0% cigarette butts) to 12.01 N/mm^2 (0.1% cigarette butts). But it later decreased when the percentage of cigarette butts was increased from 0.1% to 0.25%. But these results of flexural strength are above 4.5 N/mm^2. Hence, there is no problem in incorporating concrete paver blocks with permissible percentages of cigarette butts.

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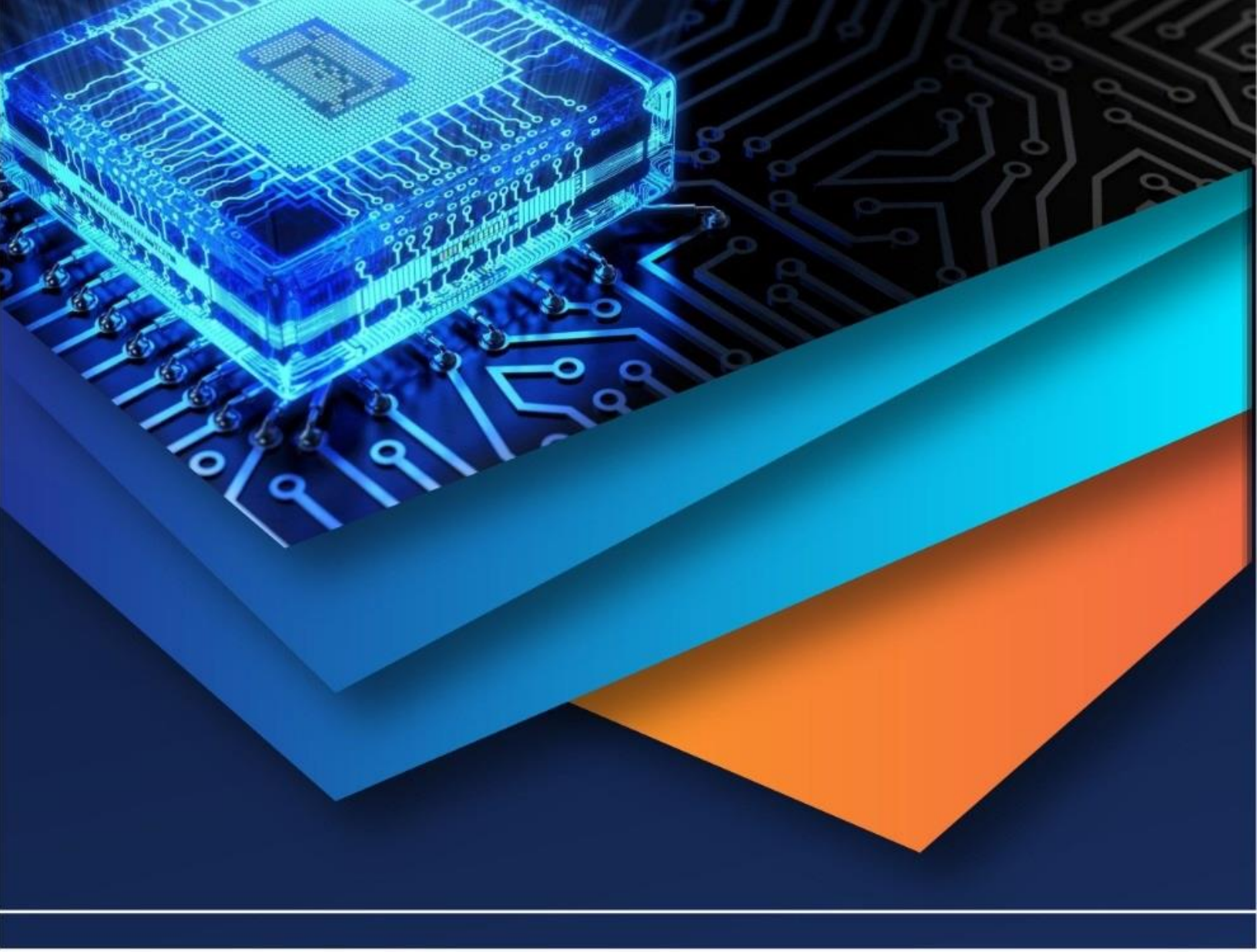

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