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Economical Application of Industrial Waste in Road Construction

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ABSTRACT

In present scenario, safe disposal of industrial waste is a major issue. These waste materials pollute the environment, and many of them are nonbiodegradable. The industrial waste utilization in road construction has proved to be of great use in efficient handling of waste material generated by industries and has enhanced the properties of road. By properly utilizing the resources, it has also reduced pollution and disposal issues. In road building, a variety of industrial wastes are used as a whole or partial replacement. A study of different types of industrial waste has been discussed by many researchers and numerous experiments have been carried out to improve quality of road and have appropriate replacement in order to reduce pollution, cost of disposing waste and saving natural traditional road constructing material. This paper emphasizes on reduction of expenditure of traditional road material and have a suitable replacement of natural resources which would benefit environment and society.

Keywords: Industrial Waste, Cost Saving, Pavement, Road Construction

I. INTRODUCTION

The Road is considered as a medium for transportation for man and goods. It is also responsible for development of locality, area and surrounding. The Road in its preliminary stage had a very crude composition. Since there was no development on transportation technology and vehicles like carts, carriage and simple wagons constituted majorly of road vehicles.

Over the centuries as the human race progressed this resulted in development of other things. So as per the proverb: "Necessity is the mother of invention" [1].

Human race passed the era of Modernization and industrialization which made a huge impact on human society and remarkable discoveries took place which created history. One of such discovery was making of motor vehicle on 29 January 1886, Carl Benz. And after that many modifications took place simultaneously there was modification in road construction. In the past, road construction has relied on soil, stone aggregates, sand, bitumen, and cement, among other materials. The number of employers grew as a result of man's increased need. Due to all this development, there was increase in vehicles like cars, buses, truck and there has been urge to create roads for Municipal Corporation or private companies [2]. To meet the ever-increasing population demand and mans greed has costed the environment badly like deforestation, mining in order to extract materials for road etc. On the contrary the roads are imposed to tremendous loads and exposed to harsh climatic conditions which leads to roads deterioration. Due to this government has to carry separate budget for maintenance of road for every year [3].

Generally, in present scenario due to problems like exhausting of traditional road material and striving to save environment made it essential to use these materials carefully. Industrial waste product is one such category which is suggested by the scientist as the alternative material for highway construction. These industrial wastes are currently causing a disposal and pollution crisis, so their effective use in road construction can help to alleviate pollution and disposal issues [4], [5].

Waste materials such as blast furnace slag from steel industries, fly-ash from thermal power plants and coal-fired industries cement kiln dust from cement industries, phosphatic fertilizer industry phosphogypsum, and a variety of other solid waste have proven to be beneficial for road construction [6].

II. SOURCES OF INDUSTRIAL WASTE

The term "industrial waste" refers to solid, liquid, and gaseous emissions, as well as residual and undesirable scraps generated by an industrial activity or process[7].They are specialized to a given industry and their properties can range from inert to extremely biodegradable, toxic, reactive, odorous, corrosive, hot, cold, colorful, viscous, inflammable, and so on[8]. Classification of industrial waste and their sources are as follows;

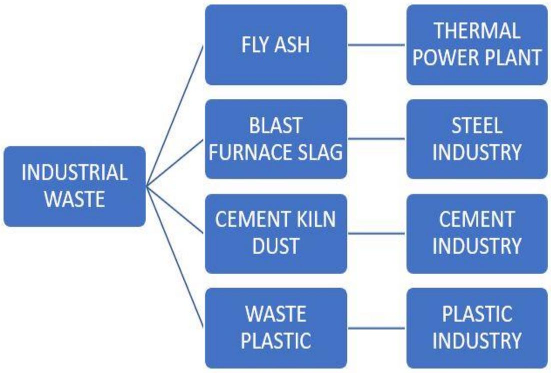

Figure 1: Classification of industrial waste [6]

1) Fly ash:

Fly ash is a finely divided residue produced by the burning of pulverised coal that is conveyed from the combustion chamber by exhaust gases. Fly ash is produced by coal-fired power and steam generating plants [6].

Classification of fly ash:

➢ F Class Fly Ash:

Fly ash is categorised as class F if it contains at least 70% silica, alumina, and iron oxide and has a low amount of calcium oxide (Cao) d) In other words, tougher, older anthracite and bituminous coal creates Class F fly ash when burned. This fly ash is pozzolanic in nature, with less than 20% lime (Cao) content [9].

➢ C Class Fly Ash:

It contains at least 50% silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) by mass, and the calcium oxide (Cao) concentration is high (from 10% to 30%), with a strong reactivity of practically all elements. Class C fly is typically created by burning lignite or subbituminous coal [9].

2) Slag:

There are two types of slag depending upon Physiochemical and mineralogical characteristics:

a) Blast Furnace Slag.

Blast furnace slag is a calcium-silicate based material that is collected off the top of molten iron after it has been removed from ore in a blast furnace[10].There are two types of BF slag are as follows;

b) Granulated Blast Furnace Slag (GBFS).

c) Air Cooled blast furnace slag.

3) Steel Slag.

Basic oxygen steelmaking (BOF) slag, commonly known as Linz–Donawitz steelmaking slag. Steel slag is formed in BOF convertor where steel scrap and melted pig iron are reacted by oxygen blowing [10].

4) Cement Kiln Dust:

Cement kiln dust is hazardous bypass dust produced in large quantities during the manufacturing of Portland cement [11].

5) Plastic waste:

Polymers are substances with a high molecular mass that are made up of a large number of repeating structural units derived from simple molecules Monomers are simple molecules that combine to form polymers[12][13].

III. WASTE GENERATION

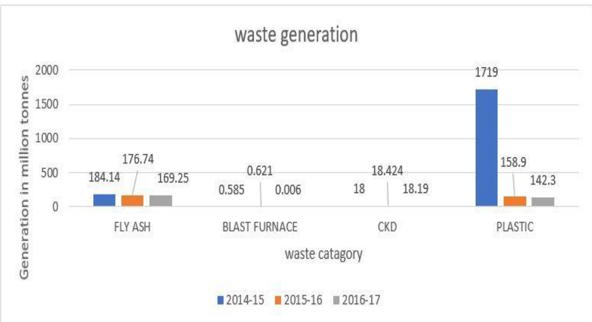

Figure 2: Waste generation data [14]–[18]

IV. INTRODUCTION TO PAVEMENT

The term pavement is normally used to describe the series of layers which form the structure of road. In Engineering terms, the pavement is defined as "A man made surface on natural ground on which the people, vehicle or animals can cross or move" [19].

Figure 3: Cross section of road pavement [20]

1) Qualities required by pavement:

An Ideal Pavement should have followed qualities/ should fulfill following requirements:

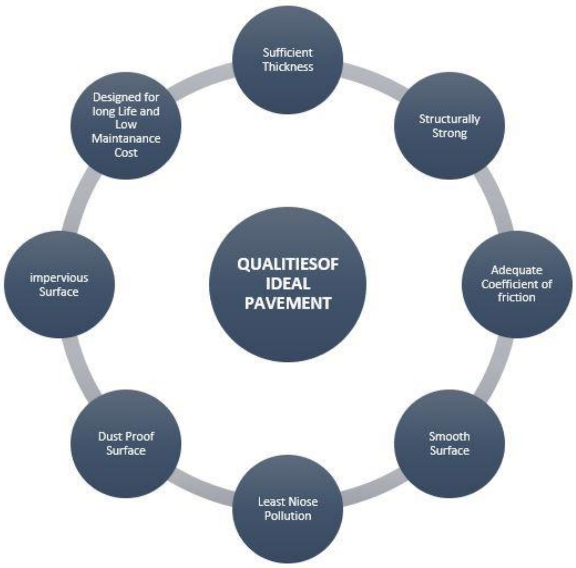

Figure 4: Qualities of ideal pavement [21], [22]

2) Types of Pavements:

The Pavement can be classified on the basis of Structural performance into two categories are as

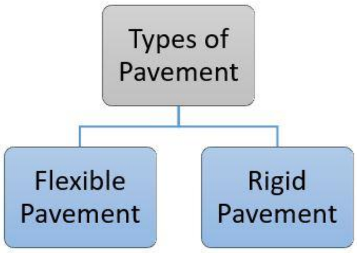

Figure 5: Types of pavements [23]

➢ Flexible Pavement:

A flexible pavement layer is one that is made up of a mixture of aggregates and bitumen that has been appropriately heated and blended before being put and compacted on a bed of granular layer [22].Flexible pavement can be constructed in multiple layers, with the top layer being of the finest quality to endure highest compressive stress as well as wear and tear. Grain-to-grain transfer through the granular structure's points of contact will carry wheel load strains to the lower layers of flexible pavements [23].Low-quality materials can be utilised in the lower levels because they are subjected to less stress[24].

➢ Rigid Pavement:

Rigid pavements are comprised of cement concrete or reinforced concrete slabs that are set over a low strength concrete layer or a well compacted layer of aggregates, or both [22].

3) Setbacks of flexible and rigid pavement

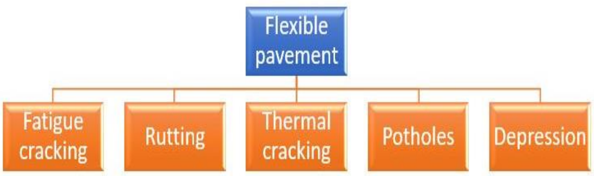

Figure 6: Setbacks of Flexible pavement [25]

Figure 7: Setbacks of Rigid pavement [25]

4) Pavement Material & Characterization:

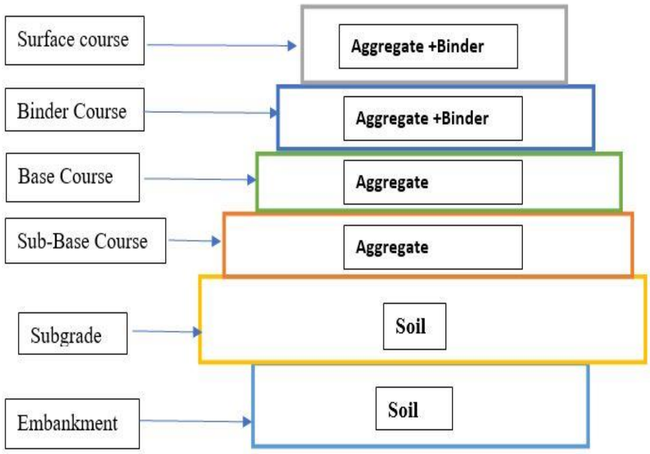

Figure 8: Pavement Material & characterization [26], [27]

V. USES & PROPERTIES OF INDUSTRIAL WASTE

1) Uses

➢ Fly ash:

i. Portland cement concrete.
ii. Stabilized base course.
iii. Soil improvement
iv. Asphalt pavements
v. Grouts for pavement sub sealing [28], [29]

➢ Blast furnace slag:

i. Cementitious binder
ii. Coarse aggregate for asphalt.
iii. Base of sub base course material.
iv. Binder in soil stabilization [30].

➢ Cement kiln dust:

i. Stabilization of base course.
ii. Binder in bituminous mix.
iii. Mineral filler in asphalt paving [31].

➢ Waste plastic:

i. Bituminous mix.
ii. Flexible pavement [32], [33].

2) Properties:

Table 1: Chemical composition of Industrial waste [6], [34], [35]

Component	Fly ash	Granulated blast Furnace Slag	Cement Kiln Dust
SiO_2	50.2–59.7	30.20-35.09	55.5%
Al_2O_3	14-32.4	17.54	4.5%
Fe_2O_3	2.7-16.6	0.7	2.1%
CaO	0.6-9	37.80-39.50	8.1%
MgO	0.2-4.7	5.50-7.50	1.3%
K_2SO_4	-	-	5.9%
Na_2SO_4	-	-	1.3%
$CaSO_4$	-	-	5.2%
KF	-	-	0.4%
SO_3	N.A	0.70-1.90	-
K_2O	0.2-4.7	0.3	-
Na_2O	0.2-1.2	0.3	-
TiO2	0.3-2.7	0.68	-
Mn_2O3	-	-	-
MnO	-	0.83	-
P_2O_3	N.A	0.37	-
P_2O_5	N.A	-	-
Fe	-	0.7	-
Sulphide Sulphur	-	0.66	-
Loss on Ignition	0.5-7.2	1.08	-

Table 2: Physical Properties of Industrial waste [17], [36], [37]

Properties	Fly Ash	Granulated Blast Furnace Slag	Cement Kiln Dust	Waste Plastic
Specific Gravity	1.90-2.55	2.08-2.45	3.01-3.16	0.94-0.96
Plasticity	Non plastic	-	0-40%	Plastic
Loose bulk density (kg/m3)	-	1052	480	570
Density	-	1236	1350-1500	-
Maximum dry density (gm/cc)	0.9-1.6	-	-	940
Water Absorption %	-	-	-	-
Moisture Content %	38.0-18.0	8.0-10.0	-	-
Cohesion (KN/m2)	Negligible	-	-	0.2
Angle of Internal Friction (ȼ)	30°-40°	-	-	-
Coefficient of Consolidation C_v (cm^2/sec)	1.75×10^{-5} - 2.01×10^{-3}	-	-	-
Compression Index (C_c)	0.05-0.4	-	-	-
Permeability	8×10^{6}- 7×10^{4}	-	3×10^{4}	-
Clay Lumps and Friable particles (%)	-	1	-	-

VI. RESULTS

Let us consider, a department has to complete a construction for road work of length 1km and 6meters wide by referring pavement design guidelines created by IRC for CBR 4% the total pavement thickness would be 610 mm whose cost can be estimated are as follows

Table 3: Abstract of Cost [38]

Description	Qty	Unit	Rate (Rs.)	Amount (Rs.)
Embankment	4050	Cum	500	20,25,000/-
Subgrade	2790	Cum	1000	27,90,000 /-
Sub-Base Course	2790	Cum	2500	69,75,000 /-
Base Course	1800	Sq.m	250	4,50,000 /-
Prime Coat	6000	Sq.m	90	5,40,000 /-
Binder Course	450	Sq.m	900	4,05,000 /-
Tack Coat	6000	Sq.m	70	4,20,000 /-
Surface Course	450	Sq.m	500	2,25,000 /-
Seal Coat	6000	Sq.m	200	12,00,000 /-
Total Amount				1,50,30,000 /-

Now as we have made replacement of plastic waste in Prime, Tack & Seal coat so we will need to calculate the cost of Prime, Tack & Seal coat by blend over of pure bitumen & plastic blended bitumen.

Calculations:

Surface Area of Road which have to be cover up by Bitumen = Length × Width

= 1000×6

= 6000 sq.m or m^2.

As per IRC guideline:

For all types of road surface requires volume of bitumen 0.98-1.10 kg per sq.m for prime, tack & seal coating.

1. Road Seal coat with pure Bitumen

- Total volume of bitumen required for Prime, Tack & Seal coat

  = (Surface area of road) × (Volume of Bitumen required per sq.m)

  =6000×1 (Say 1 kg Bitumen is reqd. per Sq.m)

  = 6000 Kg.

- Total cost of pure bitumen Prime coat

  = (Total volume of bitumen required for Prime coat) × (Rate)

  = 6000 × 90

  = Rs. 5,40,000 /-.

- Total cost of pure bitumen Tack coat

  = (Total volume of bitumen required for Tack coat) × (Rate)

  = 6000 × 70

  = Rs. 4,20,000 /-.

- Total cost of pure bitumen Seal coat

  = (Total volume of bitumen required for Seal Coat) × (Rate)

  = 6000 × 200

  = Rs. 12,00,000 /-.

2. Road Seal Coat with Bitumen and Shredded Waste Plastic

As per IRC 098:2013 Guideline,

For Road Construction use of plastic waste mixing in bitumen is in between 6% to 8% of weight of Bitumen.

- Cost of waste shredded plastic in Kilograms is in between Rs.10/Kg to Rs.16/Kg

(Above Rate is given by Rudra Environmental Solutions (India) Ltd.)

Table 4: Costing of waste plastic [39]

Sr. No	Particulars	Approx. Rate (Rs/Kg)
1	Waste Plastic	0
2	Collection of plastic	2
3	Transportation	2
4	Cleaning/ Shredding	2
5	Labour Charges	3
6	Machinery Charges Including electricity / Maintenance	2
	Total	≈ Rs. 11

- Total volume of Waste shredded plastic required for Prime, Tack and Seal Coat.

  = (Total volume of bitumen required for seal coat) × 8%

  = 6000 × 8/100

= 480 Kg.

- Total Cost of Waste shredded plastic required for Prime, Tack and Seal Coat.
  = (Total volume of waste shredded plastic reqd. for seal coat) × (Cost of plastic per Kg)
  = 480 × 11
  = Rs. 5280 /-.
- Cost of Prime coating of proposed road with mixture of Bitumen & Waste Plastic.
  = (Actual cost of bitumen reqd. after plastic mixing) + (Total cost of waste Plastic)
  = ((6000 – 480) ×90) + (5280)
  = Rs. 5,02, 080 /-.
- Cost of Tack coating of proposed road with mixture of Bitumen & Waste Plastic.
  = (Actual cost of bitumen reqd. after plastic mixing) + (Total cost of waste plastic)
  = ((6000 – 480) ×70) + (5280)
  = Rs. 3,91,680 /-.
- Cost of Seal coating of proposed road with mixture of Bitumen & Waste Plastic.
  = (Actual cost of bitumen reqd. after plastic mixing) + (Total cost of waste plastic)
  = ((6000 – 480) ×200) + (5280)
  = Rs. 11,09,280 /-.
- Total cost of plastic mixed coats
  =Prime coat+ Tack coat + Seal coat
  = 5,02,080 + 3,91,680 + 11,09,280
  = Rs. 20,03,340 /-.
- Total cost of conventional coats
  = Prime coat+ Tack coat + Seal coat
  = 5,40,000 + 4,20,000 + 12,00,000
  = Rs. 21,60,000 /-.

Table 5: Comparison of cost between coats

Layers	Cost by conventional method	Cost by plastic mixing
Prime coat	5,40,000	5,02,280
Tack coat	4,20,000	3,93,680
Seal coat	12,00,000	11,09,280

- Savings
  = Total cost of conventional coat - Total cost of plastic mixed coats
  = 21,60.000 – 20,03,040
  = Rs. 1,56,960 /-.
- Savings %
  = (Saving in Rs. / Total cost of conventional coats)
  = (1,56,960 / 21,60,000) × 100
  = 7.26 %

When compared to standard bitumen Prime, Tack & Seal coat, the cost savings gained are 7.26 percent. The cost savings from employing plastic in the prime, seal, and tack coat are Rs.1,56,960/-. The amended coatings have the extra benefit of lowering the viscosity of the bituminous mix. This enables a lower operating temperature, resulting in decreased VOC and CO emissions. In terms of wear resistance, plastic-bitumen composite roads exceed normal asphalt concrete roads.

VII. CONCLUSION

From this study paper it concludes that around 7.26% of cost has been cut back following the use of waste plastic in bitumen. Using this modified bitumen seal coat not only reduces the budget but also enhances the properties of coat layer. The use of industrial waste in various road projects will eventually result declination of waste in dumping yards. The industrial waste reduces the use of exhaustible conventional materials, which contributed to environmental pollution and also required high cost of extraction. In accordance to the above point, the use of industrial waste should be encouraged in construction of road projects in India, since it not only proves to be cost friendly but also eco-friendly in an already overly polluted environment.

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