

## USE OF PLASTIC WASTE IN CONSTRUCTION OF ROADS

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### Abstract

Plastic is one of the toxic substance in nature. The major problem today is the disposal of waste plastics. These are non-biodegradable elements and can be removed only burning which will result air pollution and land pollution and hygiene problems. Instead of burning them or burying them we can use the plastic waste in construction of roads. This usage will be based on Economical, Technical, and Ecological criteria. Every year we produce some million metric tons of plastic waste. These wastes will be cleaned and cut into small pieces to get mixed well. These materials will also cost us less when compared to that of some traditional road materials. In road construction, they will get modified with the Asphalt, forming a mixture which can be used as a top layer for flexible pavements. If these wastes are used appropriately in construction of roads, the disposal and pollution problems can be controlled to a large extent. They can provide better binding property, Stability, Density, Durability and resistant to water. The use of this innovative technology will not strengthen the road construction but will also increase the life time and helps to improve the environment.

### 1. Introduction

Plastic became a very common thing everywhere in today's life style. The biggest problem which the human race is facing today is what to do with the waste plastic. Plastic is a non-degradable substance and the usage of plastic was increasing day by day. This is polluting all natural resources and is showing some adverse effects on human beings. Many research works have been made on waste plastic and they found that this substance will remain unchanged even after 4500 years. Because of its biodegradability property it creates stagnation of waste and hygiene problems. The experimentation at several institutes demonstrate that the waste plastic, when mixed with hot aggregate will form a fine coat of plastic over the aggregate and when these types of aggregates are mixed with asphalt it will result in higher strength, higher resistance to water and a better performance for a certain period.

In the same time the road traffic is also increasing rapidly which made us to create new methods for increasing the load bearing capacities of roads. These both issues led the research people to make a new outcome that is using of plastic in the construction of asphalt pavement. The research people started using waste plastic in construction of roads by processing it. This step can control the pollution caused by plastic to some extent and helps the durability of

road by increasing its binding property. Use of plastic along with asphalt in construction of roads will not only increase the lifetime and smoothness but also makes the roads economically sound and environmental friendly. Plastic waste will be used as a modifier of bitumen to improve some asphalt properties. The plastic roads are found to perform better when compared to that of conventional asphalt. [1]

## 2. LITERATURE REVIEW

Since a long time back the application of plastic in flexible pavements has been done to increase the stability, durability of roads at a lesser cost of construction by substituting some percentage of bitumen with that of processed waste plastic. The LDPE (Low density polyethylene) is the only plastic that can be used in this technique as it gets softened at a required temperature of 160 degrees(320F) and will be laminated over the aggregates.

There will be no alteration required because the plastic will be mixed at the same time when the aggregates are discharged into the hot mix plant for a time between 30 to 50 seconds. Due to this there will be no fuel utilization. Still there is a constant research work is going on to attain the optimality and many scientists stated that we can use waste plastic in construction of roads. In construction of roads, the asphalt plays a role of binding the aggregates together by coating over the aggregates. But the binder is poor to resistant to water, when mixed with the polymers it will be having a better resistant to temperature and water.

The use of waste plastic in asphalt will increase the binding property when compared to that of conventional bitumen. This will improve the properties of bitumen resulting in increase in softening point and in turn will decrease the penetration value thus bettering the durability. The polymer mixing will reduce the formation of air voids. The use of plastic in construction of roads can save the environment, increase the life time of the road, reduce the use of petroleum products, and serves the society with additional income for those associated with it. [4]

## 3. PLASTIC GENERATION IN INDIA

The material which consists of one or more organic polymers of giant molecular weight, in a solid finished state, and at another state while assembling or processing into finished pieces, can be carved by its flow is known as plastic. The plastic constitutes two major categories;

- Thermoplastics
- Thermoset Plastics

### **Thermoplastics**

Thermoplastic is a plastic material, that becomes liable or moldable at a specific temperature and solidifies upon cooling. Therefore, thermoplastics can be reshaped by heating. We use polyethylene a type of thermoplastic in construction of roads.

### **Thermoset Plastics**

Thermoset plastics are synthetic materials that strengthen during heating and but cannot be remolded after the initial process was completed. [5]

Table 1. Plastics Consumption in India [5]

S. No.	Year	Consumption (Tones)
1.	1996	61,000
2.	2000	3,00,000
3.	2001	4,00,000
4.	2007	8,500,000

Table 2. Polymers Demands in India (Million Tones) [5]

S. No.	Type of polymer	1995-96	2001-02	2006-07
1.	Polyethylene	0.83	1.83	3.27
2.	Polypropylene	0.34	0.88	1.79
3.	Polyvinyl chloride	0.49	0.87	1.29
4.	Poly Ethylene Terephthalate	0.03	0.14	0.29

Table 3: Plastic usage in different countries [8]

Rank	Country	Percentage of waste that is mismanaged	Quantity of mismanaged plastic waste (MMT/year)	Percentage of global mismanaged plastic waste	Quantity of plastic marine debris (MMT/year)
1	China	76	8.82	27.7	1.32-3.53
2	Indonesia	83	3.22	10.1	0.48-1.29
3	Philippines	83	1.88	5.9	0.28-0.75
4	Vietnam	88	1.83	5.8	0.28-0.73
5	Sri Lanka	84	1.59	5.0	0.24-0.64
6	Thailand	75	1.03	3.2	0.15-0.41
7	Egypt	69	0.97	3.0	0.15-0.39
8	Malaysia	57	0.94	2.9	0.14-0.37
9	Nigeria	83	0.85	2.7	0.13-0.34
10	Bangladesh	89	0.79	2.5	0.12-0.31
11	South Africa	56	0.63	2.0	0.09-0.25
12	India	87	0.60	1.9	0.09-0.24
13	Algeria	60	0.52	1.6	0.08-0.21
14	Turkey	18	0.49	1.5	0.07-0.19
15	Pakistan	88	0.48	1.5	0.07-0.19
16	Brazil	11	0.47	1.5	0.07-0.19
17	Burma	89	0.46	1.4	0.07-0.18
18	Morocco	68	0.31	1.0	0.05-0.12
19	North Korea	90	0.30	1.0	0.05-0.12
20	United States	2	0.28	0.9	0.04-0.11

MMT = million metric tons  
Adapted from Jambeck et al. (2015)<sup>4</sup>

### 3.1 PLASTIC CLEANING PROCESS:

The cleaning process of plastic involves in four steps. They are;

- Segregation
- Cleaning
- Shredding
- Collection.

**Segregation Process:** In this process the total plastic wastes from different places are collected and must be separated from other waste sources. The maximum thickness of the plastic should not be more than 60 microns. The Low-Density Poly ethylene plastic should be taken separately.



Figure 1. Waste Plastic collection [9]

**3.2 Cleaning Process:** In this process the plastic collected will be washed with chemicals and will be dried. The cleaning process should be done with high care because the additional of chemicals in more quantities may lead to decomposition of plastic with release of harmful toxic gases. While adding chemicals, the person should be having proper protection wear in order to avoid injuries.



Figure 2. Cleaning of Waste Plastic [9]



**3.3 Shredding Process:** In this process the plastic cleaned will be sent through the shredding machine and the waste particles are shredded into small pieces of required size. The shredded plastic will in of different colors but the material composition is same. Even after the cleaning process some unnecessary particles will be present in the mixture and this can be identified and be removed by manually or during sieve analysis process.



**Figure3: Shredding of Waste Plastic [9]**

**3.4 Collection Process:** In this process the plastic which was shredded will be collected in sieve analysis machine. When the machine was turned on it will starts vibrating and the materials get sieved automatically and they will pass through different layers of the machine. For mixing as a binder, we need finely processed plastic. The plastic which is left after passing through the 4.75 and 2.36 mm sieves will be collected and will transferred into another chamber for mixing process [9].



**Figure4: Collection of Plastic [9]**

### 3.5 Plastic Roads in America

The usage of plastic waste in construction of roads came into existence in the year 1911 in Michigan State. During first world war they used the PVC pipes in form of transition mats for the transportation of war equipment's from one part to another part. The "Transition mats" consists of successively large pipes which ease the transition of tires from the approach onto plastic roads. Making the primary 2-inch pipe within the mat to support wheel a lot of schedule 80 will increase mat durability. The transmission mats increase the environmental sensitivity by eliminating the necessity for ramping up to plastic road with soil, that typically must be borrowed from somewhere. The use of transition mats reduces the forces enforced on the plastic roads when the tire rolls on it. The longitudinal forces tend to expel the plastic road in the direction that the vehicle moves leading to the gaining of set of soil. Absence of this set will lead to the soil aerating and increased rutting as the plastic road slides and point loads from individual pipe vary in location of soil.



**Figure 5. Transition Mats [7]**

The steeper grades or existence of cross-slope will result in loss of traction. The traction loss may take place in between the tires and the PVC pipes causing it to work out of soil ramp if so installed. In the recent cases, a wave may form in the crossing system which can lead to failure if the system folds on over itself.

Due to lack of proper knowledge and implementation it costed the government a huge amount of money which made them to withdraw this process and started to use of tires in construction of roads which costed them very less amount when compared to that of conventional roads. From the year 1982 several institutions had started conducting studies to increase the strength of roads by using waste plastic. These studies made them to implement in 15 states in the year 1994 as the growth of plastic waste was so alarming [7].



Figure 6: Plastic Road Worked out from Soil Ramp [7]

### 3.6 Texas Roads Made from Plastic

The state of Texas spends almost \$10 billion a year in the transportation. As per the records from “Texas Department of Transportation” it is almost less than \$5 billion they required. The amount includes all the construction process, maintenance of roads and the repair of roads. The Lone star state alone has 311,000 miles of road. The amount of road alone is an expensive issue, however, the maintenance is also a big issue for the length of roads. The main factor is that the state was built on “expansive clay”. This type of soil will have properties of contraction during wet weather and swelling. This results in chances of formation of cracks more than other part of the country.

In the year 2004 Dr. Sahadat Hossain a civil engineering professor from “The University of Texas at Arlington” had kept a proposal like “What is there is way to spend to 200,000 to 300,000 \$ for repairs instead of keeping millions and billions in decomposition of plastic as well as repairing of roads”. His idea is to use recycled plastic bottles to create pins to maintain the roads and abate proportion of cracks and buckling, and thereby making the roads to last for longer time. This method is not only cheap fixer, but also lasts for a longer time than the traditional one. Each pin is constructed from at least 500 recycled bottles, so that the environment is also positively affected which gives Texas a green fix to a decades-old problem.

According to the report in “The Atlantic Cities” a two-year feasible study was done on sections of Texas Route 287 where 10-foot long pins were drilled into one section of roadway slope. The remaining part was left undisturbed. After this study, they



concluded that supported section had moved only two inches, where the uncontrolled sections had moved 15 inches deeper.

The Texas DOT felt that this would be a great idea to implement to cash on and gave Dr. Hossain a \$714,000 grant to work on two other Texas highways in the districts of Dallas and Fort worth districts in between the years 2009-2013. Later he was awarded a grant of \$1.05 million in the year 2013 which is having a contract of 3 years. The professor stated that this article could be implemented in rest of the states and even in other countries too. Even though each type of soil is different, with research into pin design and placement, it could be done without any pressure. [6]



Figure 7. Road made of Plastic [6]

#### 4. MIXING PROCEDURE

The mixing of waste plastic with asphalt takes place in two ways, they are:

- 1) Dry Process
- 2) Wet Process.

##### 4.1 DRY PROCESS

The plastic waste which is left after passing through the 4.75mm sieve and residing on 2.36mm will be collected. Proper care should be taken because PVC (Poly Vinyl Chloride) waste should be eliminated before it proceeds into next step. The aggregates mix will be heated in a chamber at a temperature of 1650C (3002F). Now the plastic collected will be sent into this chamber and will be heated along with the aggregate.

The plastic will get coated uniformly over the aggregate within 30 to 45 seconds. It will give an oily coated look to the aggregate mixture. The mixed residue will be passed into other mixing chamber. The percentage of plastic content varies with the location and its climatic condition. Maximum of 15% of plastic can be used and a minimum of 8% can be used in dry process. In the same way, the asphalt will be heated at a temperature of 1600C (2912F). This process is done in order to attain good binding and to prevent weak bonding. The main important thing that must be kept in mind is monitoring of temperature.

In the next step the hot aggregate mix will be mixed with the hot asphalt for laying roads. The road laying temperature should be in between 1100 (2012F) to 1200C (2192F). The road roller used must be of 8-ton capacity one.





Figure 8. Hot Mix Plant [8]

#### Advantages

- 1) The plastic that is coated over the stones will improve the surface properties of the aggregates.
- 2) The usage of plastic can be more than 15 percent.
- 3) The plastic will double the binding property of aggregates.
- 4) There is no need of any new equipment.
- 5) The bitumen bonding will be more than normal.
- 6) The coated aggregates will show more strength.
- 7) The degradation of roads will not take place even after 5-6 years.
- 8) This can be practical in all types of climates.
- 9) The emission of toxic gases cannot be possible below 180C(356F).

#### Disadvantages

- 1) This process is applicable only for plastic waste material. [3]

## 4.2 WET PROCESS

The shredded plastic that is remained after passing through the 4.75mm sieve and residing over 2.36mm sieve will be collected. The aggregate mix will be heated to 1650C(3002F) and from there it will be transferred to mixing chamber. In another chamber the asphalt will be heated to a temperature of 1600C(2912F) until it comes to viscous state. In this hot asphalt, the shredded plastic will be added and the plastic gets melted within 45 seconds. The maximum percentage of plastic usage should not be more than 8. The two residues will be transferred into the mixing chamber and it will be in active mode till the mixture gets perfect. The processed mixture will be used for laying of pavements. The laying temperature of roads must be in between 1100(2012F) to 1200C(2192F). The capacity of the road roller used should not be less than 8-tons.

## Advantages

- 1) This process can be utilized for recycling of any type, size, shape of waste material.

## Disadvantages

- 1) This a time taking process, it requires more energy of blending.
- 2) Due to lack of proper cooling there will be chances of formation of air pockets in roads.
- 3) Not more than 8% of plastic cannot be used. [3]

## 5. Comparison of Plastic Roads then and Now

In Chennai a street named Jambulingam, the asphalt pavement was subjected to wear and tear due to severe monsoon, floods and heavy traffic flow. In this street in the year 2002 plastic roads replaced the normal roads. Till now the road has not developed any mosaic of cracks, potholes or crackers or craters that commonly make their display after it rains. A polymer glue from the shredded plastic will hold the road together in a unremarkable manner.

This environmentally conscious approach of road construction was started 15 years ago, in India in response to the growth of plastic junk. As the time goes on the polymer roads have proved to be surprisingly durable, winning support and been accepted in other countries. The Plastic roads have not developed any potholes, rutting, raveling, even after four years of laying the pavement which was mentioned in the report submitted by “Indian Central Pollution Control Board”. There are more than 21,000 miles of plastic roads in India out of which more than half of the roads are in Tamil Nadu state only. Large number of rural roads and small number of roads are built in cities like Chennai and Mumbai are plastic roads only. Addition of flexible polymers to asphalt had come into practice in 1970’s in Europe. Now North America is having 35% share of global market.[11]



Figure 9: The Plastic Road in Chennai [11]

## 5.1 Tests Conducted for Comparison

The following tests are conducted in order to show the difference between the plastic roads to that of normal convention roads. They are

- Specific Gravity test.
- Stripping Value test
- Water Absorption test.
- Los Angeles Abrasion test.

## 5.2 Specific Gravity Test

The specific gravity of an aggregate is the indirect measure of its strength. The higher the specific gravity value, the more is the strength. The value of specific gravity of plain aggregate is less than that of plastic coated aggregate. The range of the specific gravity should be within 2.5-3.0%.

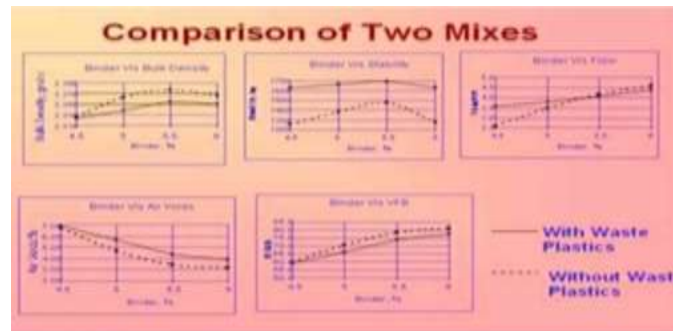


Figure 10: Comparison of specific gravity test results [8]

## 5.3 Stripping Value Test

The stripping value gives the effect of moisture upon the adhesion of asphalt film to the surface particles of the aggregate. The plastic coating on the aggregates gives zero value of stripping. This indicates that the aggregates are more suitable for asphalt pavement than plain aggregates. The range should be less than 25%.

## 5.4 Water Absorption Test

The aggregates are also chosen on the moisture absorption capacity. The aggregates when coated with plastic shows improved quality with respect to moisture absorption. The coating layer of the plastic decreases the moisture absorption and helps to improve the quality of the aggregate and its performance. The range should not be less than 10%.

## 5.5 Los Angeles Abrasion Test

The repeated movement of the vehicles on the pavement will produce some wear and tear over the surface of the pavement. This test will give us the wear and tear percentage. The percentage of wear and tear values of plastic coated aggregate is found to be less than that of normal aggregates. The plastic percentage also shows its effect on the wear and tear percentage. The high the percentage value of plastic the more will be the decreasing value of wear and tear percentage. [10]



## CONCLUSION

The usage of plastic will increase in the melting point of the asphalt. The plastic coating on aggregates will give better performance of the roads. This will help for a better binding strength of asphalt which will result in increase of bonding and area of contact between the polymers and asphalt. The plastic coating will reduce the formation of void spaces. This will prevent in the development of moisture penetration and oxidation of asphalt by seduced air. This will reduce the rutting, raveling and formation of pot holes to maximum extent. This will not only strengthen the road construction but also increases the life period of the roads.

The roads can withstand to heavy traffic with heavy loads and have good durability when compared to normal roads. It will reduce the consumption of asphalt by near to 10% and avoid use of anti-stripping agents. Decreases the pollution caused by plastic waste to a smaller extent. The maintenance cost will also be very less when compared to that of normal roads. The indirect tensile strength increases by 3 times to that of normal roads. The compressive strength will be very high. This process will cause less bleeding of road during the summer season. The use of this innovative technology not only increased the strength of the roads but also the life span of the roads. This helped us to use the waste plastic without burning them and releasing toxic gases into the atmosphere. It is an eco-friendly process and socially highly relevant.

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