Feasibility in Using Plastic Waste in Road Construction

Lakshya Singh Solanki, Aashish Kumar Jha

Abstract— **About 6 million tonnes of plastic waste is generated in India and the toxic truth about these wastes that they are non biodegradable. India is the second largest populated country so as the use of resources is par to maximum and so as the generation of waste respectively. To adapt the sustainability between the resources available and the reusable waste, consuming plastic waste for recycling and reusing is fruitful for future generation. The organic polymer, plastic with high mass of molecules includes the substances like polyethylene terephthalate (PET) and polyvinyl chloride (PVC) while polystyrene and polymethyl methacrylate is much used plastic compound. As per the studies, plastic is added to bitumin in two ways that is dry process and wet process, in both these processes dry process is preferred because it is less expensive compared to wet process and also wet process requires large areas which is not easily approachable. While approaching to plastic, waste of plastic is shredded first and heated up to melting point then mixed with bitumin to make the composite material which is known as plastic modified bitumin (PMB). Performing the laboratory experiments it is studied that 5-7.5% PET can be mixed with bitumin for road construction and adding plastic in bitumin helps in improving the rheological properties of bitumin and with this replacement it helps in less consumption of bitumin which in turn saves the resources and also best way of disposing the plastic waste. This review presents the plastic waste is used to adapt sustainability to maintain economic approach and to recycle and reuse the plastic waste as the best deed of disposal. It also seeks the attention of the environmentalist and the scientist to work upon the emission of toxic gases in the environment which endangers lives causing diseases to living beings after the plastic roads are laid.**

Index Terms— **Plastic waste generation, Waste recycling and reuse, Plastic modified bitumen**

I. INTRODUCTION

As per the information, India is the second most populated country in the world and due to rapid increase in the population of country, It is essential to limit the use of resources before it gets endangered and it is the duty of every individual to preserve the resources for our coming generations. Due to the high raised population, the use of resources is also high respectively. Due to this, the resource depletion is increasing day by day. Rapid consuming of resources before replenition is resource depletion. Renewable resources and non-renewable resources are the two forms of Natural resources and either of the resources used at the verge upto endanger is resource depletion[1]. So it is to be imposed to by every individual to their self to consume resources limitedly as the dependability of economic growth is somehow on the Natural resources also. In all these resources, plastic is one the major resource which is widely used. The reason behind the consumption of the material is due to its malleability that it can be moulded into many forms of usables. They are organic polymers with high mass of molecules which includes several substances. They usually obtained from petrochemicals. Many variables are made from renewable materials such as polylactic acid from corn, cellulosics from cotton linters[2]. As the use of plastic is increased while a time so as the increase in the plastic wastes. Varied about 6 to 9.4 million tonnes of plastic wastes generates in India yearly in which 42 to 43 percent is used for packaging and about 40 percent waste is not collected and in most of the cases plastic is used for one time[3]. For the circulatory economy and for the removal of plastic pollution in nature, this is initiated by the volunteer multi- stakeholder for which the study is conducted by UN-Platic Collective(UPC)[4]. Prime minister of India, Shree Narendra Modi also announced on Independence Day'2019 about "New Mass movement" that India has to eliminate the use of Single-use plastic by 2022. To adapt the sustainability between the resources available and the reusable waste, consuming plastic waste for recycling and reusing is fruitful for future generation. Hence the use of plastic wastes to construct the roadways is the best way of disposing plastic waste and utilising it into another helpful resource.The organic polymer plastic includes the substances like polyethylene terephthalate (PET) and polyvinyl chloride (PVC) while polystyrene and polymethyl methacrylate is much used plastic compound. As per the studies, plastic is added to bitumin in two ways that is dry process and wet process, in both these processes dry process is preferred because it is less expensive compared to wet process and also wet process requires large areas which is not easily approachable. While approaching to plastic, waste of plastic is shredded first and heated up to melting point then mixed with bitumin to make the composite material which is known as plastic modified bitumin (PMB). Performing the laboratory experiments it is studied that 5-7.5% PET can be mixed with bitumin for road construction and adding plastic in bitumin helps in improving the rheological properties of bitumin and with this replacement it helps in less consumption of bitumin which in turn saves the resources and also best way of disposing the plastic waste. While making use of plastic wastes, the topic also seeks the attention of the environmentalist and the scientist to work upon the emission of toxic gases in the environment which endangers lives causing diseases to living beings after the plastic roads are laid

II. PLASTIC

Plastics is a synthetic material made up of organic compounds, plastic is one the major resource which is widely used. The reason behind the consumption of the material is due to its malleability that it can be moulded into many forms of usables. They are organic polymers with high mass of molecules which includes several substances. They usually obtained from petrochemicals. Many variables are made from renewable materials such as polylactic acid from corn, cellulosics from cotton linters.

In many cases plastics contain organic polymers.[5] The majority of these polymers are formed from carbon atoms chains, with the addition of oxygen, nitrogen, sulfur or pure. chains includes many units repeated which are formed from monomers. The backbone is the part of the chain that is on the "main path", linking together a large number of repeat units.

For customization of plastic properties, different molecular groups "hang" from this backbone. These pendant units are usually "hung" on the monomers, before the monomers themselves are linked together to form the polymer chain. The structure of the side chains influence the properties of the polymer.

2.1 Composition of plastic

Plastics includes materials composed of elements like carbon, nitrogen, hydrogen oxygen, chlorine, and sulphur. Each molecule of plastic can have thousands of atoms bound together due to high molecular weight. Naturally occurring materials, such as wood, horn and rosin, are also composed of molecules of high molecular weight. The synthesized or manufactured plastics are designed to similarize the properties of natural materials. Plastics, also called polymers which are produced by the converting natural products and by the synthesis from primary chemicals obtained from oil, natural gas, or coal.

In many cases plastics are based on the carbon atom. Silicones are based on the silicon atom, are an exception. The carbon atom can link to other atoms with up to four chemical bonds. When all of the bonds are to other carbon atoms, diamonds or graphite or carbon black soot may result. For plastics the carbon atoms are also connected to the hydrogen, oxygen, nitrogen, chlorine, or sulphur. Connections of atoms when result in long chains, like pearls on a string of pearls, the polymer is called a thermoplastic. Thermoplastics are characterized by its melleability. The thermoplastics all have repeat units, the smallest section of the chain that is identical. We call these repeat units ‘unit cells’. The vast majority of plastics, about 92%, are thermoplastics.[6]

2.2 Properties of plastic

Properties of plastic are as follows:

1. Strength

The plastics are strong enough and can be used to bear the load structural members. The strength of plastics can be increased by reinforcing it with different fibrous materials.

- Cost of construction is high
- Temperature susceptibility is high
- Poor stiffness
- Being subjected to creep under constant load

2. Fire resistance

Plastics, being organic in nature, are combustible. Structure of plastic specifies its resistance to plastic.

- Cellulose acetale plastics burn slowly.
- Polyvinyl chloride (PVC) plastics are non-inflammable.
- Phenol formaldehyde and urea formaldehyde plastics are used as fire proofing materials.

3. Weather resistance

The plastics, prepared from phenolic resins, are good source for resisting weather effects. Ultraviolet rays affects some plastics.

4. Durability

Plastics generally possess sufficient durability, provided they offer sufficient surface hardness. Thermoplastic varieties are found to be attacked by termites and rodents.

5. Dimensional properties

Plastics easily maintain its shape and do not go under plastic deformations.

6. Thermal resistance

The plastics have low thermal conductivity and therefore foamed or expanded varieties of plastics are used as thermal insulators.

7. Chemical resistance

Plastics offer great resistance to moisture, chemicals and solvents. Many plastics are found to possess excellent corrosion resistance. Plastics are used to convey chemicals.

8. Working conditions

All operations like drilling, sawing, punching, clamping etc. are carried out easily on plastics, just like wood.

9. Moisture resistance

This property depends upon variety of plastics used, for example, cellulose plastics are considerably affected by the presence of moisture, whereas polyvinyl chloride plastics offer high resistance to moisture.

10. Ductility

Plastics, generally, have low ductility and hence plastic structural members may fail without prior warning.

11. Miscellaneous properties

In addition to above properties, plastics have following qualities. Plastics are available in variety of colors, both opaque and transparent.

Normally thermo-plastics have low melting point and cannot be used where temperature or heat condition persists. Plastics possess excellent insulating property, so used as electric insulators. They possess good optical and sound absorption qualities. Plastics are clean, light and shining, so they need not be given any finish such as painting, polishing etc.

2.3 Uses of plastic in India

An estimate by the Ministry of Petroleum and Natural gas suggests that the annual per capita consumption in India would be 20 kgs by 2022.

As per CPCB reports, plastic contributes to 8% of the total solid waste, with Delhi producing the maximum quantity followed by Kolkata and Ahmedabad.

Only 60% of the total plastic waste is being recycled. Households generate maximum plastic waste, of which water and soft drink bottles form a large number.

In India, around 43% of manufactured plastics are used for packaging purpose and most are of single use. Multi Layered Plastics are categorized under either recyclable, energy recoverable or with some other alternate use, but their recycling is an expensive process.

Average per capita consumption of plastic in India is about 11kgs.[8]

III. PLASTIC WASTE

Plastic waste describes plastic objects which have not been recycled properly. Between one and eight million tons of plastic waste enters the Earth's oceans every year,[9] and the World Economic Forum predicts this will double by 2030 if no action is taken.[10] Thin plastic objects such as plastic bags can be accidentally blown away by the wind.[11] This can cause drainage problems on land and pollution at sea.[11] Some countries banned plastic drinking straws in response to a video showing a turtle with a straw stuck up its nose.[12][13] Paper straws are a proposed alternative as they break down after a long time in seawater.[14]

3.1 Generation of plastic waste in India

Arroud 8.3 billion tonnes of plastic has been produced globally since 1950, That has ended up in landfills or in the natural environment about 60 per cent . India generates about 9.46 million tonnes of plastic waste yearly in which 40 per cent remains uncollected and 43 per cent is used for packaging, most of which is one timely used.[4] The toxic truth about these wastes that they are non biodegradable. India is the second largest populated country so as the use of resources is par to maximum and so as the generation of waste respectively. To adapt the sustainability between the resources available and the reusable waste, consuming plastic waste for recycling and reusing is fruitful for future generation. From 9.46 million tonnes of plastic waste per year approximately 5.6 Million tonnes per annum plastic waste is recycled and 3.8 Million tonnes per year plastic waste is littered or uncollected (9,400 tonnes of waste per day)

Out of the 60% of recycled plastic[16]:

- 70% is recycled at registered facilities
- 20% is recycled by Unorganized Sector
- 10% of the plastic is recycled at home.

IV. REDUCING, RECYCLING, REUSING AND RECOVERY

Figure 1: Management of plastic waste

4.1. Reduce

Plastic is a non-bio-degradable material and also last longs more compared to other forms of waste, therefore it is necessary to reduce the use of plastic. Some of steps helps to reduce the use of plastics are:

- Discourage the use of disposal plastics
- Minimize use of Plastics cutlery
- Purchase second hand products
- Support a bag Tax or Ban
- Minimum buying of water bottles

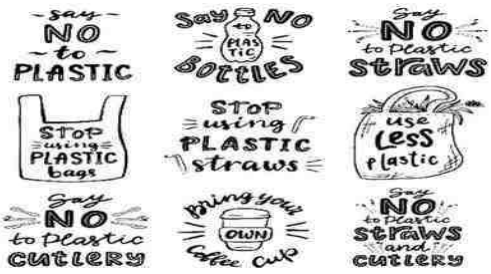

Figure 2: awareness about plastic waste

4.2. Recycle

Recycling and re-utilization of waste plastics have several advantages. It leads to a reduction of the use of virgin materials and of the use of energy, thus also a reduction of carbon dioxide emissions.

Benefits of Recycling:

- Reduces Environmental Pollution
- Energy savings : 40 - 100 MJ/kg (depends on the polymer)
- Economic Benefits • Reduces demand for virgin polymer
- Preferred to Land Filling
- Generates Employment
- Reduces depletion of Fossil fuel reserves

Difficulties in Recycling:

- Hard to separate from non-plastics (no 'magnet' equivalent)
- Differing composition of plastic resins means they are largely incompatible
- Degradation of polymer chains on recycling
- Recycled polymer is of lower quality than virgin polymer
- Most waste plastics films specially thin plastics films have limited market value, therefore effort is not spent in collecting them.

A number of recycling techniques of the plastics have been collected which can be adopted by the municipality in dealing the issue of plastic waste. It includes technology like:

1. Mechanical Recycling
2. Feedstock Recycling
3. Plastic to Road Construction
4. Plastic to Toilet / Pavement Blocks
5. Recycling of Multi-layered plastic

4.3. Reusing

Reuse is a step up from recycling. It diverts plastic and takes pressure off the recycling services. In fact, reuse is the middleman between reduce and recycle.

- Plastic waste incineration and moulding into different usables
- Using plastic waste in making plastic roads.

4.4. Recovery

Another alternative is recovering the energy stored in residual material. That means turning waste into fuel for manufacturing processes or equipment designed to produce energy. Various mechanical, biological and caloric systems and technologies can convert, reprocess or break up wastes into new materials or energy.

V. PLASTIC ROADS

The exchange of plastic waste and converting it into the construction of roads is the best way of disposing plastic waste. Plastic roads include the plastic along with the other composites of road constructing materials.

VI. MATERIALS AND METHODS

The types of plastic that can be used for construction of roads are Polystyrene (PS) (Hard packaging, cartons, plates, vending cups etc.); Polypropylene (PP) (ketchup bottles, yogurt cups etc.); Polyethylene (PE) (both high and low density) (plastic bags, water bottle, shampoo bottle etc.). Please note that Poly Vinyl Chloride (PVC) sheets or Flux sheets should not be used because it releases dioxins when burned; so it cannot be directly heated with aggregate at high temperature.

6.1. Methods

The plastic waste is collected , segregated , cleaned and then shredded , this whole process is used to utilize the waste for recyclation and convert it into the new usables. The shredded waste plastic shall pass through 4.75 mm sieve and be retained on 1 mm.This also indicates indirectly that the size of the shredded plastic should normally be 2-3 mm for better spread and coating the aggregate and mixed with bitumen Plastic modified bitumen(PMB) is obtained and plastic roads are laid as the mixture of both.

The steps evolved are shown in the figure below.

Figure 4: steps of plastic waste recyclation

6.2. Flowchart of plastic bitumen road process

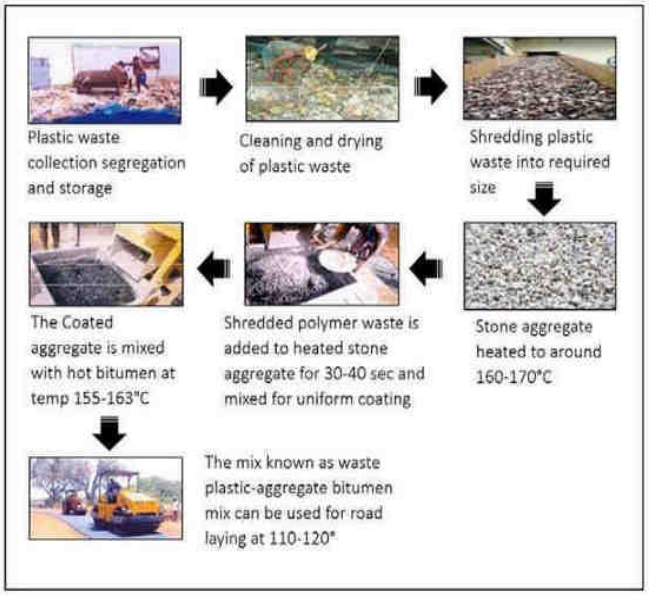

Figure 3: flowchart of plastic bitumen road process

6.3. Types of process:

For plastic bitumen road two processes are there:

1. Dry process
2. Wet Process

In dry process, the aggregate is heated up to 170°C in a mini hot mix plant and when the aggregate is heated, the plastic waste which is threaded is mixed in the equal proportion with the heated aggregate are mixed.

In wet process, waste plastic is directly mixed with hot bitumin at 160°C and the requirement for mixing this compound is mechanical steering by which the compound is mixed properly and then the stabilizers are added for proper mixing and stability of the compound and cooling is done.

Since the wet process requires a lot of investment, bigger plants, land areas so it is rarely used.

6.4. Types of plants used in plastic bitumen roads:

1. Mini hot mix plant

The stone aggregate mix (as per specification) is transferred to the mix cylinder where it is heated to 165 °C (as per the IRC specification) and then it is transferred to the mixing puddler. The temperature can be monitored using IR thermometer, while transferring the hot aggregate into the puddler, calculated quantity of shredded plastics is sprayed over the hot aggregate within 30 seconds. The sprayed plastic films melts and gets coated over the aggregate thus forming an oily coating . Similarly, the bitumen is to be heated to a maximum of 160 °C (HRS Specification) in a separate chamber and kept ready (The temperature should be monitored to have good binding and to prevent weak bonding). At the mixing paddler, the hot bitumen is added over the plastic coated aggregate and the resulted mix is used for road construction as shown in figure. The road laying temperature is between 110°C to 120°C. The roller used is a one with 8-ton capacity.

2. Central mixing plant (CMP):

The Central Mixing Plant technique includes three material types:

Materials I– The hoppers are filled with necessary aggregates as per the mix formula

Materials ii– Plastic films (thickness not more than 60microns) to be cut to a size less than 4 X 4 mm. It should not exceed this size.

Materials iii– Bitumen of type 60/70 or 80/100 to be used In Central Mixing, the stone is heated and at the same time the plastics films get melted over the heated stone and gets coated. Slowly the plastics coated aggregate moves forward where this polymer coated aggregate mix is mixed with bitumen. Overall the process consists the following steps:

1. The aggregate materials are transferred to the cylinder through the conveyer belt.
2. The shredded plastic is sprayed over the aggregate while it is moving in the conveyer belt.
   - The spraying is done by manual labors standing up on both side of the conveyer belt of the central mixing plant. While one person adds the shredded plastics on the conveyer belt, in the meantime another person keeps another bucket full of plastics ready so that the addition of plastics is continuous and done quantitatively.
   - The amount of plastic to be added is calculated as follows:
   - In the CMP, at the control room the addition of bitumen is monitored.
   - The amount of bitumen sprayed per minute inside the cylinder is to be checked. For example, If the bitumen quantity per minute is 10Kg, the plastic need to be added is 1Kg. (i.e. a bucket can be used which can hold 1 Kg at a time).
   - Hence, the shredded plastics taken in the bucket are sprayed with a speed of 1Kg/min.
   - As the plastic is added over the aggregate, the mix (aggregate and plastics) moves into the cylinder.
3. The polymer coated aggregate bitumen mix is then transferred to the dipper

6.5. Comparison between bituminous road and plastic bitumen road

COMPARISON BETWEEN ORDINARY BITUMINOUS ROADS AND WASTE PLASTIC BITUMINOUS ROADS:-

S.No.	Properties	Plastic Road	Ordinary Road
1.	MARSHALL STABILITY VALUE	MORE	LESS
2.	BINDING PROPERTY	BETTER	GOOD
3.	SOFTENING POINT	LESS	MORE
4.	PENETRATION VALUE	MORE	LESS
5.	TENSILE STRENGTH	HIGH	LESS
6.	RUTTING	LESS	MORE
7.	STRIPPING(POT HOLES)	NO	MORE
8.	SEEPAGE OF WATER	NO	YES
9	DURABILITY OF THE ROADS	BETTER	GOOD

Table 1: Comparison between ordinary road and plastic road

6.5.1. Performance evaluation of polymer coated bitumen road

The Central Pollution Control Board has prepared a performance evaluation report (Programme Objective Series: PROBES/122/2008-2009) titled Performance Evaluation of Polymer Coated Bitumen Built Roads to evaluate the performance of certain roads.

The results obtained for these roads mentioned in the table below helped to conclude that these roads are performing very well in spite of their age. Under the similar conditions most of the bitumen roads are not performing well at all. These roads have not developed even small cracking and a pothole. The roads were distributed over the different localities of Tamil Nadu exposed to various environmental conditions like temperature, rainfall, etc., yet roads are performing well.

Table: Consolidated Test Results

Road	Year laid	Unevenness (mm /km)/ roughness	Skid number / resistance	Sand Texture Depth(mm)	Field Density	rebound Deflection (mm)/ Benkelman Beam
Jambulingam Street	2002	2700	41	0.63	2.55	0.85
Veerabadhra Street	2003	3785	45	0.70	2.62	0.60
Vandiyur road,	2004	3005	41	0.66	2.75	0.84
Vilachery Road, MDU	2005	3891	45	0.50	2.89	0.86
Canteen Road, TCE	2006	3100	45	0.65	2.88	0.86
Plain Bitumen Road	2002	5200	76	0.63	2.33	1.55
Tolerance Value*	——	4000	<65	0.6	2.86	0.5-1

1. Unevenness / Roughness; Source IRC: SP: 16-2004
2. Skid Resistance/ Skid Number; Standardized in UK under BS:812-1967
3. Sand Texture Depth: BS 598 part 105(1990)
4. Rebound Deflection / Benkelman Beam; IRC:81-1997
5. Field Density; Highway Engineering by S. K. Khanna, C.E.G. Justo; New Chand & Bros, Roorkee (U.A); Eighth edition ;2001

Table 2: Consolidated Test Results

6.5.2. Advantages of Plastic Bitumen Road

- Presence of plastic increases the binding capacity better bonding of the mixture, making the roads more resistant to external conditions such as extreme heat (UV radiation), etc., and makes roads stronger with increased Marshall Stability Value
- Bitumen film is often stripped off the aggregates because of the penetration of water, which results in pothole formation. This is accelerated during the movement of vehicle.
- When polymer is coated over aggregate, the coating reduces its affinity for water due to non-wetting nature of the polymer and this resists the penetration of water, thereby reducing pothole formation during rains
- Making roads with plastic mixture reduces the cost and frequency of maintenance
- The cost incurred in construction of a Bitumen- plastic road is significantly lesser than that of an only Bitumen road
- Salt deposition on the pores of stone which results in road degradation, is also prevented
- Consumption of bitumen decreases by around 10%. For 1km x 3.75m road, 1 ton of plastic (10 lakh carry bags) is used and 1 ton of bitumen is saved.[18]

6.5.3. Cost comparison between respective roads

S No	Material Needed	Plain Bitumen Process	Plastic Bitumen road
1	Road Construction Cost	Rs. 21.00 lakhs	Rs. 18.90 lakhs
2	Maintenance Cost @ Rs. / km per year	Rs. 14,000 per km per year for rural roads. Thus for five years Rs. 70,000	No Maintenance cost for a min five years Maintenance not needed up to 10 years
3	Road Renewal Cost	Roads renewed after 5 years costing Rs. 3.5 lakhs	Nil
4	Total Cost for min. service of five years	Rs. 25.2 lakhs	Rs. 18.9 lakhs
5	Use of Waste Plastics	Nil	One Tonne per Km
6	Total Cost Saved	Nil	Rs. 6.3 lakhs

Cost Comparison implies Rs. 6.3 lakhs can be saved when constructing plastic bitumen road of 1 km length by 3.75 m width.

*The data has been compiled from Padma Shri. Dr. R Vasudevan who is also called as the 'Plastic Man of India'.

Table 3: Cost Comparison between Roads

VII. Role of Government in Construction of Plastic Roads

The Ministry of Road Transport & Highways, Government of India has made it mandatory for road developers to use waste plastic along with bituminous mixes for road construction to overcome the problem of disposal of plastic waste in India's urban centres.The road developers will now have to use waste plastic along with hot mixes for constructing bitumen roads within 50 km of periphery of any city that has a population of over 5 lakh. IN case of non-availability of waste plastic the developer has to seek ministry's approval for constructing bitumen only roads.

VIII. Environmental Problems

As like plastic waste creates problem in the environment such as polluting air, affecting water quality, threatens the life of living beings. Some of the similarities can also be seen while recycling plastic waste into other forms and in laying the plastic roads respectively.

8.1 Impact on environment by turning waste into good

Studies reveal that even heating plastics such as PP, PE and PS releases moderate to highly toxic emissions such as carbon monoxide, acrolein, formic acid, acetone, formaldehyde, acetaldehyde, toluene and ethylbenzene. These toxic gases pollutes the environment harming the purity air.

8.2 Problems faced by living beings

By the emission of gases mentioned above which creates the problem of air pollution so as the problem arises for the living beings. Workers working for recycling of the waste face harmful toxic gases, every human being faces the problem of asthma, lung cancer, ventricular hypertrophy, etc. due to the air pollution. While these gases pollute seas, lakes, and water sources in which water prone animals get affected and lose their lives.

IX. Control over Problem

As the problem of emission of toxic and harmful gases post laying of plastic roads seeks the attention of Environmentalist and scientists to work upon. Still there are some common measures can be taken for slight reduction of the effect of these gases. The soil used before laying the roads can be mixed with chemical fertilizers, pesticides and manure must be used conscientiously. Additionally, low-cost inhibitors that regulate nitrogen processes in soils should be implemented. Minimize the use of resources which causes air pollution such as motor vehicles, etc. And lastly plantation of trees is beneficial for the control.

X. Future Perspective

- Due to 4r's of plastic waste, it will going to manage the balance in use plastic and the resources will be saved.
- It will going to lift up the economic growth of the country as it has some dependability on the resources available.
- By constructing plastic roads, the source of bitumen will be saved as plastic waste will become its alternative.
- Resources will be saved for future generations.
- Prime minister of India, Shree Narendra Modi also announced on Independence Day'2019 about "New Mass movement" that India has to eliminate the use of Single-use plastic by 2022. To adapt the sustainability between the resources available and the reusable waste, consuming plastic waste for recycling and reusing is fruitful for future generation.

Conclusion

This paper concludes:

- By the research over plastic roads, it can be concluded that plastic is the material which empowers the rheological properties more than plain bitumen roads.
- By constructing plastic roads, the best way of disposing the plastic waste is obtained
- By recycling and reusing plastic waste it not only saves resources but it also creates awareness to every

individual that it is our responsibility to preserve the resources for our coming generations.

- This research paper also seeks the attention of environmentalist and scientists to work upon the emission of toxic gases by plastic waste.
- In addition, the growth in advancement of construction will increase, and simultaneously there will be rise in economic growth of the country as the resources will be used in the refined form.

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