International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-05, Issue-01, April 2019

Highway Construction Using Plastic Waste

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Abstract:-**This work is a comparative study of normal bitumen and waste plastic added bitumen.The study helps in increasing the strength of bitumen by addition of non- degradable plastic waste which provides reduction in the percentage of bitumen. The waste plastics like polythene bags, milk covers from various sources are collected, cleaned and dried for further processing. The shredded plastic waste is then added to the aggregate. The plastic waste coated aggregate is mixed with hot bitumen and the resulting mix is used for road construction. The road laying temperature is between 110°c to 120 The waste plastic is then processed in shredding machine and the shredded plastic is then mixed with the hot bitumen. The normal bitumen and waste plastic added bitumen is tested as per specifications in IRC: SP: 53: 2010, IS 3370.Bitumen can be modified with waste plastic pieces and which can be used as a top layer coat of flexible pavement. This waste plastic modified bitumen show 20% better in stability, density and more resistant to water. Plastic will increase the melting point of the bitumen. Innovative technology not only strengthened the road construction but also increased the road. Plastic boon for india hot climate which will relieve the earth from all type of plastic waste.**

Keywords – Construction, plastic waste

I. INTRODUCTION

A material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is called as 'Plastic'. Plastics are durable and degrade very slowly; the chemical bonds that make plastic so durable make it equally resistant to natural processes of degradation. Plastics can be divided in to two major categories: thermoses and thermoplastics. A thermoset solidifies or "sets" irreversibly when heated. They are useful for their durability and strength, and are therefore used primarily in automobiles and construction applications. These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene, polytetrafluorethylene, and polyethyleneterephthalate. A thermoplastic softens when exposed to heat and returns to original condition at room temperature. Thermoplastics can easily be shaped and moulded into products such as milk jugs, floor coverings, credit cards, and carpet fibres. These plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin, silicone, and polyurethane. According to recent studies, plastics can stay unchanged for as long as 4500 years on earth with increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. Plastic in different forms is found to be almost 5% in municipal solid waste, which is toxic in nature. It is a common sight in both urban and rural areas to find empty plastic bags and other type of plastic packing material littering the roads as well as drains. Due to its biodegradability it creates stagnation of water and associated hygiene problems. In order to contain this problem experiments have been carried out whether this waste plastic can be reused productively. The experimentation at several institutes indicated that the waste plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregate, when mixed with the binder is found to give higher strength, higher resistance to water and better performance over a period of time. Waste plastic such as carry bags, disposable cups and laminated pouches like chips, pan masala, aluminium foil and packaging material used for biscuits, chocolates, milk and grocery items can be used for surfacing roads. Use of plastic along with the bitumen in construction of roads not only increases its life and smoothness but also makes it economically sound and environment friendly. Plastic waste is used as modifier of bitumen to improve some of bitumen properties Roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with conventional bitumen.

1.1 Basic process

Waste plastic is ground and made into powder; 3 to 4 % plastic is mixed with the bitumen. Plastic increases the melting point of the bitumen and makes the road retain its flexibility during winters resulting in its long life. Use of shredded plastic waste acts as a strong "binding agent" for

 DOI : 10.18231/2454-9150.2019.0252

tar making the asphalt last long. By mixing plastic with bitumen the ability of the bitumen to withstand high temperature increases. The plastic waste is melted and mixed with bitumen in a particular ratio. Normally, blending takes place when temperature reaches 45.5°C but when plastic is mixed, it remains stable even at 55°C. The vigorous tests at the laboratory level proved that the bituminous concrete mixes prepared using the treated bitumen binder fulfilled all the specified Marshall mix design criteria for surface course of road pavement. There was a substantial increase in Marshall Stability value of the BC mix, of the order of two to three times higher value in comparison with the untreated or ordinary bitumen. Another important observation was that the bituminous mixes prepared using the treated binder could withstand adverse soaking conditions under water for longer duration.

1.2 Plastic roads

Plastic use in road construction is not new. It is already in use as PVC or HDPE pipe mat crossings built by cabling together PVC (polyvinyl chloride) or HDPE (high-density polyethylene) pipes to form plastic mats. The plastic roads include transition mats to ease the passage of tyres up to and down from the crossing. Both options help protect wetland haul roads from rutting by distributing the load across the surface. But the use of plastic-waste has been a concern for scientists and engineers for a quite long time. Recent studies in this direction have shown some hope in terms of using plastic-waste in road construction i.e., Plastic roads. A Bangalore-based firm and a team of engineers from R. V. College of Engineering, Bangalore, have developed a way of using plastic waste for road construction. An initial study was conducted in 1997 by the team to test for strength and durability. Plastic roads mainly use plastic carry-bags, disposable cups and PET bottles that are collected from garbage dumps as an important ingredient of the construction material. When mixed with hot bitumen, plastics melt to form an oily coat over the aggregate and the mixture is laid on the road surface like a normal tar road.

1.3 Problem statement

The debate on the use and abuse of plastics vis-à-vis environmental protection can go on, without yielding results until practical steps are initiated at the grassroots level by everyone who is in a position to do something about it. The plastic wastes could be used in road construction and the field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the roads and also solve environmental problems. The present write-up highlights the developments in using plastics waste to make plastic roads. The rapid rate of urbanization and development has led to increasing plastic waste generation. As plastic is non biodegradable in nature, it remains in environment for several years and disposing plastic wastes at landfill are unsafe since toxic chemicals leach out into the soil, and under-ground water and pollute the water bodies. Due to littering habits, inadequate waste management system / infrastructure, plastic waste disposal continue to be a major problem for the civic authorities, especially in the urban areas. As stated above, plastic disposal is one of the major problems for developing countries like India, at a same time India needs a large network of roads for its smooth economic and social development. Scarcity of bitumen needs a deep thinking to ensure fast road construction.

II. PROCESSING OF PLASTIC

2.1 Plastics recycling

In recent years, there has been a dramatic increase in investigating ways in which mixed plastics can be recycled or reclaimed for reprocessing. There are usually two methodologies when dealing with recycling mixed plastics that consist of different polymers. One method is to grind up the mixed material and then to add in a small amount of this regrind back into the process of making new parts or products. The other method is to separate the mixed polymers, in order to re-obtain the pure components. The area of separation is investigated to determine its technological potential to be used to separate thermotropic liquid crystalline polymer from composites generated from polypropylene and these liquid crystalline polymers. The area of recycling thermotropic liquid crystalline polymer / thermoplastic composites is explored to demonstrate how this technique not only leads to losses in properties, but can not be used to process new composites that have the highest properties possible.

2.1.2 Reclamation via shredding and density separation

A common form of mixed plastics recycling is shredding the mixture and then using differences in density to bring about a flotation separation. This type of process works on the assumption, that the blended system can be shredded into small enough pieces, that the resulting mixture contains a distribution of pure component pieces. These pieces are then separated by using some type of device that utilizes the difference in densities to bring about a bulk separation of the various materials. This particular device works by first shredding the material, then washing the material to remove contaminants, then blowing the material into a tower for density classification, then grinding the material down into smaller pieces, then passing the pieces through an air classifier system, then washing and drying the pieces, and then passing the pieces through an extruder for compounding purposes. However, even after two density-type separations, the material is still very impure and the mechanical properties are lower than the virgin material. Another device or system that works along this same principle is a very new invention for the separation of

 DOI : 10.18231/2454-9150.2019.0252

ISSN : 2454-9150 Vol-05, Issue-01, April 2019

carpet materials. Dilly-Louis and coworkers, developed a process for separating carpet materials into three distinct components: nylon, polyester, and polypropylene. This system works on the same principle that if the compounded material can be shredded into small enough pieces, the resulting distribution will contain only pure components of all three plastics. And, because these materials have different densities, the particles can be separated by using a flotation type device. The uniqueness to this particular invention is that the process for density separation utilizes liquids, instead of air, as the separation media. This type of difficult separation, using liquids, is only possible by controlling the density of the separating solution. . The density of the aqueous solution is manipulated by adding in various amounts of an aqueous salt, such as CaCl·2H2O. The pre-shredded pieces are dumped into a double-cone full-jacketed screw centrifuge that contains this liquid, whose density has been selectively adjusted to be higher than one of the pure materials and lower than the other materials. Therefore, only the pure component of one of the materials will float to the top to be screened off after centrifugation.

2.1.3 Developments

The office of the chief minister, New Delhi has a given a green signal to a private company for supply of bitumen mixed with plastic which is used for construction of roads. The company has already constructed a two-km road in Bangalore with bitumen mixed with plastic. The government of Karnataka was pleased by the success of the experiment and the state chief minister himself inaugurated the field test of construction 500 m of road in three places in and around Bangalore with the help of PWD using the innovative technology.

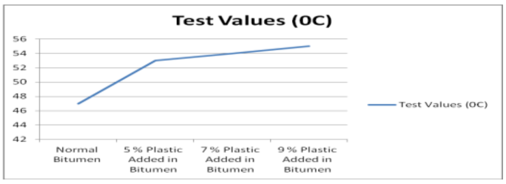
III. EXPERIMENTATION

3.1Softening point

3.1.1Observation and calculations:

Softening point	Test result (degree C)
Normal bitumen	42.5
5% lastic added in bitumen	53
7% plastic added in bitumen	54
9% plastic added in bitumen	55

Table 1: Test results for Softening Point



3.1.2Penetration test

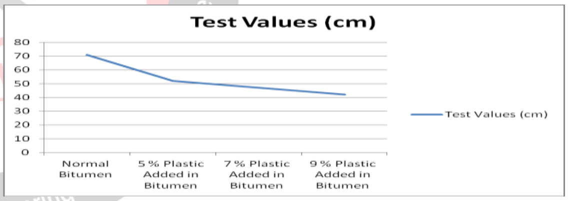
Table 2: Test results for penetration test

Penetration test	Test result (mm)
Normal bitumen	64
5% plastic added added	60.5
7% plastic added	58.6
9% plastic added	56.3

3.1.3 DUCTILITY TEST

Table 3: Test results for Ductility test

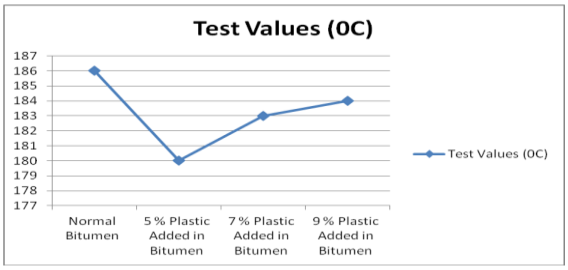
Ductility test	Test result (cm)
normal bitumen	79
5% plastic added	52
7% plastic added	47
9% plastic added	42



3.1.4 FIRE POINT TEST

Table 4: test result for fire point test

Fire point test	Test result
Normal bitumen	186
5% plastic added	180
7% plastic added	183
9% plastic added	184



DOI : 10.18231/2454-9150.2019.0252

3.1.5 FLASH POINT TESTTABLE 5: TEST RESULTS FOR FLASH POINT TEST

Flash point	Test result
Normal bitumen	180
5% plastic added	173
7% plastic added	175
9% plastic added	177

3.1.6 MARSHALL STABILITY TEST

MARSHALL STABILITY TEST	TEST RESULT (KN)	FLOW (%)
NORMAL BITUMEN	17.77	4.16
5% PLASTIC ADDED	15.20	3.72
7% PLASTIC ADDED	18.58	3.71
9% PLASTIC ADDED	18.70	4.26

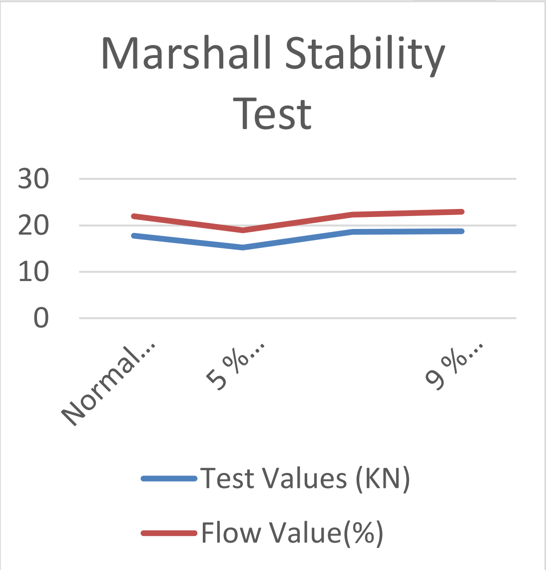
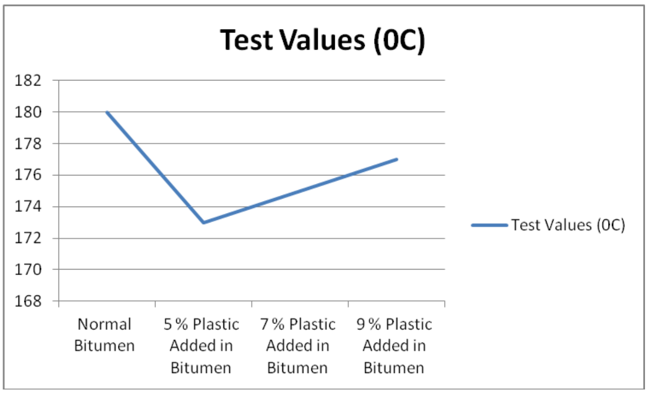


Table 6: Test results for Marshall Stability test



IV. MATERIAL USED

4.1 Plain bituminous mix

Bitumen is a black, oily, viscous material that is a naturally-occurring organic by product of decomposed organic materials. Also known as asphalt or tar, bitumen was mixed with other materials throughout prehistory and throughout the world for use as a sealant, adhesive, building mortar, incense, and decorative application on pots, buildings, or human skin. The material was also useful in waterproofing canoes and other water transport. A good design of bituminous mix is expected to result in a mix which is adequately (i) strong (ii) durable (iii) resistive to fatigue and permanent deformation (iv) Environment friendly (v) economical and so on.

4.2 Selection of mix constituents

Binder and aggregates are the two main constituents of bituminous mix:

4.2.1 Binder

Generally binders are selected based on some simple tests and other site-specific requirements. These tests could be different depending of the type of binder viz. penetration grade, cutback, emulsion, modified binder etc. For most of these tests, the test conditions are pre-fixed in the specifications. Temperature is an important parameter which affects the modulus as well as the aging of binder. Superpave specifications [Superpave 1997, 2001] suggest that these acceptability tests are to be carried out at the prevalent field temperatures, not in a laboratory specified temperature. This is an important consideration because, binder from two different sources may show same physical properties at a particular temperature, but their performances may vary drastically at other temperatures. In Superpave specifications, therefore, only the acceptable test values are recommended, and not the test temperatures. The temperature values are found out from the most prevalent maximum and minimum temperatures at the field at a given probability level.

4.2.2 Aggregate

Number of tests is recommended in the specifications to judge the properties of the aggregates, e.g. strength, hardness, toughness, durability, angularity, shape factors, clay content, adhesion to binder etc. Angularity ensures

 DOI : 10.18231/2454-9150.2019.0252

adequate shear strength due to aggregate interlocking, and limiting flakiness ensures that aggregates will not break during compaction and handling. Theoretically, it is difficult [Senov 1987, Aberg 1996] to predict the aggregate volumetric parameters, even the resultant void ratio, when the gradation curve is known. The Fuller's experimental study for minimum void distribution [Fuller and Thompson 1907] still forms the basis of these exercises. Strategic Highway Research Program (SHRP), USA formed a 14 member expert task group for evolution of appropriate aggregate gradation to be used for superpave. The group, after several rounds of discussions decided to use 0.45 power Fuller's gradation as the reference gradation, with certain restricted zones and control points.

4.2.3 Bitumen

Bitumen is used as binders in pavements constructions. Bitumen may be derived from the residue left by the refinery from naturally occurring asphalt. As per definition given by the American Society of Testing Materials bitumen has been defined as "Mixtures of hydrocarbons of natural or pyrogenous origin, or combination of both, frequently accompanied by their non-metallic derivatives, which may be gaseous, liquid, semi-solid or solid, and which are completely soluble in carbon disulphide." Bitumen found in natural state known as asphalt contains large quantities of solid mineral matter. When petroleum crude is refined in a refinery, they are separated by fractional distillation in the order of decreasing volatility. On distillation of the residual bituminous residue, straight-run bitumen is obtained. This bitumen is known as penetration grade bitumen or steam refined petroleum bitumen. The grades of bitumen used for pavement construction is known as paving grades and that used for water proofing of structures is known as industrial grades. The grade of straight run bitumen is chosen depending upon the climatic conditions of the region in which surface dressing is to be constructed. In most parts of India 80/100 and 180/200 grade bitumen is used. Heavier grade cut backs, rapid setting emulsions or heavier grade tars may also be used. The grade of basic bitumen is altered either by controlled refining or by mixing with diesel oil or other oils. For single dressings on WBM base course, quantity of bitumen needed ranges from 17 to 195 kg per 10 m2 areas and 10 to 12 kg per 10 m2 area in case of renewal of black top surfacing.

For second coat of surface dressing, the quantity of bitumen needed ranges from 10 to 12 kg per 10 m2 area. Bulk bitumen Lorries with tanks of capacity ranging from 5000 to 15000 litres are used to transport bulk bitumen. As per PMC, the bitumen content in a mix should be 4% of weight by total mix for B.M. The paving bitumen available in India is classified into two categories: Paving bitumen from Assam petroleum denoted as A-type and designated as grades A35, A90, etc. Paving bitumen from other sources denoted as S-type and designated as grades S35, S90, etc. Important properties of bitumen are: Viscosity of bitumen should be adequate at the time of mixing and compaction. It is achieved by heating prior to mixing and by use of cutbacks and emulsion. In presence of water bitumen should not strip off from aggregate. Bitumen should be durable in all seasons. It should not become too soft during summers and develop cracks during winters.

Bitumen: 60/70, 80/100 grade bitumen

4.2.5 Plastic material

Plastics are usually classified by their chemical structure of the polymer's backbone and side chains. Some important groups in these classifications are the acrylics, polyesters, silicones, polyurethanes, and halogenated plastics. Plastics can also be classified by the chemical process used in their synthesis, such as condensation, polyaddition, and crosslinking. There are two types of plastics: thermoplastics and thermosetting polymers. Thermoplastics are the plastics that do not undergo chemical change in their composition when heated and can be moulded again and again. Examples include polyethylene, polypropylene, polystyrene, polyvinyl chloride, and polytetrafluoroethylene (PTFE In the thermosetting process, a chemical reaction occurs that is irreversible. The vulcanization of rubber is a thermosetting process. Before heating with sulfur, the polyisoprene is a tacky, slightly runny material, but after vulcanization the product is rigid and non-tacky. The properties of plastics are defined chiefly by the organic chemistry of the polymer. such as hardness, density, and resistance to heat, organic solvents, oxidation, and ionizing radiation.

4.2.4 Types of plastics

- PET, polyethylene terephthalate
- HDPE, high-density polyethylene
- PVC, polyvinyl chloride
- LDPE, low-density polyethylene
- PP, polypropylene
- PS, polystyrene

Plastics are durable and degrade very slowly; the chemical bonds that make plastic so durable make it equally resistant to natural processes of degradation. Since the 1950s, one billion tons of plastic have been discarded and may persist for hundreds or even thousands of years. Perhaps the biggest environmental threat from plastic comes from nurdles, which are the raw material from which all plastics are made. They are tiny pre-plastic pellets that kill large numbers of fish and birds that mistake them for food. Prior to the ban on the use of CFCs in extrusion of polystyrene (and general use, except in life-critical fire suppression systems; see Montreal Protocol), the production of polystyrene contributed to the depletion of the ozone layer; however, non-CFCs are currently used in the extrusion process. Thermoplastics can be remelted and reused, and

 DOI : 10.18231/2454-9150.2019.0252

thermoset plastics can be ground up and used as filler, although the purity of the material tends to degrade with each reuse cycle. There are methods by which plastics can be broken back down to a feedstock state.

4.2.6 Classification of plastic waste

a) Polyethylene

LDPE (Low Density Poly-Ethylene): Low density poly-ethylene this plastic waste available in the form of carry bags generally in stores these plastic bags are very thin and also easily available. HDPE (High Density Poly-Ethylene): Generally High density poly-ethylene type of plastic waste is available in the form of carry bags and easily available in the market.

b) Polypropylene

This plastic may be available in the form of carry bags or solid plastic it's depend upon the use and need of the industries. It is available in the form of plastic bottles and mat sheets etc.

V. NEED OF STUDY

- According to the World watch Institute, "From 1950 to 2012, plastics growth averaged 8.7 percent per year, booming from 1.7 million tons to the nearly 300 million tons of today."
- Every year, about 8 million tons of plastic waste is dumped into our oceans. Floating bags of plastic are mistaken for jelly fish and consumed by whales and turtles. Brightly coloured plastic items attract sea birds and mammals that ingest them and die. Midway Atoll is 2000 miles from the nearest human settlement in the Pacific. But its beaches are littered with plastic trash.
- Plastics dumped on land too break down into tiny pieces and are washed down water courses into rivers, lakes and seas. These micro plastics are hugely problematic. They absorb other pollutants like legacy pesticides and carcinogenic hydrocarbons from the ocean or aquatic environment. These microscopic toxic bombs tend to be mistaken for food and ingested by zooplankton. Planktons are the foundations of any aquatic food chain, and plastics has found a way to contaminate that.
- Plastics themselves contribute to approximately 10% of discarded waste. Many kinds of plastics exist depending on their precursors and the method for their polymerization. Depending on their chemical composition, plastics and resins have varying properties related to contaminant absorption and adsorption. Polymer degradation takes much longer as a result of haline environments and the cooling effect of the sea.
- It is estimated that a foam plastic cup will take 50 years, a plastic beverage holder will take 400 years, disposable diaper will take 450 years, and fishing line will take 600 years to degrade.
- Despite all the talk about "Reduce, Reuse and Recycle" — a mantra that ironically was promoted by the plastics manufacturers themselves – plastics production continues to grow at a steady rate of 9 percent.

By this we can understand that:

- Disposal of waste plastic is a major problem.
- It is non-biodegradable
- Burning of these waste plastic bags causes environmental pollution.
- It mainly consists of low-density polyethylene
- With the help of this, we can find its utility in bituminous mixes for road construction.
- Laboratory performance studies were conducted on bituminous mixes. These studies proved that waste plastic enhances the property of the mix.
- Therefore, Improvement in properties of bituminous mix provides the solution for a useful disposal of plastic waste.

4.1 Advantages:

- Stronger road with increased Marshall Stability Value.
- Better resistance towards rainwater and water stagnation 18
- No stripping and no potholes.
- Increase binding and better bonding of the mix.
- Reduction in pores in aggregate and hence less rutting and raveling.
- No effect of radiation likes UV.
- The strength of the road is increased by 100%.
- The load is withstanding property increases. It helps to satisfy today's need for increased road transport.
- For 1km X 3.75m road, 1 ton of plastic (10 lakh carry bags) is used, and 1 ton of bitumen is saved.
- Value addition to the waste plastics (cost per kilogram increased from Rs 4 to Rs12).
- The cost of road construction is also decreased.
- The maintenance cost of the road is almost nil.
- Disposal of waste plastic will no longer be a problem.
- The use of waste plastics on the road has helped to provide the better place for burying the plastic waste without causing disposal problem.
- Employment for unskilled labourers will be generated.

 DOI : 10.18231/2454-9150.2019.0252

- Today, plastic waste treatment is largely hazardous to the environment as most of the plastic is burnt resulting in toxic gasses being released in the environment. By effectively managing the collection, separation and processing of plastic waste, the environmental damages can be limited by eliminating the waste from our streets. We can have international standard roads and pavements which are litter free. Here are economies and advantages which would accrue to various communities if the plastic road project is implemented on a wide scale.
- **MSWM (MUNICIPAL SOLID WASTE MANAGEMENT):**
  Households and other units wrap all garbage in plastic bags and dispose of them. The non-biodegradable plastic bags acts as a covering on the trash preventing it from being converted into compost. At present, only 20% of the MSW is converted into compost. This can be considerably increased by 80-85% and more by systematically managing the plastic waste.
- **FARMING COMMUNITY:**
  One of the foremost areas that would directly benefit is agriculture. At present, only 20% of MSW is converted into compost. This can be converted to 80-85% once the plastic from the MSW is segregated. Farmers can directly purchase from MSWM if plastic separated.
- **NATIONAL ECONOMY:**
  Cumulative benefits to the National Economy
  –Environmental
  –Employment generation
  –Agricultural efficiency
- When the life of a road is doubled, then the savings that accrue to the national exchequer are in thousands of crores. Segregating the plastic from the MSW at the municipal yard involves the application of resources, the cost of which runs into crores of rupees. A substantial amount of this can be saved.
- The Central Government's annual allocation of funds towards roads and highways is approx. 35 thousand crores. Lab tests and real-time tests have revealed that the life expectancy of a plastic polymer road as compared to a normal road is at least 100% more In addition to the savings accrued at the central level, every state Municipal Solid Waste Management would save crores of rupees by eliminating the plastic segregation process at its yards.

4.2 Dis-advantages:

- **Cleaning process:**
  Toxics present in the co-mingled plastic waste would start leaching.
- **During the road laying process:**

In the presence of chlorine will definitely release noxious HCL gas.

- **After the road laying:**

It is opined that the first rain will trigger leaching.
As the plastic will merely form a sticky layer, (mechanical abrasion).
The components of the road, once it has been laid, are not inert.

VI. CONCLUSION

The generation of waste plastics is increasing day by day. The major polymers, namely polyethylene, polypropylene, and polystyrene show adhesion property in their molten state. Plastics will increase the melting point of the bitumen. Hence, the use of waste plastics for pavement is one of the best methods for easy disposal of waste plastics.

The use of the innovative technology not only strengthened the road construction but also increased the road life as well as creating a source of income. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C, and torrential rains create havoc, leaving most of the roads with big potholes. It is hoped that in near future we will have strong, durable and eco-friendly roads that will relieve the earth from all type of plastic waste.

Polymer Modified Bitumen is used due to its better performance. But in the case of higher percentage of polymer bitumen blend, the blend is a more polymer dispersion in bitumen, which get separated on cooling. This may affect the properties and quality of the blend and also the road laid using such blend.

In the modified process (dry process) plastics-waste is coated over aggregate. This helps to have better binding of bitumen with the plastic-waste coated aggregate due to increased bonding and increased area of contact between polymer and bitumen. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air.

Therefore it has resulted in reduced rutting, raveling, and there is not pothole formation. The road can withstand heavy traffic and show better durability.

The dry process thus helps to:

- Use higher percentage of plastic waste.
- Reduce the need of bitumen by around 10%.
- Increase the strength and performance of the road.
- Avoid the use of anti-stripping agents.

 DOI : 10.18231/2454-9150.2019.0252

ISSN : 2454-9150 Vol-05, Issue-01, April 2019

- Reduce the cost to around Rs. 5000/Km. of single lane road.
- Carry the process in situ.
- Avoid disposal of plastic waste by incineration and land filling.
- Add value to plastic waste.
- Generate jobs for rag pickers.
- Develop a technology, which is eco-friendly.

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