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Waste Plastics Use for Road Development: A Review

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Abstract: *India, produces 9.46 million tonnes of waste plastic annually, of which 40% remains uncollected. The waste plastic materials have become an enormous environmental problem for the society. On the other hand, the reuse of waste plastic has great opportunities through certain processes. The waste plastics alongside bitumen are often utilized for the development of roads/pavements because the plastic provide high tensile strength. This is often one of among the characteristics necessary for the development of roads. These roads are stronger as compared to normal roads with an increased Marshall Stability value due to the use of waste plastics. Plastic material can increase strength by 100% and has no effect of radiation like ultraviolet rays. The studies have revealed that the superior road performance towards rainwater, water stagnation, load withstanding, durability, maintenance cost, binding property, etc. could be achieved.*

The waste plastic utilization becomes important in terms of cost reduction, increase in strength, sturdiness and air voids compensate when the plastics are heated and coated upon the mineral aggregates (160˚C). It also binds with aggregate to strengthen stability.

In this paper, an effort has been made to review the outcomes of the varied studies conducted so far to utilize post-consumer plastic packaging waste for the roads development and explore other similar use of waste plastic and to save the environment as well.

Key Words: *Bitumen, Aggregate, Plastic Road, Marshall Stability, Polyethylene, Single-Use Plastic, Asphalt.*

1. INTRODUCTION:

In India, the waste plastics are mainly generated from all residential, commercial, industrial, institutional areas etc. and picked up and transported by the municipal bodies to the dump yards or is shipped for landfill or incineration. These disposal methods don't come without environmental problems. In one hand, incineration emits a high amounts of air pollutants which harms mankind and animals as well. On the other hand, landfills with plastic waste deteriorate the soil properties and dump yards acquire an outsized amount of area which may make the area unfit for future use. It can also cause problems in construction buildings or other structures over there at later stage. Moreover, waste plastics are being generated in huge amounts and improperly disposed off at public places, beaches, historic places, rivers, sea/ coastal areas, vacant lands etc.

Generally, the waste created by man contains plastic materials which ultimately chokes stray animals to death, obstructing flow in canals, drains, sever system and leads to a multitude like clogged drains etc. resulting in city floods particularly in rainy season. While waste plastics within the fields block germination, prevent groundwater recharge by rainwater, adversely impact aquatic life, human & animal health etc. apart from creating anaesthetic landscapes. Plastic is the main reason for the aforesaid problems associated with waste plastic disposal because it cannot be destroyed. Thus, it is to be solved by recycle or reuse. Using waste plastics/rejects for development of roads are a noble, economical, efficient & effective way to achieve the plastic-free environment.

UN estimate indicated that each year the world uses 500 billion plastic bags. Half of which is 'single-use' or 'disposable items' like food & grocery packaging/ wrappings, carry bags, bottles, cutlery and straws. A study conducted by Un-Plastic Collective (UPC) co-founded by the Confederation of Indian Industry (CII), United Nations Environment Programme (UNEP) and World Wide Fund-India (WWFI) to eliminate waste plastic menace and move towards a circular economy. A study report indicated that globally, over 8.3 billion metric tons of plastic are produced since 1950, and about 60 percent of that has ended up in landfills or within the natural environment. Further, it had been concluded that India generates 9.46 million tons of waste plastic annually. Out of which 40 percent, remains uncollected; 43 percent is employed for packaging, wrapping mostly 'single-use'. The Chairman, UPC said that he would get along businesses, government, NGOs and civil society to focus efforts on collaborative approaches and maximize synergies to un-plastic the country in a phased manner.

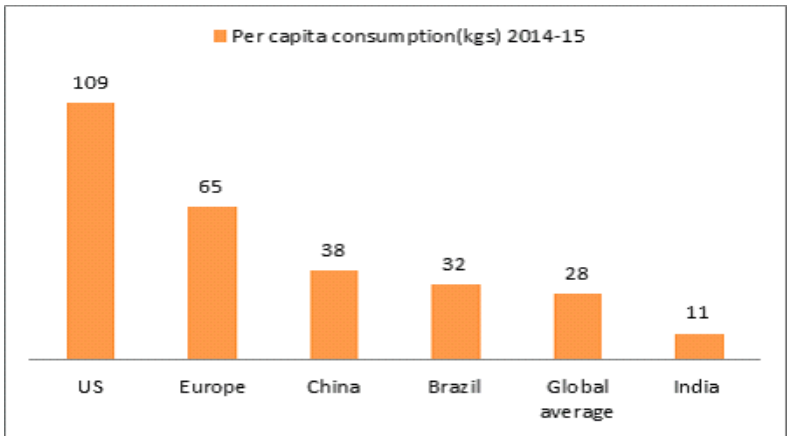

*Fig. 1-Average per capita consumption of plastic in India is about 11kgs (*Source: *FICCI).*

In 2010-12, India generated 25,940 tons of plastic per day totalling 9.5 million tons per annum according to the Central Pollution Control Board (CPCB) report, September 2017. It contributes eight percent of the entire solid wastes. The study also estimated that 60 major Indian cities generated 4,059 tonnes (about 405 truckloads) per day of plastic waste during 2010-12 with top five plastic producing cities being Delhi (689 tonnes), Chennai (429 tonnes), Kolkata (425 tonnes), Mumbai (408 tonnes) and Bengaluru (313 tonnes). It had estimated the efficiency of waste Plastic collection as 80.28% in 2014. Out of which only 28.4% was treated and remaining quantities were disposed off in landfills or open dumps (1). FICCI has estimated Indian plastic consumption at 11 Kg per capita during the year 2014-15 which remains far behind of developed countries (Fig-1).

Most of the plastic produced is used by the packaging industry and is estimated to grow to 22 million tonnes a year by 2020 from 13.4 million tonnes in 2015. Nearly half of this is often single-use plastic as per the study by the Federation of Indian Chambers of Commerce and Industry. Online retail and food-delivery apps have also contributed towards increase in the use of plastic, though the study is yet to be done. During a September 2018, Zomato Chief Deepinder Goyal said that orders through food-delivery aggregators were adding up to 22,000 tonnes of plastic waste each month in India.

The Ministry of Petroleum & Gas suggests the increase of plastic consumption in India and is estimated at 20 kgs per capita annually by 2022. A recent study reveals that 15000 tons of plastic waste is generated a day by 60 major cities alone in India. About 6000 tonnes remain uncollected which poses an enormous problem to the inhabitants in these cities. On "Independence Day" in 2019 Indian Prime Minister Shri Narendra Modi had echoed in his speech, about India's commitment and impressive plan to put a full stop to '*single-use plastic*' by 2022. As a gesture, Indian parliament secretariat has prohibited the use of non-recyclable plastic water bottles and other plastic items within the Parliament from Aug. 20, 2019 the government-run railways also intends to ban single-use plastic at least in its stations, on trains and each one vendors and staff are to be encouraged to use reusable bags(2).

2. PROBLEMS AND OPPORTUNITIES

The plastic and post-consumer plastic packaging waste like wrappers of betel nuts, chocolates, chips, confectionery wrappers, cutlery items, food bags, straws, carry bags, milk bags, bread bags, cups, cold drink & water bottles and other forms can create significant environmental problems if left unattended. In manufacturing firms, construction industries and merchandise delivery services, the use of plastic could even be a priority to handle and pack things comfortably due to its lightweight, cost-effectiveness and strength. It is made up of various chemical elements and is a highly pestilent and non-degradable material within the natural environment when disposed off after its usage. They also consume massive energy and other natural resources impacting the environment in various ways. Perhaps, banning plastics completely won't be feasible as it's being a substitute to natural resources like paper, wood, metals to a large extent (3).

It is comprehensively concluded that the plastic wastes are deadly non-environment friendly being non-decompose-able. If destroyed by the burning process, it causes pollution by releasing highly toxic gases like phosgene, carbon monoxide, chlorine, sulphur dioxide, nitrogen oxide etc. It also forms poisonous soluble metal oxides which must be controlled by recovery/detoxification / disposal (4). Certainly, the reuse of waste plastic in some processes could even be a good idea to unravel these problems and to derive benefits.

India is one among the few countries which have already tried to use recycled/waste plastics within the past few years. One among such major use is material for road development. In November 2015, a government order made

it mandatory for the road developers within the country to use waste plastics alongside bituminous mixes for road development. Similar projects were implemented in other countries too.

The post-consumer plastic packaging waste comprising polythene, polyethylene (PE), polypropylene (PP), polystyrene (PS) etc. up to 60µ thickness excluding PVC sheets and flux sheets are often utilized within the development of plastic roads. The waste plastic use is first of all introduced to the varied basic steps like collection, transportation & sorting, cleaning, shredding and storage for further processing for use.

Bituminous Concrete (BC) is a material mostly utilized in construction projects like road surfacing, airports, parking lots, walkways/flooring etc. It consists of bitumen (used as a binder) or asphalt and mineral aggregate which are mixed & laid down in layers then compacted. Nowadays, the steady increment in high traffic intensity in terms of commercial vehicles and therefore the many variation in daily and seasonal temperature forced us to explore some alternatives for the improvisation of the pavement characteristics and quality by applying some necessary modifications which shall satisfy both the strength also as economic aspects (5). During the studies of the behaviour of polythene modified BC mix, it had been found that an increase of Marshall stability value with polyethylene content up to 4% and then decreases, and thus Marshall flow value decreases upon addition of polythene i.e. the resistance to deformations under heavy wheel loads increases. Further, it had been observed that the values of the parameters like VMA, VA, VFB were also within the prescribed specifications. Thus, it has been concluded that a more durable and stable mix for the pavements/roads are often obtained by polymer modifications and also conserve considerable amount of energy during its construction and maintenance.

These studies opened new opportunities not only for utilizing the waste non-degradable plastics beneficially but also improving the pavements with superior strength and longer lifespan. Such pavements would be a boon for India's hot and really humid climate, where temperature touches 50°C and torrential rains create havoc, leaving most of the roads with heavy distress.

3. LITERATURE REVIEW:

Many cities in India have banned the usage of plastics but the disposal of an outsized quantity of non-biodegradable wastes being accumulated daily has posed a challenging task for the governments and a worrying factor for environmentalists. Though re-cycling of plastics has started addressing the problems to some extent but still a lot of actions needs to be taken. Using waste plastic materials to develop roads might be a recent concept, but is fast catching up here in India.

Plastic roads are made entirely of plastic or a mix of plastic with other road materials. Plastic roads are different as against conventional roads built from mineral aggregates and asphalt. So far, regular roads using pure plastic haven't been tried. However, the composite plastic road development has been demonstrated to possess superior characteristics over conventional asphalt concrete roads. Specifically, they show better wear and tear resistance. United States, UK, Australia, India, Indonesia, and a lot of other countries have incorporated plastic wastes into an asphalt mix road development project. Various studies cited herein revealed that the utilization of waste plastics/ post use consumer plastic has opened an enormous potential and great opportunity as a binder within the road development sector and to urge obviate environmental menace also.

Justo et al (2002) studied using processed plastic bags as an additive in asphalt concrete mixes and therefore, the properties of this modified bitumen were compared with ordinary bitumen. It had been noted that penetration and ductility values of modified bitumen had decreased with the increase of the plastic additive proportion (up to 12% by weight). About 25 km of plastic modified bituminous concrete road was laid in Bangalore. This plastic road showed improvement in smoothness, uniformity and lesser rutting as compared to a conventional BC road laid simultaneously, which began developing “crocodile cracks” very soon after. In 2003, the method has also been approved by the CRRI (Central Road Research Institute, Delhi). CRRI specified that the shredded plastic must undergo 3mm sieve and retain on 1mm sieve and the percentage of waste plastic should be kept 8% of bitumen by weight for dry process (6). However, Dr R. Vasudevan suggests that it should undergo 4.75mm sieve and retain on 1mm sieve and the percentage of shredded waste plastics might be kept 10% of bitumen for an equivalent. Also, the aggregates which passed through 12.5mm sieve and retained on 10mm sieve were selected for the plastic road development (7).

Gawande, A.P. et al (2012) evaluated flexural fatigue lifetime of asphalt concrete modified by 3% crumb rubber as part of aggregate and reported that fatigue life and creep properties of the polymer-modified mixes increased significantly as compared to normal asphalt mixes (8).

Shukla, R.S. et al (1984) in their study concluded that the effect of wax in bitumen are often reduced by adding 4% of EVA (Ethyl Vinyl Acetate) or 8% of aromatic resin or 6% SBS (Styrene Butadiene Styrene) in it. These additives effectively reduce the susceptibility to high temperatures, bleeding at high temperatures and brittleness at a low temperature of the mixes (9).

Anzar Hamid Mir (2015) studied the visco-elastic nature of binders for the waste plastic pavement development and found that the complex modulus & phase angles of the binders, got to be measured at temperatures and loading rates at different corresponding climatic and loading conditions (10).

Mohammad T. Awwad et al (2007) and Sasane Neha B. et al (2015) studied the use of waste plastic as an efficient construction material for flexible pavement. The polyethylene is used to study the potentiality for enhancing asphalt mixture properties. Further the study also aimed to identify and select the better type of polyethylene viz. HDPE (High-Density Polyethylene) and LDPE (Low-Density Polyethylene) to be used to coat the aggregate and its percentage in bitumen. This study concludes that the grinded HDPE polyethylene modifier provides better engineering properties at 12% by the weight of bitumen content as a modifier. They also observed that it reduced the density, increased the steadiness and the air voids increased slightly which increase the voids of mineral aggregate (11, 12). The addition of 10% LDPE to the binder gives an optimum value for rutting perimeter at varying temperatures and offers better resistance against rutting compared to HDPE and CR. Furthermore, the performance grade of bitumen at high temperatures increases from 64°C to 70°C with the addition of 10% LDPE.

The utmost rutting perimeter value has been observed at varying temperatures when 4% HDPE is added and thus, the performance grade increases from 64°C to 70°C when the bitumen binder is modified with 4%, 8% and 10% HDPE. The study shows the performance improved at high temperature of 70°C after adding Crumb Rubber. Imran M. Khan, et. al. (2016) also concluded that LDPE, HDPE and CR modified binder showed notable improvement in rheological properties of the binder. The analysis of results of this research, it had been concluded that by increasing percentages of LDPE, HDPE and CR generally, featured a substantial effect on the elastic behaviour of the modified binder and increased the lifespan of pavements by reducing susceptibility to rutting and cracking(13).The use waste plastics in asphalt concrete using polyethylene as modified binders in road construction was studied and it was found that road so built were more tolerant to permanent deformation at elevated temperatures and also observed improvement in stripping characteristics of the crumb rubber modified mix as compared to normal asphalt mix.

The effects of waste PET plastic bottle using with bituminous asphaltic concrete (BAC) in flexible pavement construction has been studied for the mix design consists of 60/70 penetration-grade asphaltic concrete (5%), 68% coarse aggregate, 6% fine aggregate, and 21% filler using the dry process at 170°C. The optimum bitumen content (OBC) for typical BAC was obtained as 4% by weight of total aggregates and filler.

The Polymer-coated aggregate (PCA)-modified BAC seems preferable because it has the potential to utilize more plastic wastes with a better optimum plastic content (OPC) of 16.7% by weight of total aggregates and filler compared to that of 9% by weight of OBC achieved by PMB-BAC. For both PMB- and PCA-modified BAC, a surge in air void, void in mineral aggregate, and Marshall stability were observed.

In another study, S. Rajasekaran et. al. (2009) was studied Marshall's mix design with changing the modified bitumen content at constant optimum rubber content (CRMB55) blended at specified temperatures and subsequent tests were performed to know the varied mix design characteristics for conventional bitumen (60/70). The researchers noticed many improved characteristics as compared to straight run bitumen and which also at reduced optimum modified binder content (5.67%) (14,15). Shaikh A. et. al. (2017) studied the behaviour of BC modified by waste plastic and concluded that the modified mix possesses improved Marshall Characteristics. They observed that Marshall Stability value increases with increase in plastic content and thus the Marshall Flow value decreases upon addition of polythene i.e. the resistance to deformations under heavy wheel loads increases and enhances the varied properties of the standard bituminous concrete roads. The pavements having polymer modifier are often more stable and long-lasting. Thus, on one hand, it improves pavement quality with better strength and lifespan while on the other hand non-degradable waste plastics are utilized beneficially and environment-friendly leading in reduction of its quantity which otherwise would be disposed off either by incineration or landfill (16).

At this stage, some may argue against the spreading of such proven environmentally harmful materials which can be more disastrous on the roads. But India's experience over the past few years indicates that a lot of roads built using waste plastics on the roads & lanes have existed with none issues being reported.

4. MATERIALS AND PROCESSES:

The waste plastic is separated from other solid wastes collected from houses, industries, roads, garbage trucks, dumpsites and waste-buyers at about Rs. 10 per kg and then cleaned with water & dried to be use in the plastic road development. The various types of post-consumer plastic packaging waste up to 60micron thick made from Polyethylene (PE), Polystyrene (PS) and Polypropylene (PP) etc. are often utilized for the development of roads. The utilization of Poly Vinyl Chloride (PVC) sheets or Flux sheets is prohibited and should not be used for road development. Plastic waste should be free from dust and be shredded properly. However, hard foams (PS) any thickness, soft foams (PE and PP) any thickness, laminated plastics (aluminium coated also) of desired thick waste plastics can also be used. These materials are softened at temperatures varying between 120˚C - 160˚C (3). They don't

emit any toxic gases during heating but it tends to form a coating over the heated aggregate (at 160˚C), when it is sprayed over it.

Generally, polyethylene of 60 microns or below could also be collected and used. The waste plastics collected, sorted and washed are shredded to fine pieces by mini plant, then sieved through 4.75mm sieve and retained on 1mm sieve are then gathered. Bitumen is heated at about 170°C (17) and sieved plastic pieces are added slowly up to 8-10% and stirred for half an hour. The prepared plastic-bitumen mixture is testified for quality before use through varied tests i.e. Penetration; Ductility; Flashpoint & Fire point, Stripping, Ring & ball test and Marshall Stability value. In this process, waste plastics are coated over heated aggregate which ensures better bonding between aggregate and bitumen because it increases the area of contact at the interface. The polymer coating also reduces the void spaces present within the mixture which prevents the moisture absorption and oxidation of bitumen by the entrapped air. Such roads can withstand heavy traffic showing longer service life. Some researchers feel that more research is required to gauge their performance on various parameters (5). In another study, plastic waste is cleansed and selected a size specified by passing it through 2-3mm sieve after shredding. The aggregate mix is heated and thus, the plastic is effectively coated over the mix. This plastic waste coated mixture is combined with hot hydrocarbon to be used for road development. The process strengthens road quality and increases its lifespan. Plastic roads would be a boon for India for places where temperature rises to 50°C and really wet climate during torrential rains which produce massive potholes also (14).

There are two methods of blending waste plastics to the road materials viz. (i) dry method(a specified quantity of spreading and mixing the dry shredded waste plastic over the hot aggregate at 170^0C to prepare bituminous concrete mixes at hot mix plant at 155-163^0C), (ii) wet method (blending of specified quantities of shredded waste plastic and bitumen together at 160^0C by powerful mechanical stirrer to prepare modified bituminous concrete mixes).

In India, the dry method is commonly used which may be performed mechanically for giant projects and manually for smaller projects. Varied plastics are mixed, processed and shredded into small pieces (1). Aggregates are heated to a temperature of 160° to 170°C in a chamber and then shredded plastic waste is spread over hot aggregate layers to reinforce aggregate impact value. Simultaneously, bitumen (grades 60/70 or 80/100) is heated at a temperature of 160°C in another chamber and mixed with hot plastic-coated aggregates. The Road laying is performed at 115±5°C with a roller of normal capacity (i.e. 8 to 9 tons). This process is more economical and efficient. The plastic roads pose better quality and properties as compared to plain bitumen/ Asphalt roads.

4.1 GOVERNMENT INITIATIVES

In India, the Ministry of Environment and Forests (MoEF) has been charged to deal with the problems related to solid waste management through the Centre and State Pollution Control Boards constituted under environmental laws & rules framed under Environment Protection Act-1986 for improving management of solid waste. SWM as matter of public health and sanitation is a State subject as per Indian Constitution. Due to its local nature, Urban Development Dept. and concern Urban Local Bodies (ULBs) are responsible to implement the provisions of Solid Waste Acts & Rules made thereunder. The legal provisions and framework may play a key role in collection of waste plastics and need to be understood within the right context. The Waste Collection and its Segregation are two major components of SWM and should open up marketplace for waste management sector including reuse and recycling (18,19).

Boξ 1: The Acts & Rules for improving management of Municipal Solid Waste

- Environment Protection Act–1986
- Hazardous Waste Management and Handling Rules–1989
- Manufacturing, Storage and Transportation of Hazardous Waste Rules–1989
- Bio-Medical Waste Management and Handling Rules–1998
- Municipal Solid Waste Management and Handling Rules–2000
- Plastic Waste (Management and Handling) Rules–2011
- E-Waste (Management and Handling) Rules–2011

Under Plastic Waste Management Rules 2016, each local body has been made accountable to established an infrastructure for disposal of plastic waste. A system mentioned because the *Extended Producers Responsibility (EPR)* has mandated the producers and brand owners to plan an idea in consultation with the local bodies to introduce a "*collect-back system*" after the introduction of Plastic Waste Management (Amendment) Rules 2018. Under this, the successive provisions were made:

•EPR might be a policy approach under which producers are given an entire financial and physical responsibility (concerning segregation and collection of waste at source) for treatment or disposal of post-consumer products.

- Assigning such responsibility could provide incentives to prevent wastage at source, promote product design for the environment and support the achievement of public recycling and materials management goals.
- A new national framework on plastic waste management introduced third-party audits as a part of the monitoring mechanism.

The Guidelines for the development of Plastic Roads in rural areas are issued by the Ministry of Rural Development. The Indian government has made it mandatory for road developers to use waste plastic alongside bituminous mixes for its construction to beat the growing problem of disposal of plastic waste in India's urban centres and use waste plastic and bitumen hot mixes for constructing roads within 50 km of a periphery of any city having a population of over five lakhs. Further, the government stated that just in case of non-availability of waste plastics, the developer has permission for constructing only bitumen roads. Urban local bodies (ULBs), which face a crunch for financial resources, can make money by selling the waste plastic collected by cities to road developers. ULBs could take a cue from some best practices followed in cities like Bangalore where Dry Waste Collection Centres have not only been established but have also been proved to be a self-sustainable business model. There is a requirement to determine a monetized collection model for waste plastic processing and disposal that has economic returns for all those involved. Virgin plastics (e.g. those utilized in dry & wet food, gift wrappers /clothing packets, etc.) should be collected separately due to the higher return values.

4.2 CORPORATE INITIATIVES

Amid growing concerns of waste plastic pollution, Reliance Industries (RIL)- India's largest petrochemicals player has launched a project to use plastics in road development and has constructed three roads, so far under "plastic-to-roads project" on a pilot basis. Further, RIL intends to sell the plastic waste mixture for laying roads. The company has started its own, also outsourced garbage collection and segregation which enables the gathering of sufficient plastic to be shredded to arrange a mixing at its sites. RIL has a plus for it to bring this project up to scale being it's pan India presence in every state and municipality. It intends to engage with the National Highway Authority of India (NHAI) and state governments as 'potential' supplier a plastics-infused mix to develop few thousands of kilometres of roads.

While recyclable plastics are often reused nearly eight times, it's the single-use plastic that is the immediate reason for plastic pollution. Further. KRS Narayan, Head-Business Development explained that Plastic, when heated at an optimal temperature, acts as a binding agent for traditional road laying materials like bitumen. This mixture doesn't let water penetrate the roads leading to more durable roads. RIL under its Corporate Social Responsibility (CSR) has utilized about 50 metric tonnes of waste plastics to develop about 40-km road resurfaced in its Nago thane, Manufacturing Division, Raigad which weathered the 250 cm rainfall in previous year's monsoon with not a single pothole. It has been concluded that waste plastic recycling and circular economy projects are financially viable and created an answer for the disposal of recyclable post-consumer waste plastics.

Box 2: Reliance's initiative to supply waste plastic mixture to strengthen Indian roads

- Using 8-10% of plastic waste mixture with traditional road laying materials can reduce the cost on road laying materials by about ₹1 lakh per km of road.
- Over 86,000 tonnes of plastic are often utilized in the development of roads countrywide. RIL's project phase-I was to find an end-to-end solution. It guarantees the quality of waste plastic utilized in order that road construction gets executed properly and also makes long-lasting roads. RIL felt a need to launch a brand which will be guaranteed by it for quality and this might be a game-changer for both-road development and environment.

In Jamshedpur (Jharkhand) a similar project was tried to develop the roads from a mix of recycled plastic and bitumen. The first step in constructing them is to collect and manage the waste plastics. The plastic materials involved to build these roads consist mainly of common post-consumer products like product packaging. Variety of the foremost common plastics utilized in packaging are polyethylene terephthalate (PET or PETE), PVC (PVC), polypropylene (PP) and high & low-density polyethylene (HDPE & LDPE). These materials are first sorted from waste followed by cleaning, drying and shredding. The shredded plastic so prepared is mixed and melted at around 170°C and mixed with hot bitumen. After mixing, the mixture is laid almost like regular asphalt concrete road.

A Dutch company, VolkerWessels developed an innovative concept for creating individual construction blocks aiming to build roads entirely of recycled plastic. This concept opens new possibilities in road development which is often significantly more efficient since roads are created as individual pieces, which can be shifted or replaced in the event of damages. This is often different from traditional ways of road repair, which needs an extended time spent on site shaping asphalt to the required shape. This model of road development has many advantages. Few important ones

are (a) Plastic roads are often made much faster and conveniently into interlocking pieces which can be assembled or disassembled automatically thereby lowering the overall cost. (b) This model of plastic road construction can have cavity built-in to allow easy wiring, connecting pipes, etc. hence making the laying wires and pipes across the road hassle-free and economical. (c) Heating and power generation are incorporated into plastic roads. Heating can prevent roads from freezing in cold regions and also help evaporate water from the surface in excess rainfall areas. (d) Road damage is avoided due to extremes of temperature, water-logging and reduction of seepage through the road material. (e) Plastics accompany various chemical and physical properties which can help in engineering to satisfy specific requirements (e.g. weather and wear resistance). (f) Superior roads are built from waste plastics as against its disposal into landfill, incineration which impact the environment.

Chandra Asri, a subsidiary of PT Barito Pacific TBK, is Indonesia's largest integrated petrochemical company with the support of the Ministry of Public Works and Public Housing (PUPR) has implemented plastic asphalt road located in Cilegon, Banten has worked as a part of the government's goal to reduce 70 percent of plastic waste by 2025. The plastic asphalt at the above location stretching 6.372 m2 area, is developed with asphalt mixed with 5-6 % plastic waste by weight (i.e. around 3 tons or 2 million plastic bags). Chandra Asri also developed 350 meters plastic asphalt road in its B1/MTBE project area in collaboration with Ikatan Pemulung Indonesia utilize 3.6 tons of waste plastic equivalent 480 thousand pieces of bags and at another project area, plastic asphalt road was developed to utilize 20.4 tons of waste plastic equivalent to 2.6 million pieces bag. Until now, Chandra Asri has implemented 22.6 km of plastic asphalt roads in various cities targeting to increase the added value of plastic waste and reduced plastic waste piles of garbage within the landfills. The company used plastic bag waste made up from High Density Poly-ethylene (HDPE) and collaborated with INAPLAS and Indonesian Plastic Recycle Association (ADUPI) for sourcing the scrap plastic for the asphalt mix. Similarly, the Ministry has implemented projects in other cities like Bekasi, Bali, Makassar, Solo, Surabaya, and Tangerang.

It was concluded that the plastic waste mixture can increase resistance against asphalt deformation. Further, adding maximum 4– 6 percent plastic waste to hot asphalt mix can increase asphalt mix stability up to 40 percent which ultimately increases its durability and make it less susceptible to cracking. In addition, this can be considered one of solution to the issue of plastic waste management. It has also been estimated that plastic waste about 536,000 tons or about 10 % of the national plastic consumption can be processed and utilized into asphalt mix materials to develop a national asphalt road of about 268,000 km.

5. ANALYSIS AND DISCUSSIONS

Generally, the quantity of fresh polymer needed to enhance pavement performance should be kept as small as possible because of the high cost of these polymers(fresh) as compared to plain bitumen. This major constrains could be a positive factor using waste plastics. Waste plastic has been used as a modifying agent with bitumen in construction for better road performance. From an environmental and economic standpoint, the utilization of waste plastic as a bitumen-modifying agent may contribute to solve the problem of waste plastic disposal and also upgrade the standard of road pavements.

The economic analysis of pavements and thereby the entire savings increased due to the use of plastic waste could be considered. As waste Plastic will add to the longevity of roads by making them water proof and also increasing the resistance of roads to the changes in weather. The cost factor is yet to be analysed thoroughly for waste plastic bitumen concrete roads as compared to 100 per cent bitumen concrete roads. For sure, the cost of the previous option is going to be slightly less having additional economic and environmental benefits.

Table-1: Comparison between ordinary roads and plastic waste roads

Sr. No.	Properties	Ordinary Roads	Plastic waste Roads
1	Tensile strength	Less	High
2	Softening Point	More	Less
3	Binding property	Good	Better
4	Cost of pavement	Normal	Less
5	Seepage of water	Yes	No
6	Stripping(potholes)	More	No
7	Durability of road	Good	Better
8	Environment friendly	No	Yes
9	Maintenance cost	More	Almost Nil
10	Marshall Stability Value	Less	More

OPTIMUM WASTE PLASTIC CONTENT

The studies were conducted for varying percentages of waste plastic (by weight of bitumen) added into the heated aggregates. Marshall specimen with varying waste plastic content was tested for bulk density and stability. The utmost value of stability was considered as criteria for optimum waste plastic content within the mix. Studies were conducted on bituminous mixes using 60/70 grade and 80 /100-grade bitumen. The typical Marshall Stability Value (MSV) was 1300 kg at optimum bitumen content of 5 percent by weight of the mix. The optimum modified binder content fulfilling the Marshall Mix design criteria was found to be 5.0 % by weight of the mix (i.e. 8.0 % of prepared waste plastic by weight of added to the bitumen). It has been observed that the typical MSV of this mix was found high as 1750 kg, resulting in a three-fold increase of stability of the BC mix, which contain 4.6 % bitumen plus 0.4 % waste plastic by weight of the mix.

To gauge the ability of the mixture prepared with the above-modified bitumen to face to the adverse soaking conditions underwater, Marshall Stability tests were conducted after soaking in water at 60^0 C for about 24 hours. The typical MSV of the BC mix with the above modified binder was found to improve by about 2.6 times as compared to ordinary bitumen used. Further, laboratory studies revealed that a significant increase was found in fatigue life under repeated application of loads on roads using the modified binder. The other advantages and disadvantages of such roads are given in Table-2

Table-2: Advantages and disadvantages of waste plastic roads

Advantages	Disadvantages
● The strength is increased twice as that of the traditional roads. ● There is not any damage /effect of radiation like ultraviolet rays. ● Binding property is far better than the traditional roads. ● There are less chances of rutting in the road. ● The road provides better resistance towards rainwater. ● The Marshall Stability value is increased. ● The cost of road development is economical. ● The Maintenance cost of such construction is minimal. ● Disposal of waste plastic will no longer be a problem, the method being environment friendly ● For two-lanes of 1km × 3.5m road, about 1 ton of plastic is used i.e. saving of 1 ton of bitumen.	● The toxics present within the plastic waste may start leaching during the cleaning process. ● The presence of chlorine may release harmful gases at the time of road laying ● The road may leach at the time of the initial rain.

However, the optimum plastic content (8%-10%) for blending with the bitumen (of grades 60/70 or 80/100) as a binder for the road development alike the standard method is usually recommended. The chemical composition of plastic wastes is critical because the mechanical properties for restricting hazardous substances from being circulated undesirably. Further, aside from the quantity and quality of plastic wastes, ensuring the sustainability of the entire recycling chain must be assessed and optimized before launching operations to understand both economic and environmental benefits for the society and operators.

ECONOMIC AND ENVIRONMENTAL IMPLICATIONS

The application of an idea of circular economy in the processing of plastic waste in Indonesia, it had been concluded that *single-use plastic* waste is often reused into high-value products and does not end up at the ultimate Disposal Site. Further, analysis demonstrated that one-kilometre-long road, with 7 m in breadth and 5 cm in thickness can absorb between 3 tons and 3.5 tons of the plastic waste as asphalt feedstock.

Through various studies, it has been concluded that the global demand for flexible paved roads is large on one hand while on the other hand the generation of waste plastic is tremendously growing. This matching potential could be considered for modification of BAC. Utilization of plastic wastes in flexible pavement construction and road rehabilitations would significantly mop up several million metric tons of the plastic wastes effecting the environment positively by reducing environmental pollution. Further, the reduction of burdens from greenhouse emissions and littered plastics, drainage problems reduction arising from drainage networks being blocked by wastes, prolonged service lives of landfills, and conservation of natural resources used in production of BAC like asphalt. This option may

certainly remove non-biodegradable wastes from the ecosystem and stop bioaccumulation of plastics in food chains (20).

Consequently, use of the modified BACs would significantly expand the service lives of the roads with economic implications like provision of additional source of income for waste managers, reduction of construction and maintenance costs of pavements, reduction of accidents, and improved rides. The financial savings as a result of these are often availed by the government for other developmental programs. The regulations need to be put in situ to facilitate road construction firms in a similar manner as has been done by United Kingdom (21) and in California where 35% composition of rubberized tire material by weight of asphalt is required for pavement development (22).

CONCLUSION AND WAY FORWARD

Certainly, the use of plastics for a variety of purposes are increasing each day and thus, waste plastics are bound to increase proportionally. Presently, the plentiful waste plastics are generated from residential complexes, commercial, industrial, and institutional areas. It is collected then transported by the municipal bodies for disposal either to the dump yards or into landfill or for incineration/energy generation which are often inherited with adverse impact on the environment. The government had enacted various laws to tackle the environmental problems.

The waste plastics show the adhesion property in molten state and enhances the melting point of the bitumen when mixed with it. Certainly, the plastic-bitumen-concrete roads have better properties as compared to plain bitumen concrete roads. These roads have more tensile strength, Marshall Stability value, durability, efficiency and significantly are economical too as compared to the energy consumption and maintenance cost.

There are enormous possibilities for the reuse of waste plastics in many ways for development of plastic and plastic bitumen concrete roads. India should seize this opportunity to accept the challenges and plan how it engages with states, individuals, academia and industry following a multidimensional approach to tackle waste plastic pollution most gainfully. Thus, the serious government initiatives are needed for putting in place the policies, actions in situ and to look at waste plastics from different ecological and economic angles. Moreover, waste reduction intervention at source and public awareness are equally important. At present, what is seriously needed in this regard, is our commitment to manage plastic waste in order that the presence of plastic is more useful, rather than ending up becoming waste.

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