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Plastic Waste Use in Road Construction: Viable Waste Management?

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1. Introduction

Recently a lot of interest has been taken in waste plastic use, for the first time in a trail one Kilometer Road construction in Islamabad, Pakistan. Waste plastic in road construction has been used, earlier in a few developed and developing countries. Plastic waste is considered a fast emerging & alarming waste management issue worldwide, including Pakistan.

Literature survey/review has indicated several research reports, with regard to assessment of plastic use viability in road construction, in terms of environment protection, public health (including workers), road quality as well its economic feasibility.

According to Ayub et al (2017), the chemicals in waste plastic do not degrade easily in natural environment and more importantly the use of plastic in product delivery services could not be banned due to its comfortability, diverse use and less cost. Bjerkli (2005) and Bailey.R et al (2001) reported waste plastic use in road construction primarily, as an economic phenomenon, with observation during studies that community attitudes, government policies, cost of waste disposal and material scarcity would create market for the consumers. Global literature also identified groups of material from other waste sources (such as waste oil, tires, aggregates, asphalt and bituminous surfaces) that has been used in waste recycling process.

Bindu and Beena (2010) carried out a study on "Waste Plastic as a Stabilizing Additive in Stone Mastic Asphalt," and the performance tests indicated the benefits of stabilizing the Stone Mastic Asphalt (SMA) with an increase in plastic content by 10%, resulting in an effective stabilizing mixture for plastic road pavements. Menaria and Sankhla (2015) claimed that the significance of waste plastic in road construction increased road durability and controlled heating (around 160 C^o) increased the strength of the pavements.

Sheema et al (2017) studied the properties of plastic waste in bituminous mixes, in which the shredded waste plastic poly-styrene was coated over aggregate and further mixed with hot bitumen which helped further strengthening and increased the durability of pavements.

Nikraz et al. (2021) reported that 8% waste PET-modified asphalt mixture could be a sustainable and cost effective/ addictive, in rutting resistance and stability of the roads so constructed. Marshall Quotient, flow and stability tests also demonstrated that 6-8% of waste plastic use with modified mixture helps to enhance and amend elasticity behavior and stiffness of asphalt binders.

In view of the above and several environmental and social considerations by Conlon (2021), in Global South context, where plastic waste quantum is high as well as existing lack of waste management infrastructure, waste plastic use in road construction could make road construction economical as well as eco-friendly.

2. Road construction with waste plastic use in other countries

Research and development work on Waste plastic road, carried out over the years in ***China***, is best described in two recent reviews by Xu et al (2022) with 174 references and Wu & Montalvo, with 200 references, entitled "Using Waste Plastics as Asphalt Modifier: A Review," and "Repurposing Waste Plastics into Cleaner Asphalt Pavement Materials: A Review," respectively. These are very comprehensive useful reviews, describing main sources of waste plastics, various forms of waste plastic used as modifiers, dry & wet waste plastic use processes, physical methods for pretreating waste plastic and many other aspects of plastic waste use in road construction. Another useful reported study in China is by Yu et al, entitled, "Evaluation of Plastic-Rubber Asphalt (PRA): Engineering property and environmental concern," (Yu et al 2014).

In ***USA*** UC San Diego built the first asphalt road made with recycled plastic binder as opposed to a petroleum –based bitumen binder (Xu et al 2022). University of California, USA in 2008 planned "Zero Waste" goals for UC campuses. According to the published report, the plastic coating on aggregate improved the quality in abrasion, soundness and in terms of impact, Asphalt and Plastic Waste Coated (PWC) Aggregates, increased the strength and performance, by reducing the need for bitumen and aggregate in pavements. The Marshall Test indicated retaining of flexibility and resulted the flow of roads with good stability. However, shredded plastic waste as binding agent did not modify poor quality aggregates. It has also been reported that between 2010-2018, the campuses waste diversion was dropped from 55% to 35%. Trashy Bags and Nelplast Ghana Limited introduced an innovative business model for sustainable plastic waste management in ***Ghana*** *and* ***Africa***. A critical analyses of plastic waste management process in Ghana, has been reported by Kortei and Quansah (2016).

For cities with scare land, such as ***Hong Kong***, the use of waste plastic and reclaimed asphalt pavement (RAP), the environmental and economic benefits would be expected to be greater than other cities. The results of a study reported by Yao et al showed that incorporating waste polyethylene terephthalate (PET) and RAP into pavement could reduce the life cycle cost and green-house gas (GHG) emissions by up to 26.20% and 29.00%, respectively (Yao et al 2022)

In June, 2021, first parking spaces and residential street were built using waste plastic in the municipality of Almere, ***Netherland*** (Yao et al 2022)**.** An initiative for plastic road, was also taken by Volker Wessels Corporation, Rotterdam, as a greener alternative to asphalt. The project insured plastic road resistance to chemical erosions that could withstand higher temperatures, low maintenance costs (less traffic congestion) and shorter construction time. In Netherland, most of the cities are mainly paved and due to climate change and heavy rainfall water cannot be drained well. Even in case, the high level of groundwater plastic roads

appeared strong and water infiltrating. These plastic roads may off possible climate-proof solutions to infrastructure.

In **India,** plastic roads have not been systematically planned but as reported, were observed to be better in performance in comparison with conventional bitumen and also, not subjected to stripping in a harsh climate. The construction of roads in rural areas, the use of waste plastic was observed to form a fine plastic coat over hot aggregate and when mixed with a binder it resulted in higher water resistance, strength and better performance. Specifically, waste plastic films (thickness up to 60 microns), hard & soft foams (of any thickness) and laminated plastic (up to 60 microns) have been recommended for use in plastic roads construction. The Indian Road Congress (2013) and National Rural Road Development Agency (2019) published guidelines, respectively for the use of waste plastic in hot bituminous mixes and for the use of waste plastic, specifically to rural roads construction. In a literature review by Duarte and Faxina revealed that since 2002, 2500 km of asphalt concrete pavements had been modified with polymer waste, using dry method. Investigations on the six selected sites indicated, the roads with waste plastic use, worked well, without potholes, raveling and rutting (Duarte and Faxina 2021).

With regard to waste plastic management in ***Ethiopia,*** a study by Genet et al. (2021) indicated poor plastic pavements performance. The study was carried out in view of the severe weather and heavy load of traffic on roads and the resulting nee to reduce the amount of bitumen and enhanced stability of asphalt mix. Optimum bitumen content, mixing time and temperature of the homogeneous mix between bitumen and plastic waste material were also studied and tested.

In **Indonesia,** Suaryana et al (2018) reported using plastic waste into the asphalt mixture as an addictive, employing both the dry and wet processes for road pavements and observed a certain amount of plastic content which decreased the raveling resistance and improved rutting resistance, moisture sensitivity and stripping resistance.

Growing interest in plastic consumption and its exploring viability in waste plastic roads has also been done in **Australia**. The first stretch of plastiphalt road (250-meter highway) in Sydney South has already been completed, using waste plastic bags, glass bottles & toners from printer cartridges (35% of 250 tons of asphalt used was recycled material (Ahmed, 2018). Australian roads project, APT6305 in construction and maintenance of asphalt roads assessed various potential issues. Samuels and Parnell (2007) pointed out that in the states of New South Wales and Queensland, study findings interpreted and explained acoustic attributes of asphalt pavements.

Investigations in ***UK, South Africa and Mexico*** have also been carried out and reported, w.r.t. evaluating the performance of waste plastic-modified asphalt mixtures by assessing the actual field performance (Yao et al 2022).

3. Waste plastic use in road construction: Material and Process

Plastic mixed pavements may replace to a large extent the conventional roads, in not-too-distant future. As also mentioned earlier, the construction material and its desired mechanical characteristics, due to modified bitumen with waste plastic, result in, among others, better density, stability and plastic road water resistance.

Types of plastic that has been used in pavements are Thermosets, Elastomers, Thermoplastics, PET, polyethylene terephthalate, HDPE, high-density polyethylene, PVC, polyvinyl chloride, LDPE, low-density polyethylene, PP, polypropylene, PS, polystyrene.

The recommended specifications for waste plastic to be used are films (thickness up to 60 microns), hard & soft foam of any thickness and laminated plastic (thickness up to 60 microns). Waste plastic material should be shredded, preferably to 2-3 mm particle size, for better spread and aggregates coating (National Rural Roads Development Agency Ministry of Rural Development, 2019).

Flexible pavements, popularly also known as plastic roads, subject to the climatic conditions, their binding properties of aggregates due to added waste plastic, become doubled in dry process. In roads construction, if the amount of plastic waste is around 6-8 percent, by the weight of bitumen, the coated aggregates have shown increased stability in the mixes. In the dry process, the collection, cleaning and shredding of waste plastic in the central mixing plant, may not necessarily produce toxic gases even at 180 C^o temperature. Besides, road strength and stability, subject to climatic conditions, plastic roads also have improved pavement performance and longevity (Indian Road Congress, 2013). Gawande et al. (2012) identified that in dry process plastic was coated over stones and with improvement of the surface property of aggregates, coating became easy and temperature required was same, as for road laying temperature. It was also observed that more than 15% of the waste plastic could also be used, however, new equipment may be required for stronger Bitumen bonding. The process could be practiced in all types of climatic conditions and no evolution of any toxic gasses was reported with even at maximum temperature (180 C^o)

In “Wet Process” 6 to 8 % of waste plastic is blended with bitumen that helps enhance its softening. Waste plastic in the recommended specific proportion, not only improves adaptability in winter season but also withstand incremental high temperatures. Waste plastic in particular, polyethylene, polypropylene and polystyrene expand in liquid states. Such waste plastic bitumen shapes better material for asphalt development. By adding finely sized shredded waste plastic, the asphalt mixture and bitumen retains 12 - to 18% strength, compared to the conventional mix. Any type, size & shape of waste material (plastics, rubber etc.) can be used in wet process which however, appeared to be more time-consuming, required more energy with requirement of powerful equipment for blending and additional cooling. The

improper addition of bitumen may cause air pockets in roads and may require addition of a maximum percentage of waste plastic (8% of the total mixture), to minimize the same (Indian Road Congress, 2013; Gawande et al. (2012).

4. Plastic roads: A viable waste management option?

The need for large road networks is considered essential for smooth social and economic development, especially in developing countries. It seems a leading idea to also ensure fast construction of roads. Quality and growth of roads was considered one of the most important indicators of a well-developed infrastructure, subject to the overall cost. In view of the fast-emerging problem of waste plastic management/disposal, waste plastic use in road construction/plastic pavements could be a viable option towards its possible viable disposal solution as well as faster road construction. According to Saini, well-constructed plastic roads increased the performance and strength of roads and would also very likely, generate formulized employment for rag pickers (Saini 2018). Reported studies in Colombia and Latin America revealed that the cost of plastic roads construction were economically favorable towards commercialization and plastic road construction on larger scales (Saieth 2020). These studies verified that plastic roads were a viable alternative, eco-friendly towards waste reduction and offered cumulative benefits to National Economy. Plastic-bitumen roads may last up to 10 years and though the initial cost being somewhat high, compared to the conventional types, but its maintenance cost has been reported low (Dwivedi et al. 2017). Hard plastic waste as bitumen modifiers for flexible pavements should be about 5-10% by weight of bitumen. The reported study's findings were that plastic use substantially improved the stability, strength, durability, corrosion resistance, abrasion & slipping tensile strength, good insulation for cold, heat, fatigue life and other desirable properties of bituminous concrete mix and subsequently improved the longevity and pavement performance, with marginal saving in bitumen usage.

Plastic has the property of absorbing sound, which also help in reducing noise pollution due to heavy traffic. However, lack of technical guidance and investments are the challenges towards construction of these plastic roads on larger scales. (Saini 2018, p.125; Jamshidi & White (2019).

5. Pakistan initiative - Plastic roads with waste plastic use in road construction:

According to the newspaper reports, Pakistan's first plastic roads (pilot test/trail roads) under "World Without Plastic" program have been completed in December 2021, at F-Park (around 250 meters length) and Ataturk Avenue (one kilometer length), Islamabad, Pakistan. For the construction/recarpeting of the completed pilot plastic roads (using 8 tons waste plastic –





Figure 1: The First (Test/Trial) Plastic Road in Islamabad. Pakistan.

PET bottles, plastic cups), under public-private partnership (Capital Development Authority (CDA), Islamabad, Coca-Cola Pakistan-Afghanistan & the National Incubation Center (NIC), Islamabad), MoU was signed in September 2021 and the work was started in October 2021 (Daily Times, 2021; Dawn, 2021, The News, 2021, The Express Tribunes, 2021 & Gulf News,2021). According to CDA, daily 33% of plastic waste (around 165 tons plastic waste/day) of municipal wastes, is collected in Islamabad and its recycling and use in plastic roads would considerably reduce the existing solid waste pollution, minimize its hazardous exposure to population, as well as the resulting environmental and health impacts. As also described in the preceding pages, the two plastic roads, since October 2021, under engineering tests/monitoring and evaluation after completion, are expected to be cost effective, stronger & of longer life compared to the traditional non-plastic asphalt roads. After the completion & evaluation of the on-going engineering tests data and if the results are positive, the plastic technology applied to the two trial roads would be considered for, more plastic roads in Islamabad as well in other cities of Pakistan (Daily Times, 2021; Dawn, 2021 & The News, 2021).

Findings, Recommendations and Way Forward

It is evident from the country case studies and reviews of research and development (R&D) studies described in the preceding pages that waste plastic binders and mixtures are gaining rapidly increasing attention due to their engineering performance, economic and eco-friendly benefits. The use of waste plastic as an asphalt modifier extends the use of waste plastic and reduces its environment burden. In general, the incorporation of plastic wastes into asphalt mixtures have shown improvement in engineering performance parameters. However, harmful emissions are produced when some type of plastics are heated at high temperature which may affect the health of the road construction workers. High melting point plastics are considered to be more suitable for dry processes and low melting points plastics more appropriate for the wet processes, when using waste plastic in asphalt. Seven major types of waste plastic are in use for plastic road construction. The mechanical properties of waste plastic may be deteriorated as compared to virgin plastics. Suitable methods of pretreatment and modifications are required for waste plastic asphalt modification (Xu et al 2022; Wu & Montalvo 2021).

In view of better road quality and engineering performance, economic and eco-friendly benefits, Pakistan initiative of plastic road construction with waste plastic use, briefly described in the preceding pages, appears to be a right step in the right direction. However, while considering construction of more plastic roads in Islamabad and other main cities of the country, the following need to be considered:

- The ongoing engineering tests and evaluation/monitoring of the test/trial plastic road at Ataturk Venue be carried out for one year (October, 22), to observe the impact of severe climatic conditions (heavy rainfall/monsoon, extreme cold & hot weather) on the plastic road conditions.
- If not already done/undertaken, monitoring of traffic density (to & fro vehicles/day) on the plastic road be carried out and same be taken into consideration, for modification of the methodology/material composition, for the new road with expected higher or lower traffic density,
- In the light of the findings of the earlier research and other countries case studies, the methodology/material composition employed in the construction of the trial/test plastic road be further improved for best road quality, engineering performance and maximum economic and eco-friendly benefits.
- In consultation with the relevant ministries & national engineering bodies, a national as well as provincial expert committees of road construction professionals, scientists and civil engineers be constituted to look into above and direly needed R & D for the same.
- A national governing and steering stakeholders committee, to provide guidance and support to the above “Expert Committees,” may also be constituted from

representatives of relevant ministries, departments, national engineering professional bodies, R&D institutions/academia/think tanks and civil society.

- To benefit from the years of experience and advancement in plastic road construction in China, close cooperation & collaboration be looked into and explored with Chinese counterparts, research and other institutions, involved with plastic road construction.

Recommended publications for detailed information

- "*Using Waste Plastics as Asphalt Modifier: A Review*" by Fengchi Xu, Yao Zhao and Kangjian Li, Materials, 15, (2022).
- *"Asphalt Concrete Mixtures Modified with Polymeric Waste by the Wet and Dry Processes: A Literature Review*" by G.M. Duarte and A.L. Faxina, Constr. Build. Mater., 312, 125408 (2021).
- "*Repurposing Waste Plastics into Cleaner Asphalt Pavement Materials*: A Critical Literature Review" by S. Wu and L. Montalvo, Journal of Cleaner Production, 280 (2021)
- "*A Review on Compatibility between Crumb Rubber and Asphalt Binder"* by W. Zheng, H. Wang, Y. Chen, J. Ji and Y. Zhang, Constr. Build. Mater., 297, 123820 (2021).
- "*Current Approaches to Waste polymer Utilization and Minimization: A Review" by* Okan, M., Aydin, H.M. and Barsbay, M., J. Chem. Technol. Biotechnol, 8 – 21 (2019)

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