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Performance Evaluation of Plastic Road

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ABSTRACT

Waste plastic, a municipal solid waste is an environmental challenge, when disposed of in landfills and stockpiles. In response, the Capital Development Authority (CDA) of Pakistan introduced a groundbreaking initiative in 2021, paving the Nation's first asphalt pavement with partially replaced aggregates with waste plastics to produce modified asphalt pavements. This study aims to evaluate the waste plastic-built pavements' performance through field and laboratory testing. The assessment encompasses the site's traffic impact, skid resistance, and International Roughness Index (IRI). Field evaluations employed the British Pendulum Tester and a Profilograph. Traffic impact assessment utilized weekly traffic data, revealing a moderate traffic type with no congestion. Results indicate better skid resistance in plastic-modified asphalt compared to virgin asphalt mixtures. The calculated IRI value of 2200mm per km for plastic-modified asphalt falls within the permissible limits. The constructed asphalt pavement with waste plastic satisfies functional performance for moderate-traffic roads. Surface friction of pavement measured from a British pendulum is less than 65. Overall, pavement performance in the study is satisfactory.

KEYWORDS: Plastic Asphalt, Skid Resistance, British Pendulum Tester, International Roughness Index, Profilograph

1 INTRODUCTION

Management of waste plastics is a significant challenge in Pakistan [1] and globally due to their significantly high volumes and non-biodegradable nature. Incorporation of plastic waste into the asphalt mixes for flexible pavements has been proven feasible through research studies [2], making it a promising way to use waste sustainably. Plastic waste management is one of the top contemporary global issues. As a result, upon directives of the "World Without Waste" program, Pakistan's first ever plastic roads were built and inaugurated in F 9-Park and Ataturk Avenue of Islamabad in December 2021, as illustrated in Figure 1. This pavement test section used approximately 8 tons of recycled polyethylene terephthalate plastics [3]. Following its official formalization on September 21, 2021, this project was executed by the cooperation of Coca-Cola Pakistan-Afghanistan, the Capital Development Authority (CDA), and the National Incubation Center [4]. Expecting to yield hefty dividends in terms of enormous savings in government expenditures for road maintenance costs as a successful transformative initiative, it is a much-welcome eco-friendly solution to the government's perennial pains of preserving taxpayers' money, which are the government's expenditures for maintenance of roads.

At the end of its first year of construction, performance data are gathered, revealing rutting and riding quality at several locations of this pioneering plastic road, although the severity is still acceptable. The detailed performance assessment of the plastic road was thus deemed necessary to demonstrate its long-term viability further and provide clear guidance for future applications. The primary aim of this research is to evaluate the performance of plastic-modified asphalt pavements. The secondary objectives of this research work are defined to accomplish this aim:

- Assessment of the traffic impact associated with plastic asphalt pavements.
- Evaluate the impact of waste plastic on the skid resistance of asphalt pavements.
- Influence of waste plastic on the International Roughness Index (IRI) of asphalt pavements.

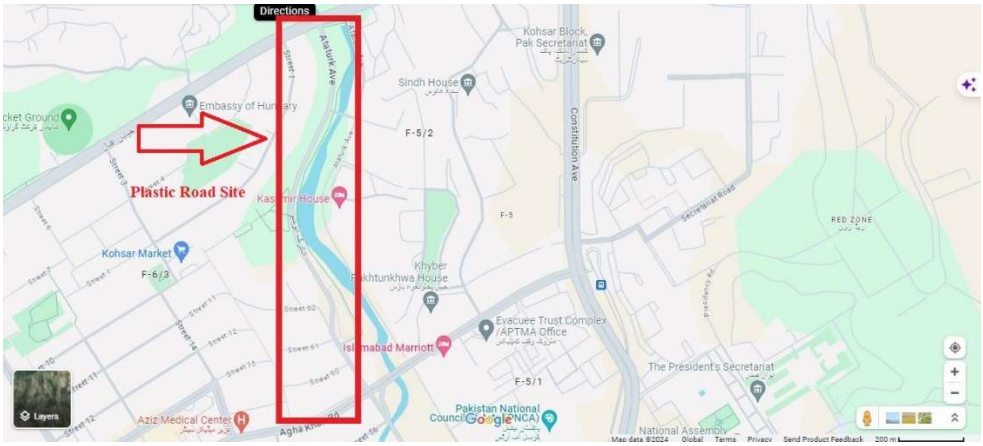

Figure 1: Plastic Road Site Location

2 MATERIALS

Penetration grade 60/70 binder obtained from Attock Refinery Limited (ARL) in Rawalpindi, Pakistan, was used in this plastic road. The penetration, softening point and ductility when measured on virgin binder was reported to be 63 °C, 51 °C, and 102 cm, respectively. The coarse aggregates used in the project were in accordance with ASTM D692. Similarly, the fine aggregates met the ASTM D1073 specifications. The mineral filler conformed to the ASTM D242 specifications. From the asphalt mix samples, aggregates were collected after the centrifuge extraction test and physical and mechanical properties of aggregates were determined. The shape analysis measured aggregate flaky and elongated properties as per BS 812-105 and found to be less than 15%. Aggregate impact value was measured as per BS 812-112 and found to be less than 20. Similarly, aggregate specific gravity and water absorption was measured as per AASHTO T 85 and reported as 2.644 and 1.7%, respectively. The waste plastic used in this road was predominantly sourced from roadside waste depots, refuse vehicles, and designated waste collection sites. Plastic waste, often manifested as thin-film carry-bags, undergoes a meticulous process of sorting, dedusting, and, if required, washing.

3 METHODOLOGY

A two-phase design methodology was designed to ascertain the study objectives. Phase I comprised of evaluating the field conditions, traffic assessment, and extracting the samples from the field. Traffic study was conducted to assess the traffic volume and vehicle type. The purpose of traffic study was to gauge the prospective traffic repercussions of a project on the performance of transportation and traffic systems. The skid resistance of an asphalt pavement as a critical parameter impact driving safety on roadways. The British Pendulum is a venerable, manually operated device with a petite rubber foot (75 x 25 mm) affixed to a pendulum oscillating above the road surface [5]. The assessment of the pavement surface profile was conducted through the utilization of computerized profilographs. The apparatus employed for gauging deviations in the pavement surface involves a central measuring wheel moving vertically in relation to the reference plane established by a 25-foot wheel truss system. IRI is quantified in meters per kilometer and can be compared through correlations recommended by various authorities [6]. The profile index calculation is outlined by the following formula as presented in eq (1) [7]:

$$Profile\ Index = \frac{1\ mile}{length\ of\ section\ in\ miles} \times total\ count\ in\ inches \qquad \text{eq (1)}$$

IRI (International roughness Index) = (2.19 * total profile Index) + 0.22 eq (2)

The road map of the study is illustrated in Figure 2:

Figure 2: Road map of the research study.

Phase II comprised of testing the field core samples in the laboratory and determining the relevant parameters of density, bitumen content, aggregate gradation etc. Samples were tested in replicate in the laboratory to cover the variability in results.

4 RESULTS AND DISCUSSIONS

4.1 Traffic Count

The primary aim of the traffic count is to evaluate the current volumes of traffic traversing Ataturk Avenue, F-5, Islamabad. To discern the specific traffic volumes categorized by vehicle type on this thoroughfare, a meticulous Seven-day manual classified count (MCC) spanning 16 hours, from 6:00 am to 10:00 pm each day, was executed at the F-5 Ataturk Avenue. The breakdown of traffic flow details obtained through this systematic assessment is depicted in Figure 3. Figure 3 shows an average value of seven-day traffic to cover the fluctuation within the week. Aggregate

load imposed on the network is calculated through comprehensive traffic count analysis. The peak hour of the traffic is identified, and the load is determined cumulatively per hour/day. This analysis provided the neat utilization patterns and stress points of the network. This extensive study helps to understand the vehicular dynamics of F-5 Ataturk Avenue.

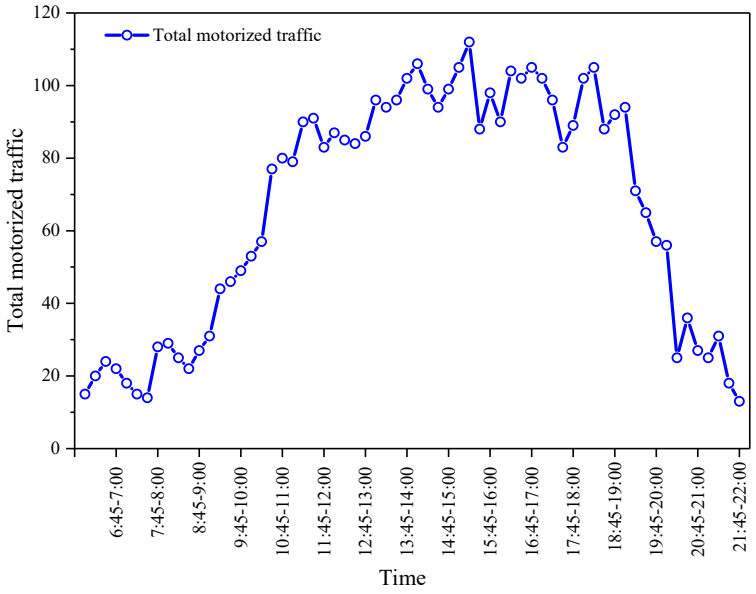

Figure 3: Motorized Traffic variation per hour.

It may be noted from Figure 3 that per hour traffic during the peak hours on the project road does not exceed 120 vehicles, which comprises of mainly cars. Within the peak hour, fluctuations was uniform showing a peak hour factor of 0.83.

4.2 Measurement of Skid Resistance with British Pendulum

British Pendulum Numbers (BPN) of the asphalt samples were obtained using a British Pendulum Skid Resistance Tester. The BPN value for an unmodified or virgin asphalt mixture is 45. Seven locations were tested within the plastic asphalt pavement. The results presented in Figure 4 provide conclusive evidence that the modified plastic asphalt provides better skid resistance than unmodified asphalt.

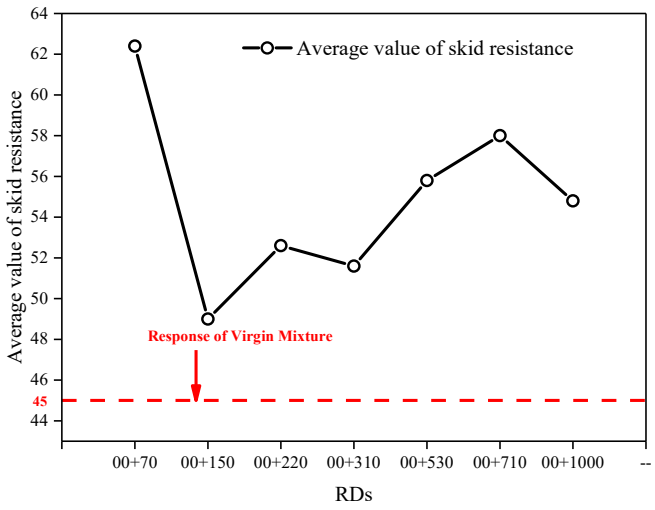

Figure 4: The British Pendulum Numbers (BPNs) of Plastic Asphalt Pavement

The mean skid resistance values measured at distinct locations (00+70, 00+150, 00+220, 00+310, 00+530, 00+710, 00+1000) were found to be 62.4, 49, 52.6, 51.6, 55.8, 58, and 54.8, respectively. After the expiry of two years, pavement surface is offering better skid in terms of British Pendulum number against the acceptable range is 55 to 66. Reference skid resistance value selected for easy sites with minor curves or bends with low intensity of traffic is recommended to 45. All the results obtained after the site measurement falls above the minimum the acceptable value of 45All examined specimens conform to the prescribed minimum skid resistance threshold of Category C (45) as well as Virgin Asphalt Mixture, as stipulated by the specifications outlined in TRRL Road Note 27 [8,9]

4.3 Measurement of surface profile with profilographs

The computerized profilograph incorporates an autonomous system for delineating elevations or depressions, quantifying them in terms of width and depth for the computation of the profile index. To assess the precision of vertical variations, the profilograph has three distinct bandwidths: a null band (0mm), a 2 mm band, and a 5mm band, as elucidated in reference [6]. Measurements were conducted with null band width parameter, employing a 5 to 8 km/hr travel speed. The calculated Profile Index (PI) values were transformed into International Roughness Index (IRI) values [10], and the results are documented in Table 1.

Table 1: IRI values of Plastic Road

Nature of the Pavement	From	To	Distance (m)	Count	International Roughness Index (IRI) value (mm/km)
Plastic Asphalt Road	0+000	0+151	151	18.70	2200

The International Roughness Index (IRI) serves as a standardized metric gauging a standardized vehicle's reaction to the roadway's profile and roughness. This simulation model produces a vibration response induced in the moving quarter car, which is maintained at a constant speed of 80 km/h, attributable to the irregularities in the road profile. In the Profile Index (PI) computation, specific ratios are selected for the masses, spring constants, and damping coefficients of the quarter car simulation model, deliberately differing from those utilized in calculating the IRI. While assessing the sections' overall performance, the international roughness index (IRI) value calculated as per eq (2) was 2200 mm/km. An acceptable International Roughness Index (IRI) for verse conditions is up to 4000 mm/km [6]. The entirety of plastic asphalt pavements conforms to this international criterion, demonstrating IRI values within this specified range.

4.4 Laboratory Test

Field extracted cores were further tested in the laboratory as per ASTM D 1188 to confirm the density of the asphalt mix. The main purpose of determining the mix density is to see the effect of traffic on mix compaction after the expiration of almost two years. Asphalt mix density and bitumen content were after the experimentation found to 2.42 and 4.1%, respectively. A centrifuge extraction test showed the obtained aggregate gradation meets NHA Class-B gradation.

5 CONCLUSIONS

This research study investigates the performance of field pavement especially the plastic waste-modified asphalt mixes. A comprehensive research methodology was designed to obtain the study objectives that comprised field and laboratory testing. Following conclusions have been drawn from this study.

- The incorporation of waste plastic enhances a critical safety parameter: skid resistance. The introduction of plastic imparts a coarse texture to the asphalt, thereby significantly improving skid resistance. The skid resistance measured by British pendulum was found generally above a critical benchmark of 45.
- The ride quality, assessed through the International Roughness Index (IRI), of sections constructed with mix was deemed satisfactory, comfortably meeting the standard criteria of 1.51to 2.68 m/km as the obtained average IRI value was 2.2 m/km.
- The laboratory testing showed that a stable and durable mix has been laid to meet the traffic and climatic conditions, which till the expiry of two years of traffic and climatic effect is performing satisfactorily.

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