GLOBAL RESEARCH NETWORK

AMERICAN Journal of Engineering, Mechanics and Architecture
Volume 2, Issue 8, 2024 ISSN (E): 2993-2637

Evaluating the Rutting Resistance of Modified Hot Mix Asphalt (MHMA) with Palm Leaves Fibers (PLFs)

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Abstract: High temperatures, high axle loads, and low-quality paving material can all contribute to the distress of rutting in flexible pavement. This paper investigates adding palm leaf fibers (PLF) to hot mix asphalt (HMA) to improve its resistance to rutting. In order to make Modified HMA (MHMA) by employing Modified Dry Process (MDP), which was prepared by adding small balls to HMA, HMA mixes were prepared with traditional mineral filler and Hydrated Lime. PLF was added at dosages of 2%, 4%, and 6% of aggregate weight. A Wheel Track device linked to a computer system monitored rutting depth as a sign of rutting resistance, and Marshall tests were also performed to assess stability and flow characteristics. According to the findings, PLF considerably increased rutting resistance throughout. The use of PLF found to be highly effective in improving rutting resistance at all dosages; the highest results were obtained at 6%. This implies that sustainable paving technologies could displace traditional techniques.

Keywords: Palm Leaves Fibers (PLFs); Hot Mix Asphalt; rutting resistance, wheel track test.

1. INTRODUCTION

Nowadays, there is an international requirement for a transition to more environmentally friendly paving technology. Naturally, in terms of mechanical performance attributes, what is available in HMA technology today approaches advanced levels[1] .Asphalt pavement makes up more than 95% of all paved roadways. Throughout its service life, asphalt pavement is exposed to numerous stresses and strains. Rutting is one of the primary distresses. Due to an increase in axial load, tire pressure, and traffic volume, rutting in asphalt pavements has emerged as one of the main distress forms in recent times. It frequently occurs in the initial years following the site's launch to traffic[2]. Rutting is the result of pavement layers accumulating persistent distortion. It manifests as longitudinal depressions in the wheel tracks and tiny upheavals to the sides and is caused by a combination of densification and shear deformation[3]. Rutting reduces tire-pavement friction and hydroplaning, which increases road roughness and traps water, both of which have a substantial negative impact on the performance of asphalt pavements[4]. Significant rutting can also result in significant structural problems[5]. In order to ensure that it meets both structural and functional criteria, asphalt pavement, for example, requires regular care. High upkeep costs result from this. It is crucial to so try to reduce rutting[6]. Many studies have shown that waste materials like iron, fly ash, oil palm shells, and coconut shells can be used to advance the pavement construction process[7-10]. Numerous investigations have been carried out to examine the impact of fibers on rutting in asphalt pavements and one way to increase road surface longevity is by adding particular additives, such as fibers or polymers, which change and improve the properties of the mix. The most promising approach for constructing flexible pavements that appears to have the best chance of increasing the pavement's service life is adding fibers or polymers to the asphalt mixture[11-14].All have demonstrated a notable improvement as a result of the mechanical bridging phenomena, and the asphalt mixture's chemical qualities have also improved. According to this research, adding waste material fiber can help uphold the sustainability principle. At the same time, the asphalt mixture's mechanical and volumetric properties are monitored to gauge the extent of improvement brought about by this addition of fiber on the rutting that is occurred on the asphalt pavements. Still, the primary goal is to describe the incremental benefit of adding varying amounts of waste fiber to the volumetric and mechanical characteristics of HMA. Furthermore, as will be seen below, the incorporating approach is distinct.

2. MATERIALS

The study employed locally sourced materials to the extent feasible in order to guarantee economic viability and explore the potential for utilizing a novel combination of local applications. Among these materials were:

2.1 Aggregate Material

The nominal maximum aggregate size (NMAS) of 12.5 mm for both coarse and fine aggregates was obtained from quarries in Karbala. As seen in Figures 1 and 2, they were categorized in accordance with the Iraqi general standard for roads and bridges (GSRP) R9[15]. The physical properties for coarse and fine aggregates are presented in Tables 1 and 2.

Figure 1 classified and graded to generate virgin aggregate

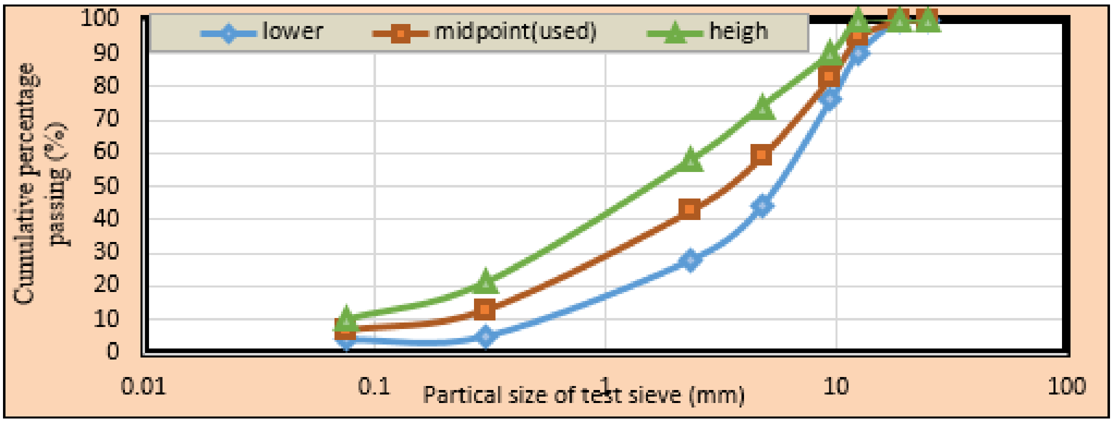

Figure 2 Distribution of Particle Sizes in the Used Gradation

Table 1 The coarse aggregate's physical properties

Coarse Aggregate			
Property	**Value**	**Standard of Tests**	**GSRB Requirements**
Bulk Density, gm /cm3	2.547	ASTM C127[16]	-
Apparent Density, gm /cm3	2.685	ASTM C127[16]	-
Water Absorption, %	2.034	ASTM C127[16]	-
Percent Wear by Los Angeles Abrasion, %	24.18	ASTM C131[17]	30% Max
Clay Lumps, %	0.065	ASTM C142[18]	-
Material finer than #200 %	1.231	ASTM C117[19]	-

Table 2 The fine aggregate's physical properties

Fine Aggregate			
Property	**Value**	**Standard of Tests**	**GSRB Requirements**
Bulk Density, gm /cm3	2.559	ASTM C128[20]	-
Apparent Density, gm/cm3	2.786	ASTM C128[20]	-
Water Absorption, %	3.177	ASTM C128[20]	-
Clay Lumps, %	1.89	ASTM C142[18]	Max 3%
Material finer than #200 %	3.846	ASTM C117[19]	-
Sand equivalent, %	48	ASTM D2419[21]	Min 45

2.2 Filler

In this study, three different types of fillers were used: Paris of Plaster (POP), hydrated lime (HL), and conventional mineral filler (CMF). Table 3 lists the characteristics of these fillers.

Table 3 The Utilized filler's properties

Properties	**Result**
Physical Properties	
Aspect ratio,	4.82
Diameter, mm	0.97
Length, mm	4.67
Chemical Properties	
SiO2	19.34
Al2O3	1.55
Fe2O3	1.51
CaO	5.20
MgO	0.53
SO3	1.19

2.3 Asphalt Material

Asphalt cement (grade type 40–50) was provided by the Al-Neisseria factory, and bitumen emulsion (Nit proof 30) was produced by the FOSROC firm. The properties of bitumen emulsion and asphalt are shown in Tables 4 and 5, respectively.

Table 4 Bitumen characteristics

Property	Test Values	ASTM Designation	GSRB Requirements
Penetration,100 gm. ,25 ° C,5sec (1/10 mm)	48	D5[22]	40-50
Specific Gravity, 25 C (gm./cm3)	1.03	D70[23]	-
Ductility, 25 °C,5 cm/min, (cm)	145	D113[24]	>100
Flash Point, (°C)	345	D92[25]	>232
Softening Point (°C)	47.5	D36[25]	-
Rotational viscosity, Pa.s	@170 -165°C @280 -153°C	D4402[22]	≤ 3000

Table 5 The Bitumen Emulsion Characteristics

Property	Value
Form	Dark brown liquid
Specific gravity	1.00
Solid's content	60 to 65%
Rubber content	Approx. 10 %
Drying time	30 minutes at 25°C
Over coating time	1 hour @ 25°C

2.3 cellulose fibers

Local palm leaves were used to make cellulose fibers, often known as palm leaf fibers (PLF). The properties of PLF shown in Tables 6

Table 6 The Properties of the Palm Leaves Fibers

Properties	Result
Physical Properties	
Aspect ratio,	4.82
Diameter, mm	0.97
Length, mm	4.67
Chemical Properties	
SiO2	19.34
Al2O3	1.55
Fe2O3	1.51
CaO	5.20
MgO	0.53
SO3	1.19

2.4 Solvent

Used 10% of the weight of the emulsion asphalt was combined with benzene (C6H6) solvent.

2.5 Preparation of fiber and additives

After drying the palm leaves was manually cut so that it could be processed with an electric grinder to create fiber. The chosen fiber was selected from passing from sieve No. 16 and remained to be on sieve No. 200. Modified dry process, or MDP, is recommended to ensure sufficient fiber distribution in the mixture. The creation of made of fiber with different gradients is an aspect of the MDP, so to produce the tiny modified balls, which are the enhancer materials, were formed by mixing the components fiber, hydrated lime, emulsion, solvent, and Paris plaster. These were added to the mixture. Table 7 displays the proportions of each in the gradient of several mixes of the tiny modified balls. At a temperature of the laboratory, six groups (P1, P2, P3, P4, P5, and P6) seized the form of the tiny modified balls.

Mix type	Add.%	add. type	Additive Ingredients				
			Palm fiber %	Paris plaster %	Hydrated Lime%	Emulsion%	Solvent%*
HMA0	0	-	0	0	0	0	0
HMA-P1	2	P1	13	2	20	65	10
	4						
	6						
HMA-P2	2	P2	17	2	20	61	10
	4						
	6						
HMA-P3	2	P3	21	2	20	57	10
	4						
	6						
HMA-P4	2	P4	25	2	20	53	10
	4						
	6						
HMA-P5	2	P5	29	2	20	49	10
	4						
	6						
HMA-P6	2	P6	33	2	20	45	10
	4						
	6						

Table 7 The proportion of material additives in HMA

2.6 preparation of specimens

To satisfy the requirements of the experiment design, the asphalt mixtures were created in two phases employing two samples for each percentage:

* Using the aggregate that accordance with the Iraqi standard R9[15], the control mixture in the first stage is the customary traditional mixture. Along with the aggregate (coarse and fine), it also contains five different concentrations of neat asphalt, ranging from 4% to 6%, with a 0.5% escalation in each level, three different types of filler: Hydrated Lime (HL) (2% in mixture and 20% in preparation for the balls); and Limestone Dust (LD) (5%). The HMA-Control mixture needs to have (OBC), as stated in ASTM D1559[26],in order to meet all of the determination criteria. and 5.5% by weight of sample was found to be the ideal binder concentration of the control mixture.

* In the second stage the control mixture, for which the ideal asphalt concentration has been determined, is supplemented with improvers in varying dosages (2%, 4%, and 6%) of the tiny modified balls. In order to ensure that the improver was distributed throughout the asphalt mixture under the same conditions and temperatures, two minutes of mixing time was added using MDP after adding the tiny modified balls that are shown in Table 7. At this point, the optimal improver ratio for the asphalt mixture was determined by using both mechanical and volumetric properties tests.

3. Methods and Conditions of Testing

The procedure for testing was carried out in compliance with Iraqi standard R9 (GSRE, 2003). These specification indices for surface coarse type III-A are displayed in Table 8. In addition, other mechanical property tests, such as the indirect tensile strength test, were included to find the anticipated change in the developed mixes. Indexes of Volumetric and mechanical Properties Test of Surface Coarse according to GSRB [15] as show in table 8.

Table 8 Indexes of Volumetric and mechanical Properties Test of Surface Coarse according to GSRB

Index	GSRB limits	Test method
Bulk density	-	ASTM D2041/D2041M[27]
Air Void (%)	3- 5	
Void Mineral Aggregate (%)	>14	
Stability Value KN	> 8	ASTM D6927[28]
Flow Value, mm	2- 4	
Rutting depth (mm)	-	BS EN 12697-22[29]

4. Results and Discussion

4.1 Volumetric Test Results

Figure 3 show that the Comparing modified Hot Mix Asphalt (HMA) to conventional HMA, the study provides that adding the additive often reduces HMA's density. With 2% additions of types P1, P2, and P3, there are exceptions, though, since they exhibit an insignificant density rise. Although not as much, densities are still decreasing when the additive dosage is increased from 2 to 6%. Air void expansion and particle movement are facilitated by the lubricating properties of the asphalt emulsion. Asphalt viscosity and content rise as the percentage of asphalt emulsion increases. As the improver is added, palm leaves fibers raise and increase particle friction and air spaces are reduced as show in figure 4. Asphalt emulsion reduces. Characteristics of air voids, which are essential to the performance and durability of asphalt mixtures, mirror this behavior.

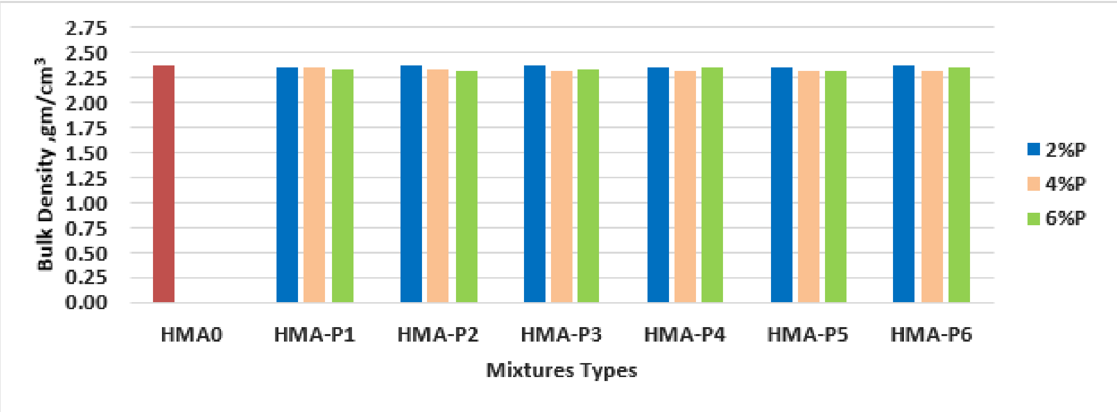

Figure 3 Bulk density results for different mixes

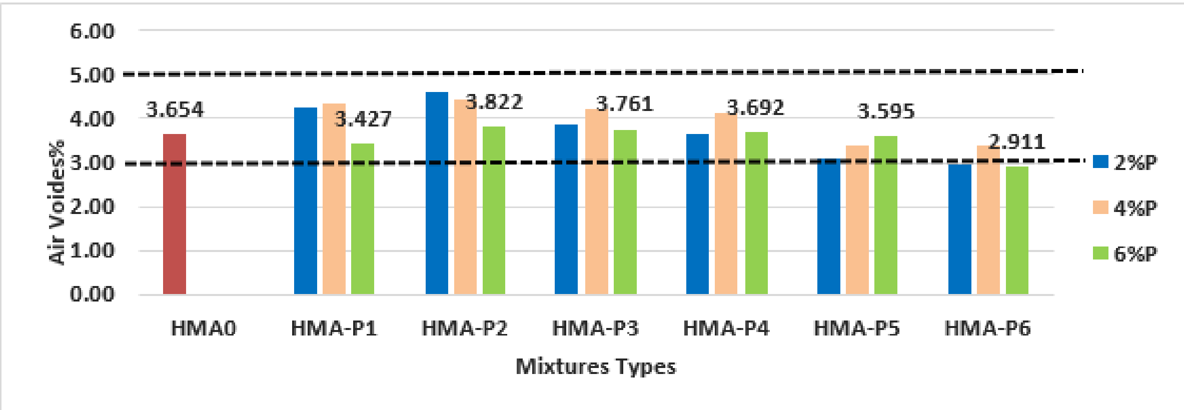

Figure 4 Air Void results for different mixes

The trend shown in Figure 5 shows that the addition reduces the Voids in Mineral Aggregate (V.M.A.) in modified Hot Mix Asphalt (HMA) as compared to conventional HMA. There is a little increase at 2% additions, but V.M.A. falls as the modifier increases further. There is a slight increase at 4% and 6% additions, with the majority of results reaching the minimum necessary level of 14% for V.M.A. In a similar, Figure 6 shows that the addition in modified HMA reduces Voids Filled with Asphalt (V.F.A.) as compared to regular HMA. There is a slight increase for 2%, 4%, and 6% additives, with the majority of results satisfying the minimal requirements of 70-85% for V.F.A.

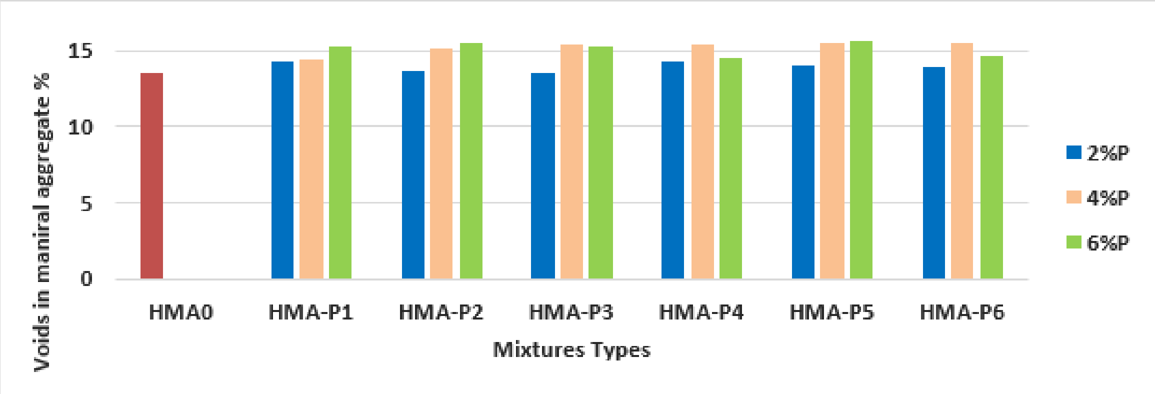

Figure 5 V.M.A% results for different mixes

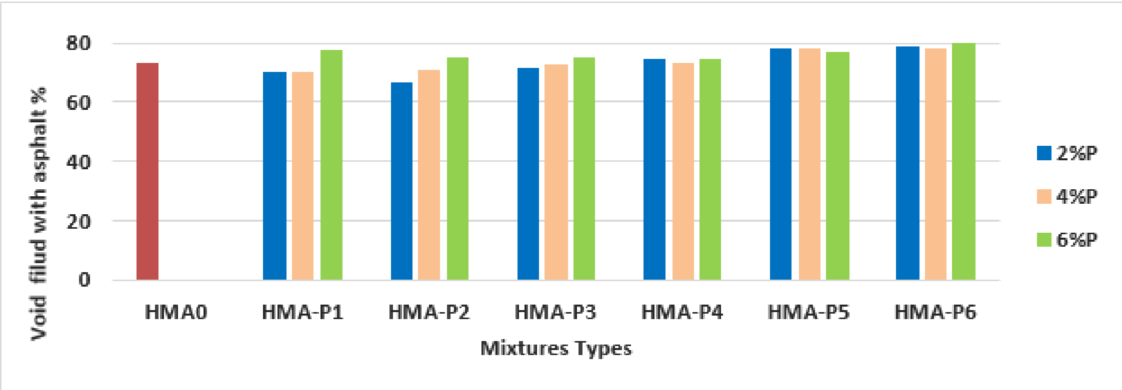

Figure 6 V.F.A% results for different mixes

4.2 Mechanical characteristics

4.2.1 Marshall Test Results

Figure 7show the results stability of HMA and improved HMAs indicate that high stability from the traditional HMA is achieved when including the additive comparison between the traditional HMA and the improved HMAs by (2 and 4%) additives. While the stability values continue to fluctuate, the 6% additives shown an ongoing increase in enhanced content. Additionally, the results demonstrated that for all types of mixes, the enhanced HMAs values were greater than the minimum required limits (> 8KN). Conversely, Figure 8 show the results of Marshall flow has an optimal value at mixture p5 for the (2,4, and 6%) additives and the lowest flow values for the improved mixtures are for the HMA-P5 mixture, which is considered the best hot asphalt mixture improved with palm leaves fibers in terms of stability and flow., which are connected with their microstructure and roughness for the fibers' ability to absorbed bitumen. Additionally, the percentage of the emulsion in relation to the fiber in the mixtures.

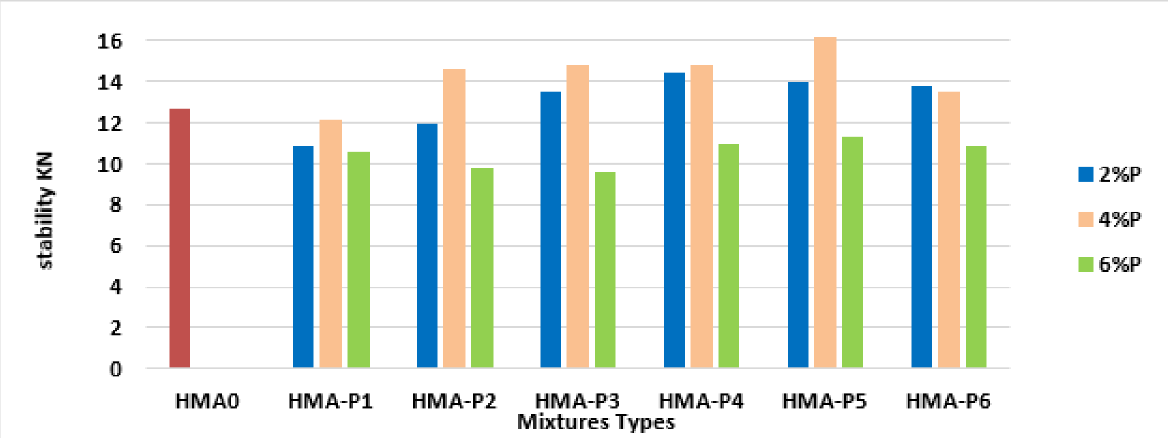

Figure 7 Stability results for different mixes

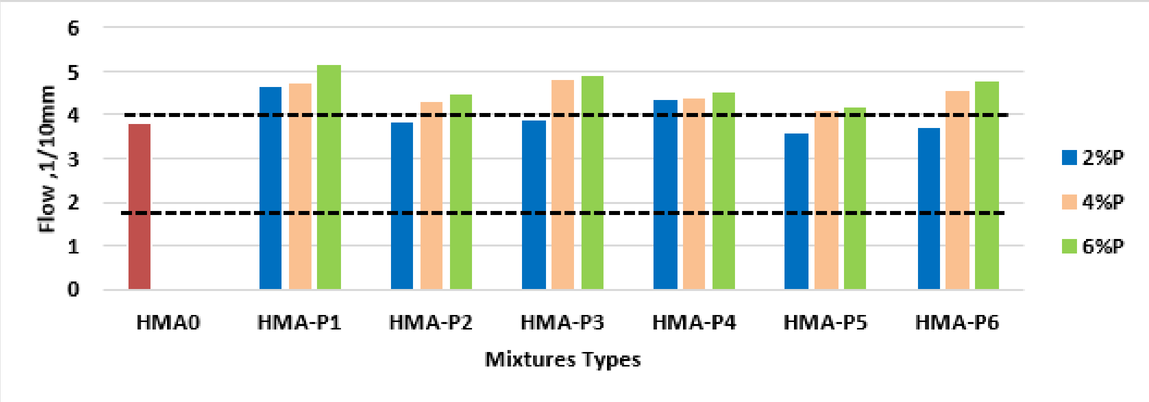

Figure 8 Flow results for different mixes

4.2.2 Wheel Track Test

The findings of the wheel track test provide information about the impact of PLF in HMAs, the superiority of MHMA over HMAs, and the importance of PLF introduction in HMAs. It is possible to interpret all of these facts as previously indicated in relation to the stability behavior of such mixtures. The results as show in figure 9 revealed several key findings regarding the effects of Modified by (PLF) in Hot Mixtures Asphalt (HMAs), the advantages of Modified Hot Mixtures Asphalt (MHMAs) over HMA, and the significance of introducing PLF in HAMs. MHMAs was found to exhibit superior stability compared to traditional HMA mixes, with PLF contributing additional benefits in terms of resistance to permanent deformation. Optimal rutting resistance was observed in HAM mixes with HMA-P5,6% PLF content, showcasing a significant reduction in rut depth compared to control HMA mixes as 43.48%. The high resistance to permanent deformation attributed to PLF can be explained by its strong contact and bonding with asphalt, which enhances the stiffness, elasticity, and viscosity of the asphalt binder. The presence of cellulose fibers in PLF further reinforces the asphalt mixture, improving cohesion and interlocking between aggregate particles. This reinforcement promotes more uniform load distribution, inhibits crack development and propagation, and prevents moisture-induced pavement weakening. Overall, the incorporation of PLF strengthens the asphalt matrix, effectively increasing resistance to permanent deformation and cracking in HMAs

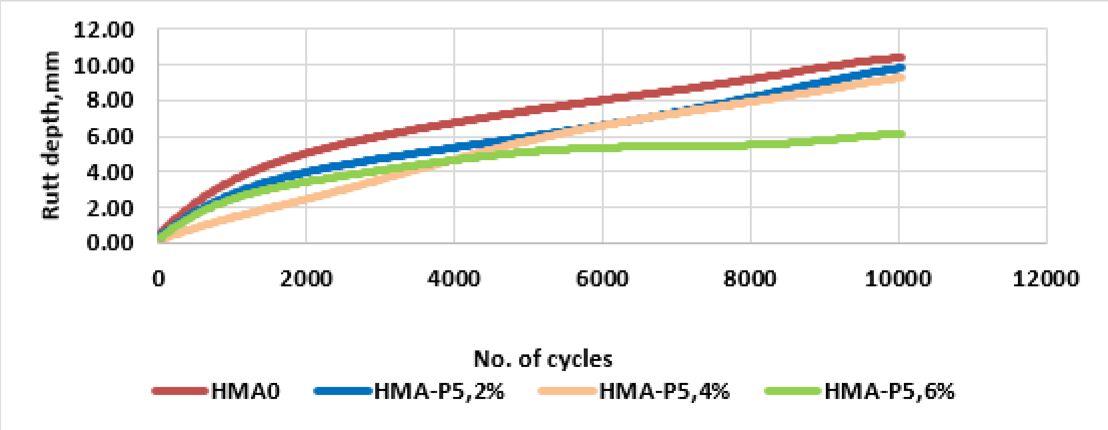

Table 9 Rutting Depth verse Cycle Number for HMA comprising PLF

As shown in Figure 10, the enhanced rutting resistance of modified HMA is attributed to the improved dynamic stability of HMA-P5,6% compared to conventional HMA by about 90.46%.

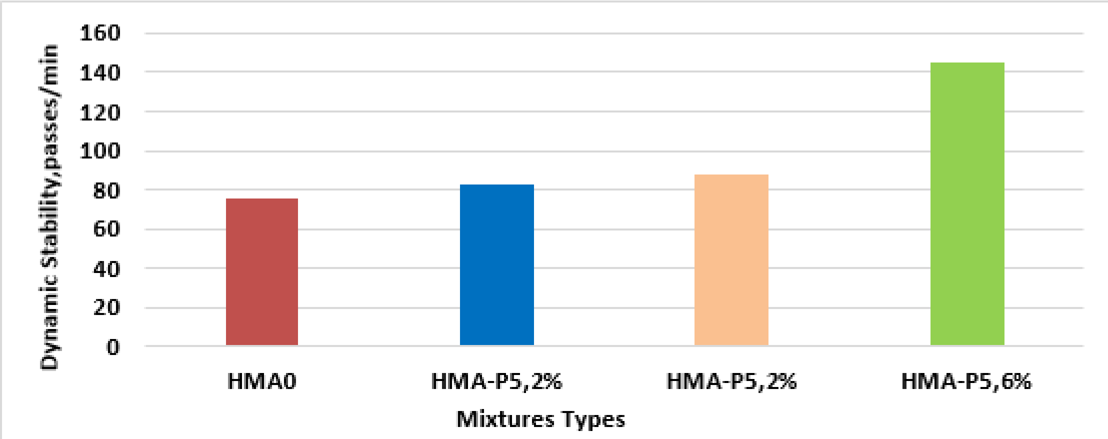

Table 10 Dynamic Stability results of HMA and HMA-P5

4. Conclusions

From the above results, it can be concluded that:

1. Marshall Stability (MS) is significantly impacted by the addition of PLF to HMA. But the stability flow connection makes this fact abundantly evident.
2. When tested by a wheel track equipment, the rutting resistance of HMAs is significantly impacted by the addition of PLF.
3. PLF might enhance HMA even further. The results of the experimental lab work show that 6% by weight of aggregate was the ideal proportion of PLF that forms as small modified balls (P5). The greatest anticipated gain in Marshall Stability and rutting resistance was brought about by this amount.
4. The maximum resistance to rutting was combined with the maximum dynamic stability of 6% for HMA-P5. which provide more evidence for the advancements made.

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