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Investigating the impact of different loading patterns on the permanent deformation behaviour in hot mix asphalt

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HIGHLIGHTS

- Permanent deformation depends on the loading patterns and testing parameters.
- Power-law model can be used to analyze the permanent deformation characteristic.
- An increase in rest period and loading duration leads to a higher permanent deformation.

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ABSTRACT

This research was conducted to evaluate the effect of different loading combinations on the permanent deformation behaviour in asphalt mixtures. Therefore, repeated loading permanent deformation test was performed considering different stress levels, loading durations, rest periods and testing temperatures. The results showed that the slope coefficient of Power-law model has a more influence on permanent deformation compared to intercept. Moreover, rutting zones are sensitive to testing parameters. Rest period could significantly affect the first zone. Nevertheless, secondary zone depends on the loading duration and deviator stress. Eventually, the testing temperature has the greatest influence on the permanent deformation behaviour.

1. Introduction

Permanent deformation in Hot Mix Asphalt (HMA) occurs predominantly at higher temperatures [1]. This distress mostly occurs in the upper layers than the subgrade when the traffic volume, tire pressure and axle loads are increased [2]. Development of permanent deformations reduce the service life of asphalt pavements. Furthermore, this distress could decrease the level of safety in road transportation networks [3].

Various laboratory tests have been introduced to study the resistance of HMA against permanent deformations [3–7]. Accordingly, the development of permanent deformation models is useful to predict the response of asphalt layers under traffic loading [8].

Among different test methods, NCHRP Project 9–19 [9] has assessed Flow Time (FT), Flow Number (FN) and Dynamic Modulus (|E*|) in order to determine a simple performance test to study the permanent deformation resistance in asphalt mixtures. According to these test methods, researchers found that the FN could be considered as a better method to evaluate the rutting resistance of HMA [4,10–12]. In addition, Faheem et al. [13] indicated that the FN is one of the most important characteristics of HMA, which has a considerable correlation with Traffic Force Index (TFI). This index shows the density of traffic during service life of asphalt pavements. Nowadays, the FN that can be obtained from Repeated Loading Permanent Deformation (RLPD) test is widely employed as an accelerated performance test by different researchers [12,14].

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The RLPD test is widely used to assess the permanent deformation characteristics of HMA since it was utilized by Monismith et al. [15] in the mid-1970. Generally, in this test method a dynamic compressive loading pulse at high temperature conditions is applied to cylindrical specimens until their failure point (i.e. FN number). [8,12,16,17]. During this test, the accumulated permanent deformation is recorded as a function of loading cycles (Fig. 1).

The accumulated permanent strain includes three different zones: primary, secondary and tertiary [8,12,18–20]. In primary zone, the accumulated permanent deformation grows rapidly until reaches the onset of secondary zone. Upon starting the secondary zone, the rate of permanent strain per cycle is reduced to achieve a constant value. In this stage, the accumulated permanent deformation grows as a linear equation until the start of the tertiary zone. In the third stage, the accumulated permanent deformation per loading cycles begins to increase rapidly until the failure in the material reaches. The starting point of this stage is called as FN [1,9,21]. As it was mentioned previously, the FN value has been recommended as a rutting resistance indicator for HMA [8].

Selecting the parameters of RLPD test can be considered as one of ambiguous points in this procedure. In this regards, Table 1

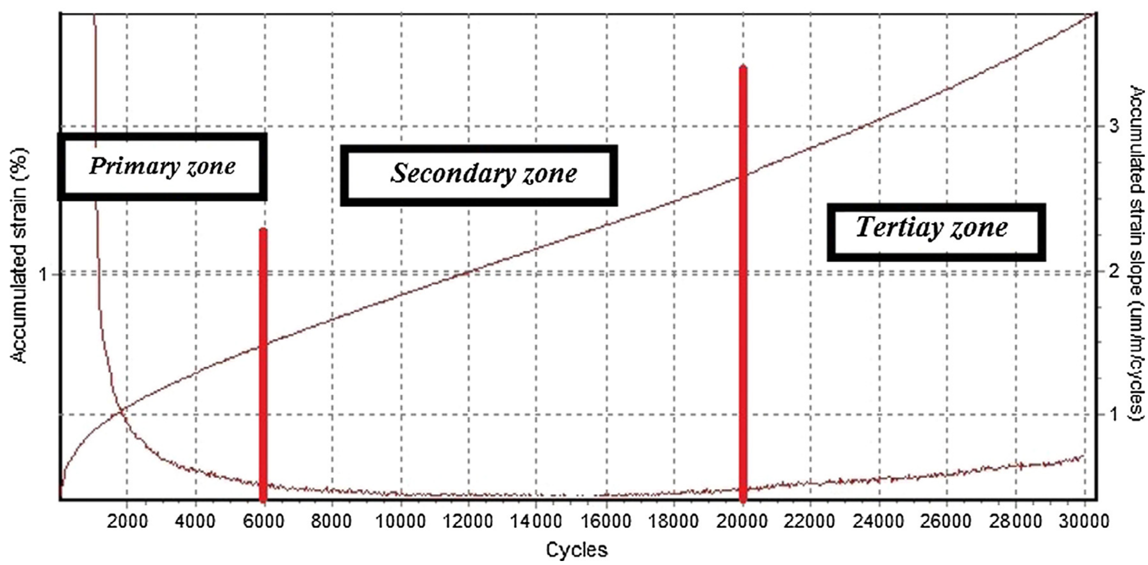

Fig. 1. Typical relationship between accumulated permanent strain, accumulated strain slope and number of cycles under a RLPD test.

Table 1
Parameters employed by previous researchers in RLPD test. (See below-mentioned references for further information.)

	Test type	Temperature	Confining pressure	Deviator stress	Loading pattern	References
NCHRP Project 9-19	Unconfined RLPD test	54 °C	0	70 - 210 kPa	Haversine waveform, 0.1 s loading duration and 0.9 s rest period	[12], [22]
	Confined RLPD test	54 °C	35 – 210 kPa	490-980 kPa		[23]
NCHRP Project 9-33	Unconfined RLPD test	-	0	600 kPa		[24]
NCHRP Project 9-30A	Confined RLPD test	-	69 kPa	483 kPa		[25]
NCHRP Project 673	Unconfined RLPD test	-	0	600 kPa		[12]
NCHRP Project 719	Confined RLPD test	-	69 kPa	482 kPa		[12]
Kaloush et al.	Unconfined RLPD test	37.8 and 57.4	0	68.9, 137.9 and 206.8 kPa		[26]
Zhou et al.	Unconfined RLPD test	40	0	138 kPa		[8]
Biligiri et al.	Unconfined RLPD test	40	0	600 kPa		[27]
Ameri et al.	Unconfined RLPD test	45	0	200 kPa		[28]
Qi et al.	Unconfined RLPD test	38 and 55 C	0	69 and 137 kPa	Loading duration: 0.1, 10 and 1000 second Rest period: 0.9, 10 and 1000 second	[3]
Australian: AS 2891.12.1	Unconfined RLPD test	-	0	200	Square pulse using 0.5 s loading duration and 1.5 s rest time	[29]
British: DD 226	Unconfined RLPD test	-	0	100	Square pulse using 1 s loading duration and 1 s rest time	[30]
European: pr EN 12697	Unconfined RLPD test	-	0	100	Square pulse using 1 s loading duration and 1 s rest time	[31]
VESYS manual	Unconfined RLPD test	-	0	138	Haversine pulse using 0.1s loading duration and 0.9 s rest time	[32]