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Wide Base Tire (WBT) load's impact on fatigue cracking of flexible pavement - Based on the Michigan Mechanistic-Empirical (ME) design method

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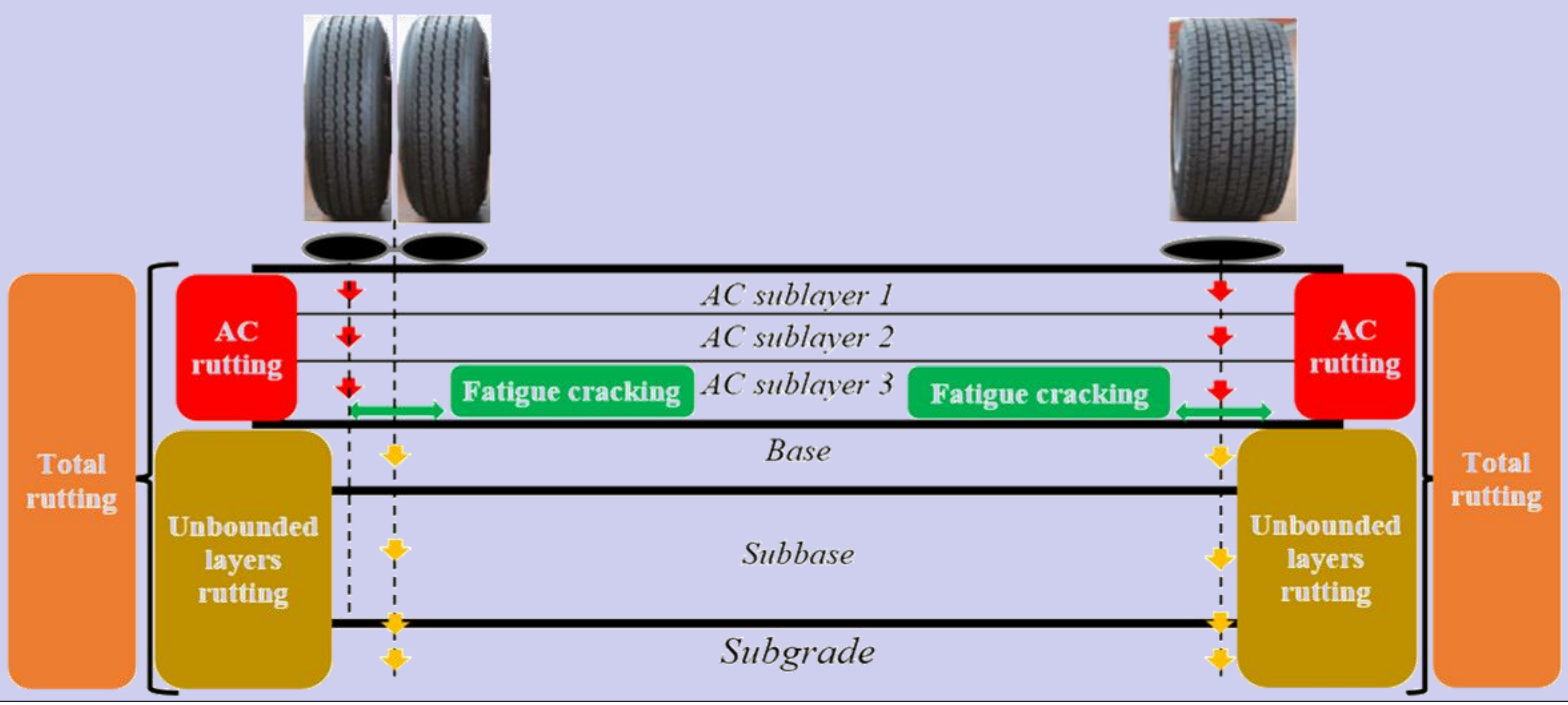
1. Background Introduction

- Wide-base tires (WBT), due to the significant saving in energy consumption and simple mechanical load assembly, are increasing progressively in truck axles in many states of the US.
- Most research has failed to consider the range of WBT proportion and AC thickness impacts, which does not lend itself well to the practical pavement design process.
- The WBT loads' impact on pavement fatigue is not well quantified. Existing Pavement ME analysis procedures cannot directly assess the effects of WBTs on pavement response and ultimate pavement performance prediction.
- This study was commissioned to identify the impact of wide-base tire (WBT) loads on the flexible pavement's fatigue cracking using the Michigan Mechanistic-Empirical pavement design (MEPD) method.

2. Research methods and design parameters setup



$$FC_{Bottom-up,50\%} = \frac{100}{1+e^{(C_1 \times C_1' + C_2 \times C_2' \times log_{10}(100D))}}$$

Where: C_1=0.5; C_2=0.56; $C_2' = -2.40874 - 39.748 \times (1+T_{AC})^{-2.856}$; C_1' =-2C_2'; T_{AC} is the total AC thickness, inch.

$$D = \frac{1}{N_f} = \frac{1}{0.00432 \times 10^{4.84(\frac{V_b}{V_a+V_b}-0.69)} \times k_1 \beta_1 (\frac{1}{\varepsilon_t})^{k_2\beta_2} (\frac{1}{E})^{k_3\beta_3}}$$

Where: V_a is the asphalt mixture's air void; V_b is effective asphalt content; ε_t is AC bottom horizontal tensile strain; E is the elastic modulus of AC; k_1=0.007566; k_2=3.9492; k_3=1.281; $\beta_1 = \beta_2 = \beta_3$=1.

$$FC_{Bottom-up,95\%} = FC_{Bottom-up,50\%} + S_e \times Z_{95}$$

Where: S_e is the standard error, and $S_e = 0.7874 + \frac{17.817}{1+e^{0.0699-0.4559 \times log_{10}(100D)}}$; Z_{95} =1.65

Table. Factors and levels in the orthogonal design

Level	T_{AC-top} (A) (inch) *	E_{AC-top} (B) (psi)	$T_{AC-leveling}$ (C) (inch)	$E_{AC-leveling}$ (D) (psi)	$T_{AC-base}$ (E) (inch)	$E_{AC-base}$ (F) (psi)
1	2	250,000	2	250,000	2	250,000
2	3	300,000	3	300,000	3	300,000
3	4	350,000	4	350,000	4	350,000
4	5	400,000	5	400,000	5	400,000
5	6	450,000	6	450,000	6	450,000

3. WBT loads' impact on fatigue cracking analysis

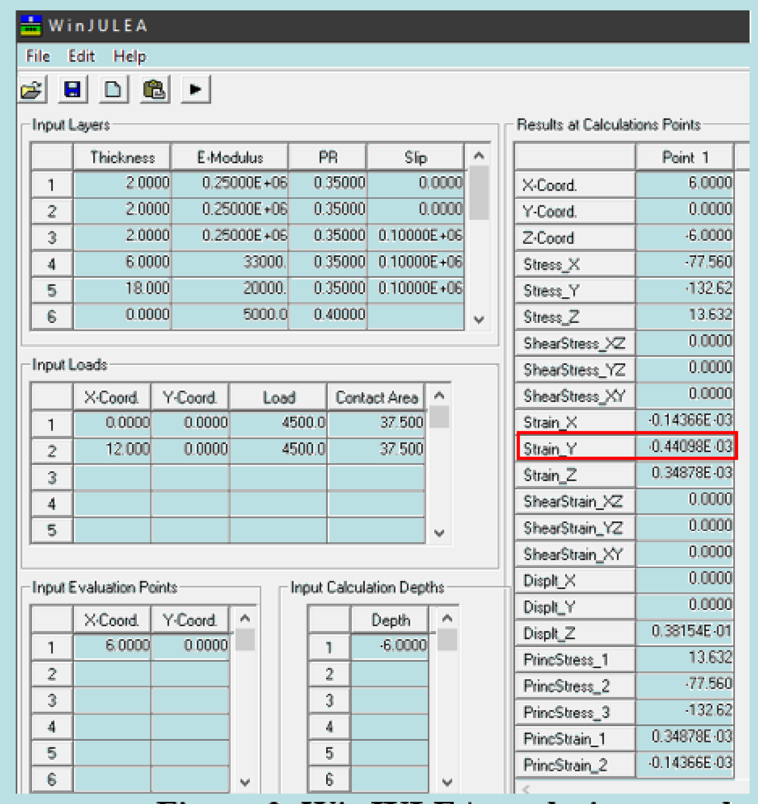


Figure 2. WinJULEA analysis examples:

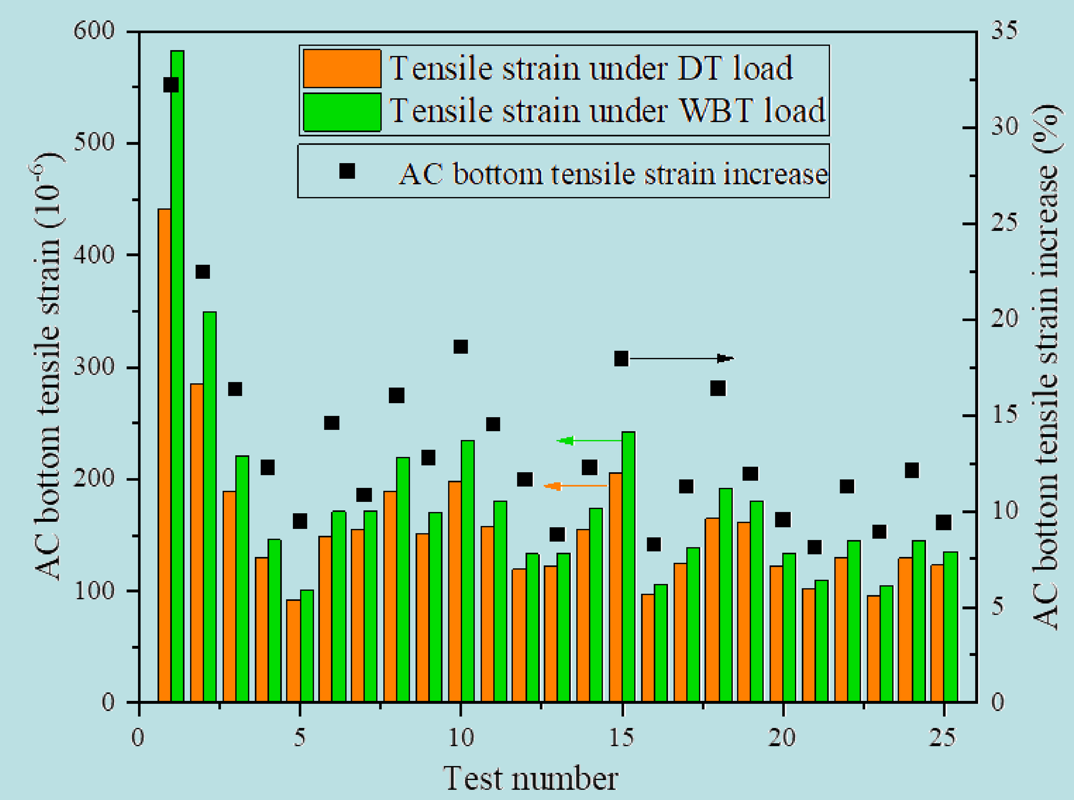


Figure 3. Comparison of AC bottom tensile strain under DT and WBT loads

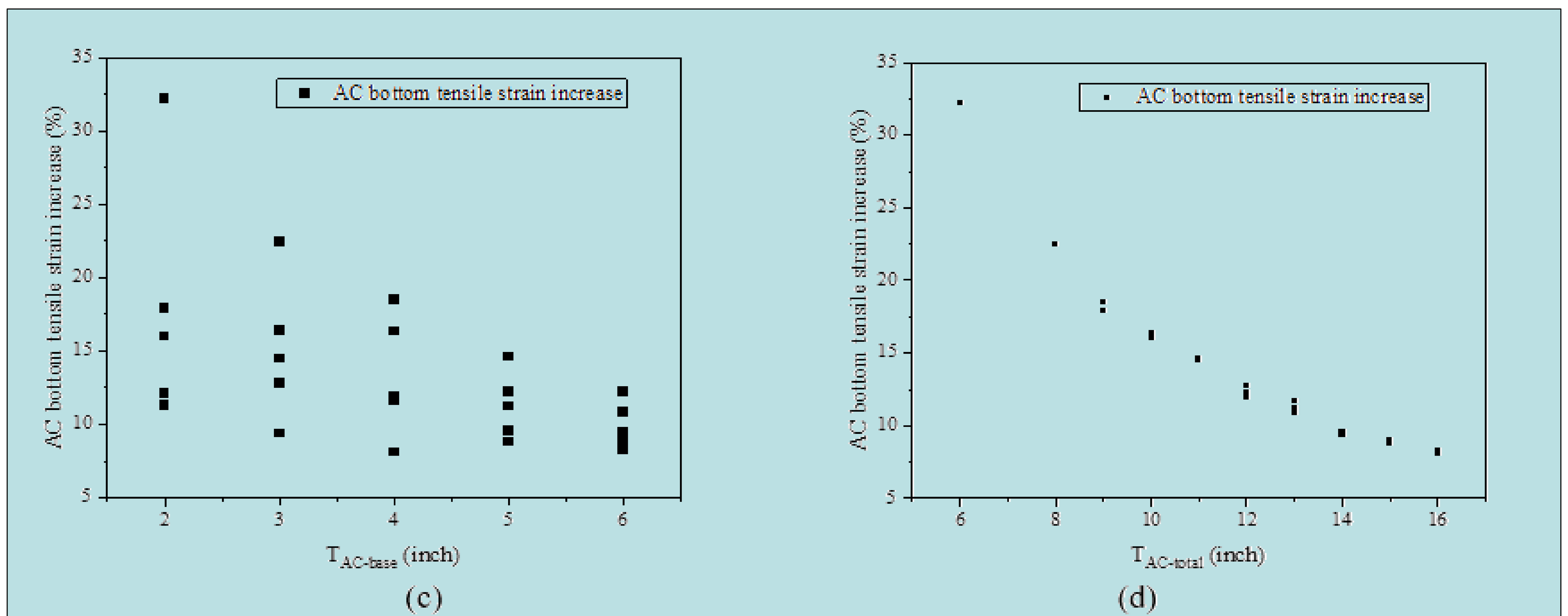


Figure 4. Relationship between AC thickness parameters and tensile strain increase with x-axle thickness of (a) AC-top layer, (b) AC-leveling layer, (c) AC-base layer, (d) Total AC layer

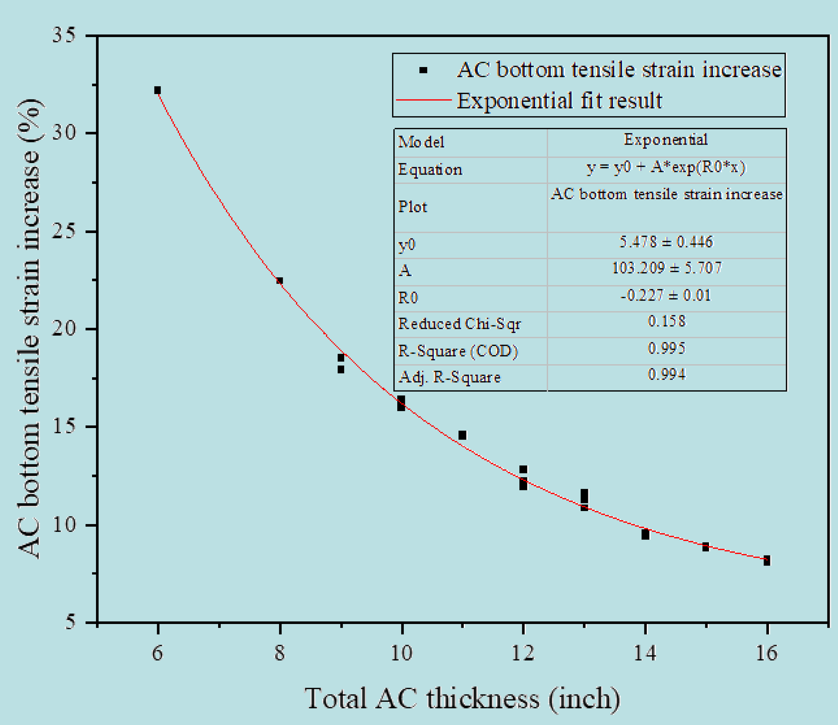


Figure 6. Fitting result of AC bottom tensile strain increase

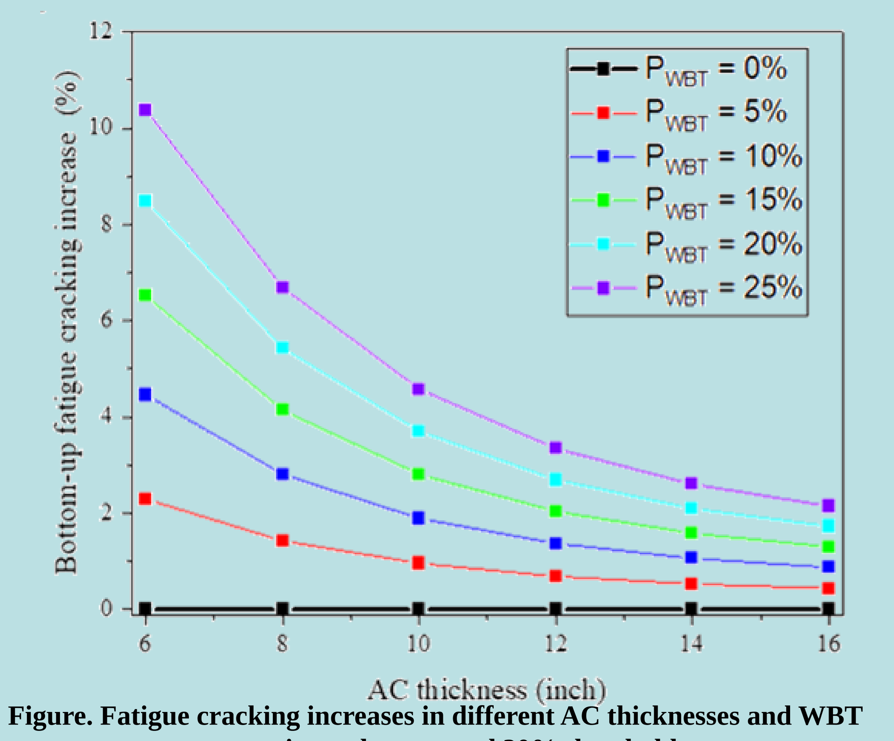


Figure. Fatigue cracking increases in different AC thicknesses and WBT proportions when around 20% threshold

$$R_{D-PWBT} = (1-0.01P_{WBT}) + R_{D-100WBT} \times 0.01P_{WBT}$$
$$= (1-0.01P_{WBT}) + 0.01 \times P_{WBT}(1.05478 + 1.03209e^{-0.227T_{AC}})^{3.9492}$$

Where, $P\Delta\varepsilon_t$ is the AC bottom tensile strain increase from under DT load to WBT load, %; T_{AC} is the total AC thickness, inch. R_{D-PWBT} is the damage index ratio in P_{WBT}, P_{WBT} is the percentage of WBT load in a certain area, %.

Adjusted bottom-up cracking threshold = 20 – (0.01distress increase) × 20

Table. Adjusted flexible pavement fatigue design threshold

Variables		Adjusted fatigue design threshold (%)					
		AC thickness (inch)					
		6	8	10	12	14	16
WBT proportion (%)	5	19.54	19.71	19.81	19.86	19.89	19.91
	10	19.11	19.44	19.62	19.73	19.79	19.83
	15	18.70	19.17	19.44	19.59	19.68	19.74
	20	18.30	18.91	19.26	19.46	19.58	19.65
	25	17.93	18.66	19.08	19.33	19.48	19.57