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Study on the Freeze-thaw Cycle Durability of Bamboo Fiber Asphalt Mixture

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Introduction & Objective

Background

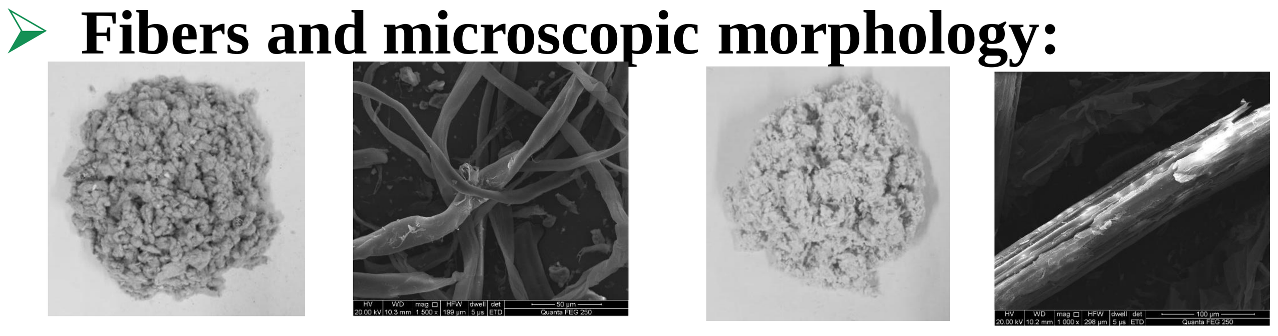
- Lignin fiber widely used in asphalt mixture is derived from logs, and its large-scale production and application will consume a lot of forest resources.
- It is urgent to find green and renewable plant fibers to replace lignin fiber.
- Bamboo is a good substitute for lignin fiber because of its rapid growth characteristic and good physical and mechanical properties.

Objective

- Evaluate the freeze-thaw cycle durability of bamboo fiber asphalt mixture and study the damage evolution law of bamboo fiber asphalt mixture during freezing-thawing.
- Establish freeze-thaw damage evolution model and propose the estimation method for the remaining life of freeze-thaw damage of bamboo fiber asphalt mixture.

Materials & Methods

- **Asphalt:** Styrene-butadiene-styrene **(SBS)** modified asphalt.
- **Fibers and microscopic morphology:**

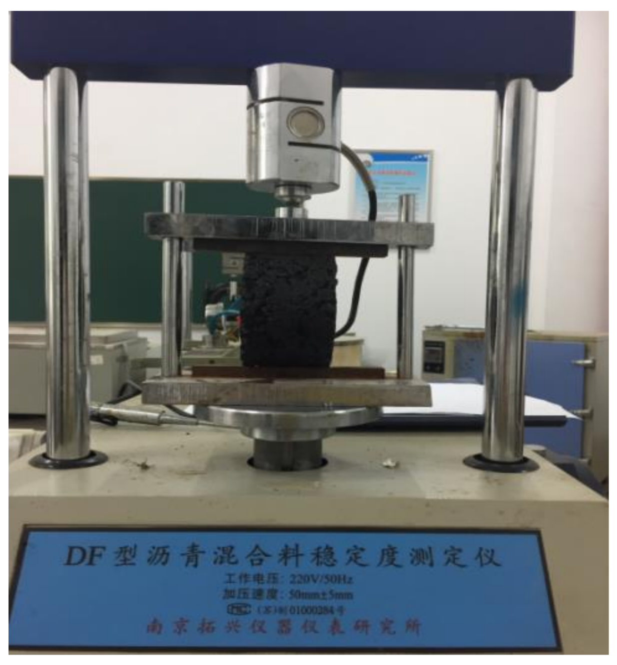


(a) Lignin fiber **(b) Bamboo fiber**

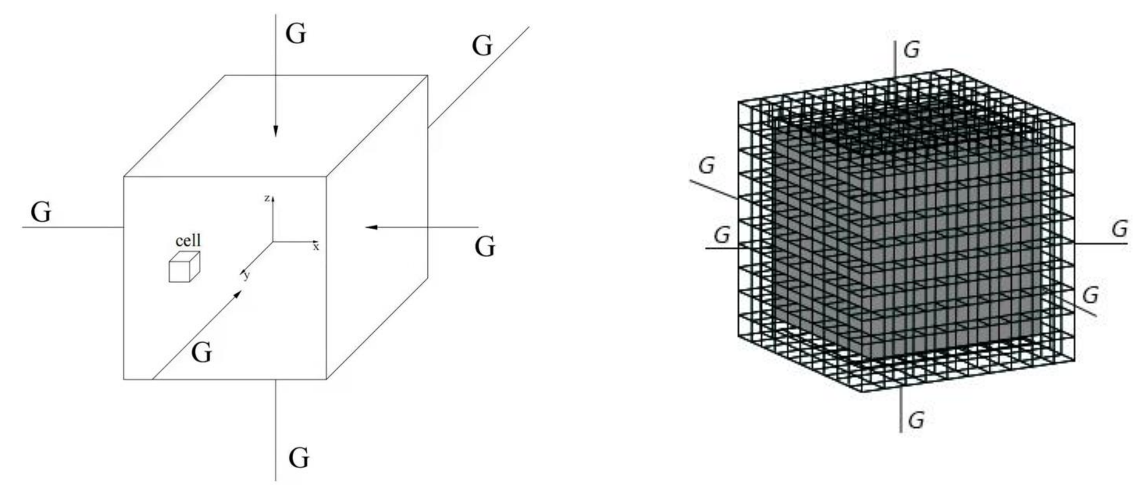
- **Aggregate gradation of asphalt mixture:**

Mixture type	Mass fraction pass each sieve ,mm										
	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
AC-13	-	100.0	95.5	80.0	46.5	35.8	26.0	19.3	14.0	10.6	7.4
AC-16	100.0	99.2	88.0	72.2	46.0	35.1	23.8	15.7	11.0	9.1	6.3
SMA-13	-	100.0	91.9	63.9	24.7	20.8	17.7	15.4	13.7	12.6	10.0
SMA-16	100.0	95.0	70.0	51.4	27.7	21.8	18.2	15.4	12.7	11.6	10.5

- **Test device:** According to the specification JTG E20-2011, cylindrical specimens for splitting tests under different freeze-thaw cycles.



- **Establishment of freeze-thaw damage evolution model:**



$$E_{(D)} = E_{(\omega)}/V_0 = N^{-3}\sum_{i=0}^{N/2-1}(6N^2 - 24iN + 24i + 8)\times\left\{1 - \exp[-(\lambda_0 t - \frac{ivt}{N/2-1})^{\alpha}]\right\}$$

$$\lambda_0 = \frac{\sqrt[\alpha]{-\ln(1-D)}}{t} \qquad D_n = (1 - \frac{I_n}{I_0})\times 100\%$$

Results & Discussions

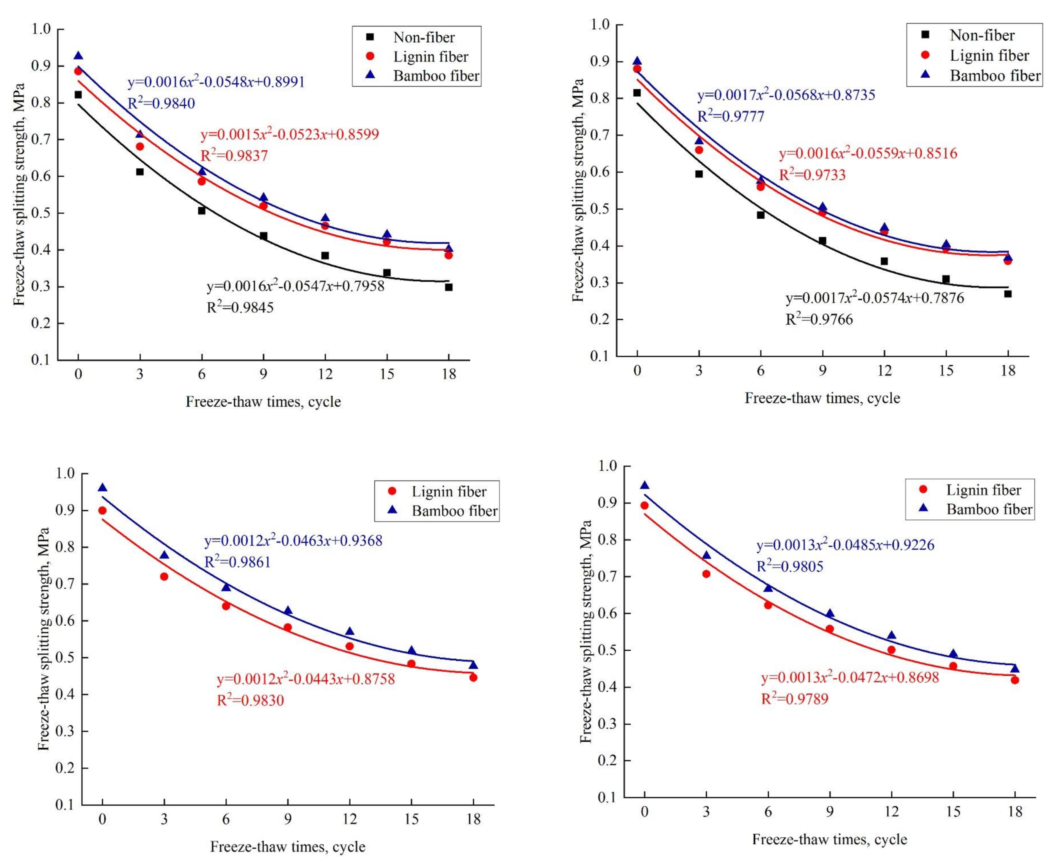


Fig 1. Freeze-thaw splitting strength test results of each fiber asphalt mixture under different freeze-thaw cycles.

- (a) AC-13 (b) AC-16
- (c)SMA-13 (d)SMA-16

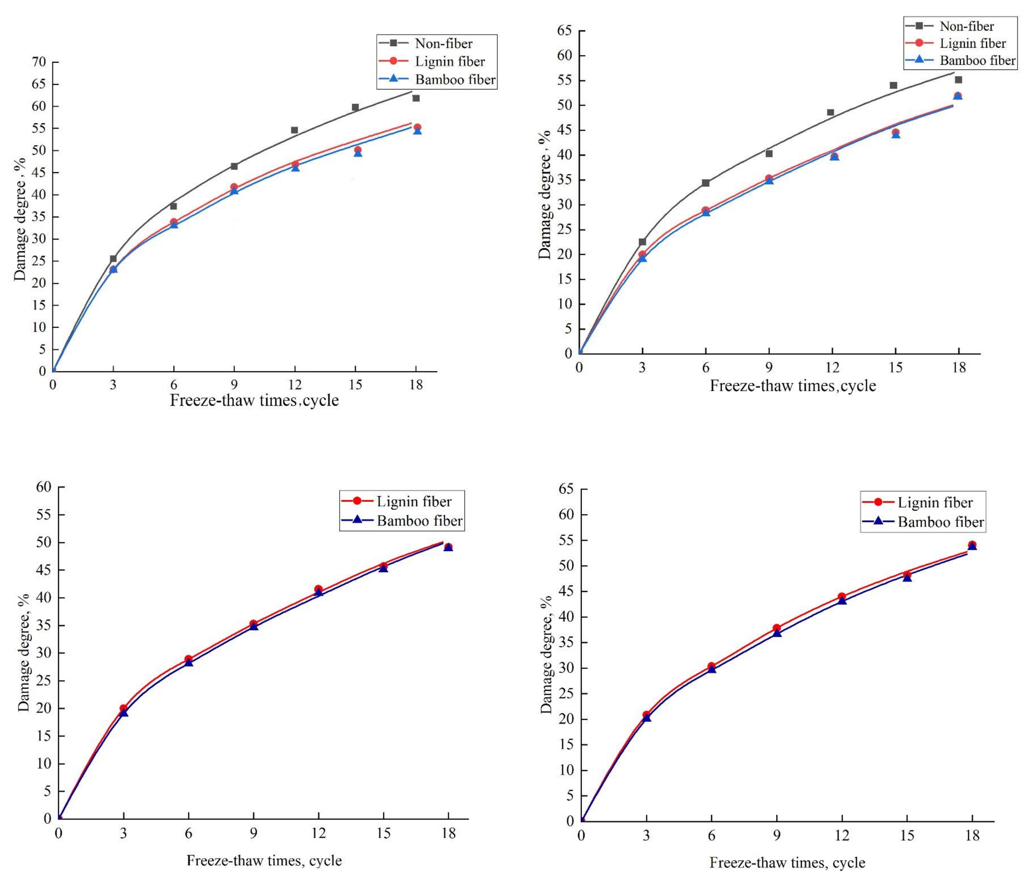


Fig 2. Comparison of measured and fitted values of fiber asphalt mixture damage evolution..

- (a) AC-13 (b) AC-16
- (c)SMA-13 (d)SMA-16

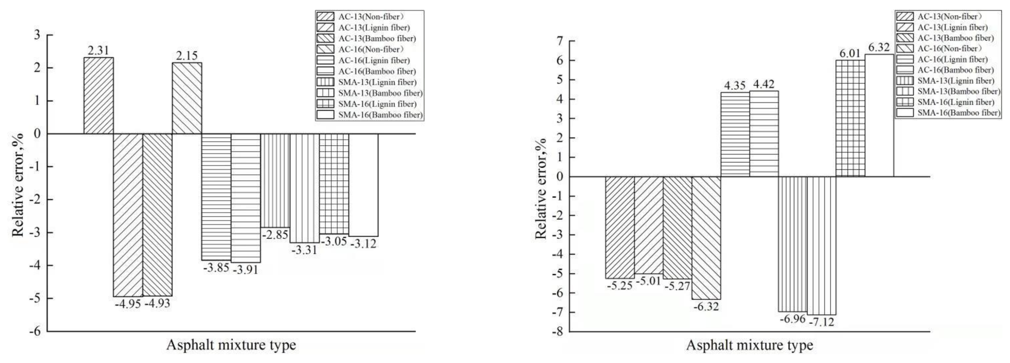


Fig 3. Relative error of fitting model for 15th and 18th freeze-thaw cyclest.

Table 1. Fitting results of damage evolution model parameters.

Gradation type	Fiber type	Correlation coefficient	Model parameter		
			α	λ_0	v
AC-13	Non-fiber	0.986	0.5616	0.0735	3.2226×10^{-7}
	Lignin fiber	0.986	0.5511	0.0655	-3.8444×10^{-7}
	Bamboo fiber	0.985	0.5233	0.0673	-3.1148×10^{-7}
AC-16	Non-fiber	0.981	0.5600	0.0790	3.9866×10^{-7}
	Lignin fiber	0.990	0.5552	0.0688	3.4226×10^{-7}
	Bamboo fiber	0.982	0.5533	0.0680	3.1326×10^{-7}
SMA-13	Lignin fiber	0.987	0.5186	0.0533	4.6767×10^{-7}
	Bamboo fiber	0.986	0.5451	0.0513	-3.3094×10^{-7}
SMA-16	Lignin fiber	0.980	0.5412	0.0550	3.2566×10^{-7}
	Bamboo fiber	0.981	0.5398	0.0539	3.6985×10^{-7}

Conclusions

- The smaller the void ratio of fiber asphalt mixture, the thicker the asphalt film, the denser the structure, and the better its freeze-thaw cycle durability. The freeze-thaw cycle durability of the SMA gradation mixture is better than that of the AC gradation mixture.
- The established freeze-thaw damage evolution model can reflect the evolution law of freeze-thaw damage of bamboo fiber asphalt mixture, and the practical significance of model parameters is analyzed.
- The actual freeze-thaw time when the splitting strength damage reaches 25% can be used as the freeze-thaw resistance life of the bamboo fiber asphalt mixture.