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3D printed rubber modified asphalt as sustainable material in pavement maintenance

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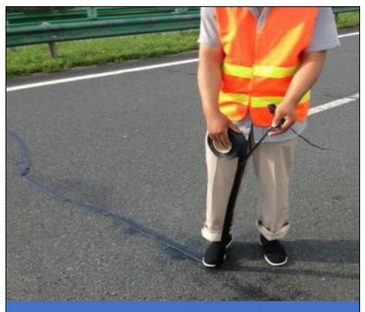
Introduction

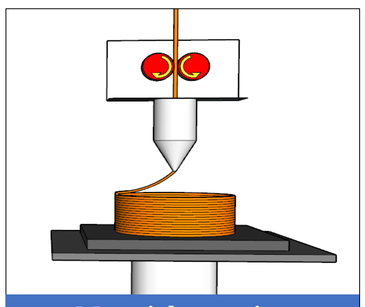
- Insufficiency of traditional pavement maintenance methods

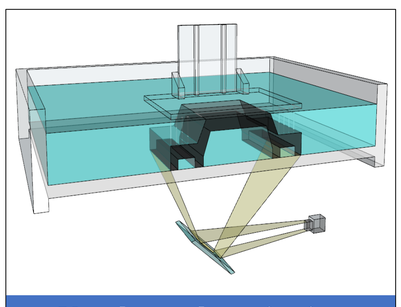

Manpower dependence

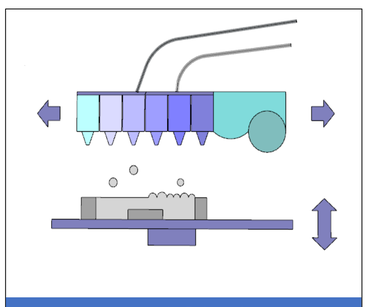

Poor safety


Low accuracy

- Automation, precision, and speed of 3D printing technology


Material extrusion


Vat photopolymerization


Material jetting

- Advantages of 3D printing in pavement maintenance
  - Improve the automation and standardization level of road engineering
  - Ensure the safety of workers
  - Enhance the adaptability to climate change

Objectives

- Prepare and optimize 3D printed asphalt (3DPA) with good high-temperature performance and printability by utilization of waste rubber powder.
- Analyze the conventional properties of rubber modified 3D printed asphalt (R-3DPA) according to the basic properties tests.
- Determine the recommended printing temperature and speed of R-3DPA according to the printability tests.

Materials and methods

Test design of 3DPA

Mesh selection of CR	Test number	A_1	A_2	A_3	A_4	A_5	A_6
	Mesh	40	60	80	100	120	150
	Content of CR (%)	18	18	18	18	18	18
	Content of C_9PR (%)	0	0	0	0	0	0
Content determination of CR	Test number	B_1	B_2	B_3	B_4	B_5	B_6	B_7
	Mesh	80	80	80	80	80	80	80
	Content of CR (%)	0	5	11	14	18	21	25
	Content of C_9PR (%)	0	0	0	0	0	0	0
Content determination of C_9PR	Test number	C_1	C_2	C_3	C_4			
	Mesh	80	80	80	80			
	Content of CR (%)	18	18	18	18			
	Content of C_9PR (%)	0	2	4	6			

Group A–CR mesh selection Group B–CR Content determination Group C-C_9PR content determination


SBS modified asphalt

Water damage resistance
Aging resistance

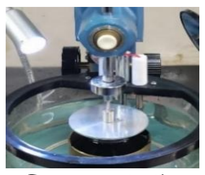

Crumb Rubber (CR)

Elastic properties
Large viscosity
Buildability


C_9 petroleum resin (C_9PR)

Compatibility
Fluidity
Extrudability

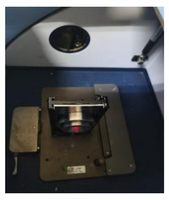
Optimize tests


Cone penetration

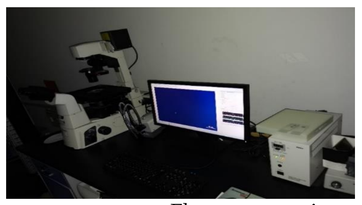

Elastic recovery rate

Needle penetration, softening point, ductility, rotational viscosity also be chosen as optimize tests.


Phase separation test

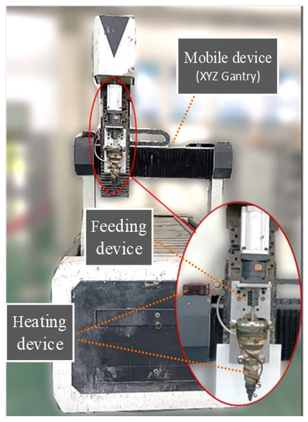

FTIR test


DSR test


Fluorescence microscope test

Basic properties tests


3D printer

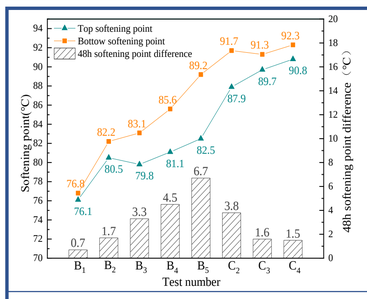


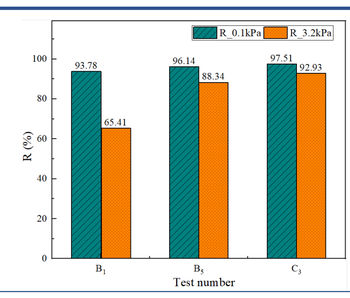
Printability tests

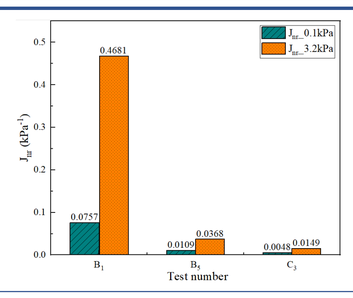
Results and discussion

- The high-temperature performance of R-3DPA could be improved by adding CR and C_9PR, but excessive C_9PR would have a negative effect.
- The elastic properties of R-3DPA could be effectively enhanced by CR, while C_9PR would play the opposite role, slightly.
- The 80 mesh, 18% CR, and 4% C_9PR are recommended as the optimal mesh and adding contents to prepare R-3DPA.

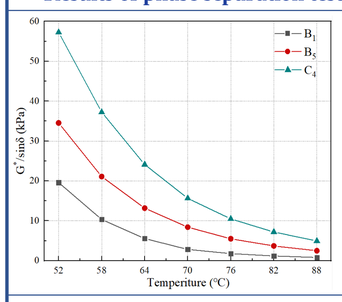
Results of optimize tests

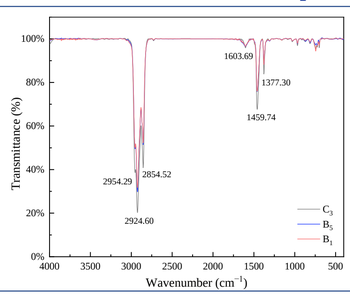


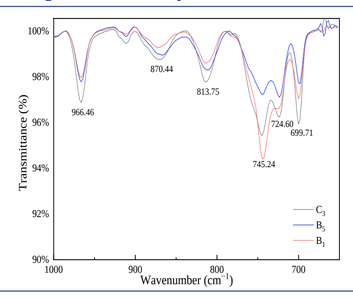




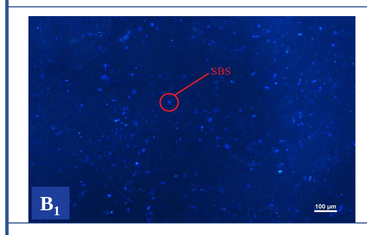
Results of phase separation test **Results of multiple stress creep and recovery test**

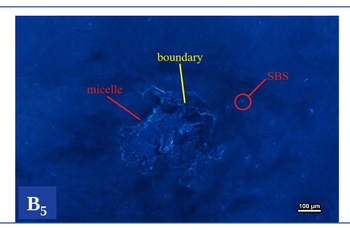


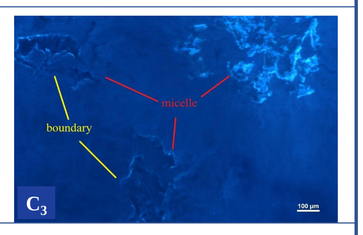




Results of temperature sweep test **Results of Fourier transform infrared spectroscopy test**



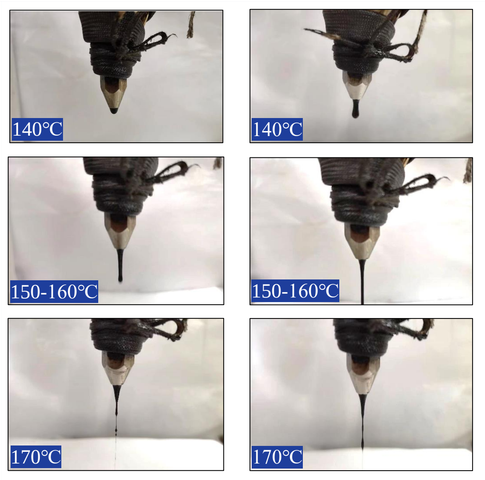


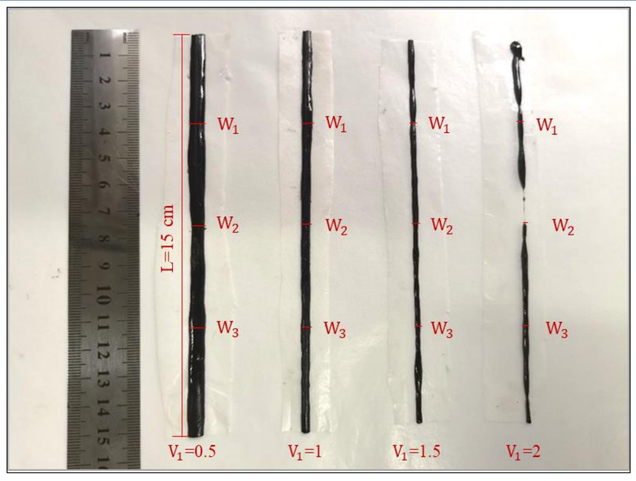


Results of fluorescence microscopy test

- Compatibility of R-3DPA could be effectively improved by C_9PR.
- Rheological properties of R-3DPA could be improved by CR and C_9PR.
- Physical modification occurs in the preparation of R-3DPA.

Results of basic properties tests





- R-3DPA can be extruded with good printability between 150℃ and 160℃.
- Width of R-3DPA filament printed at 1 cm/s presented optimal uniformity.

Results of printability tests

Conclusions

- R-3DPA has good viscosity, elasticity, compatibility, rutting resistance, and printability with 80 mesh and 18% of CR and 4% of C_9PR.
- C_9PR can play an effective compatibilization role in R-3DPA.
- Recommended printing temperature and speed of R-3DPA are 150~160℃ and 1 cm/s.

Acknowledgments

F. Y. Gong, X. J. Cheng, Y. Chen, Y. Liu, and Z. P. You, "3D printed rubber modified asphalt as sustainable material in pavement maintenance," Construction and Building Materials, vol. 354, p. 129160, 2022.