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Performance Evaluation of Coal Gasification Slag as an Alternative Filler in Asphalt Mortar

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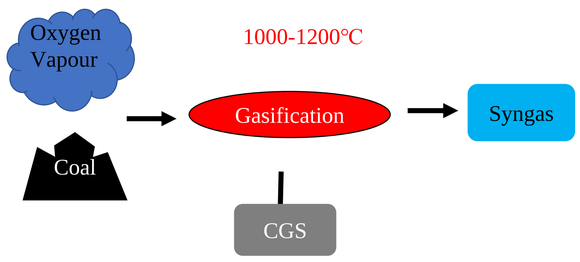
Introduction and Objective

Background



Byproduct during coal gasification process

Coal gasification slag (CGS)
- waste the land resources
- lead to serious environmental problems

Current fillers for asphalt mortar

Limestone powder (LM)
- nonrenewable
- expensive

Objective

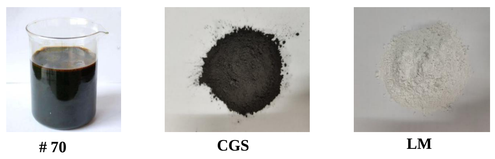
Use CGS as an alternative filler of LM in asphalt mortar

Explore the influence of CGS on the rheological properties of asphalt mortar

Sample Preparation and Experimental Method

Raw materials

- Base bitumen (#70)
- CGS
- LM



Preparation of asphalt mortar

✓ Asphalt mortar samples were prepared in the proportions: 50% of base bitumen, 50% of filler

✓ LM was replaced with CGS at 0%, 25%, 50%, 75%, and 100% in mass percentage

1. Base bitumen
2. Mix CGS and LM and preheat
3. Add the preheated fillers into the base bitumen and stir them at a speed of 1000rpm for 0.5h

Experimental method

- Particle size distribution
- XRD
- SEM
- Softening point test; Penetration test; Viscosity test
- Temperature scanning test; MSCR test

Result and Discussion

Particle size distribution of fillers

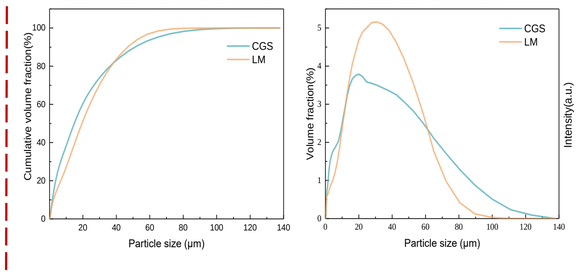


Fig. 1 Particle size distribution of the two fillers

Mineral compositions of fillers

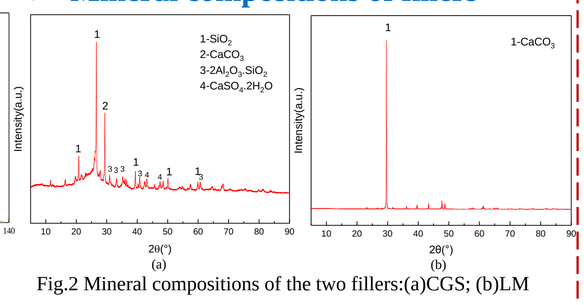


Fig.2 Mineral compositions of the two fillers:(a)CGS; (b)LM

CGS
- Smaller average particle size
- Wider size distribution
- More small-sized particles

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Increase the specific surface area of CGS

Increase the cohesive area between asphalt binder and CGS

LM — Calcite

CGS — Quartz, Mullite, Calcite

More stable in physical and chemical properties

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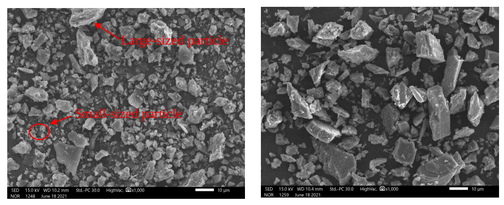
The physical and chemical properties of asphalt mortar with CGS are also more stable

Microscopic morphology of fillers



(a) CGS ×1000 (b) LM ×1000

Fig. 3 Scanning electron micrograph of two fillers

	Particle shape	Particle surface	Particle size
CGS	Quite irregularity; Granular; Globular; Clavate	Most smooth; A few rough pore	Tens of microns; distribution continuous
LM	Relatively regular; Granular	Multi-layer texture	Tens of microns

CGS can be better entangled and adsorbed with the macromolecules of the asphalt binder

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Form stronger interfacial bond between CGS and asphalt

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✦ Subjected to external force

CGS provides higher adhesion and internal friction of asphalt mortar to resistance the deformation

Physical properties analysis

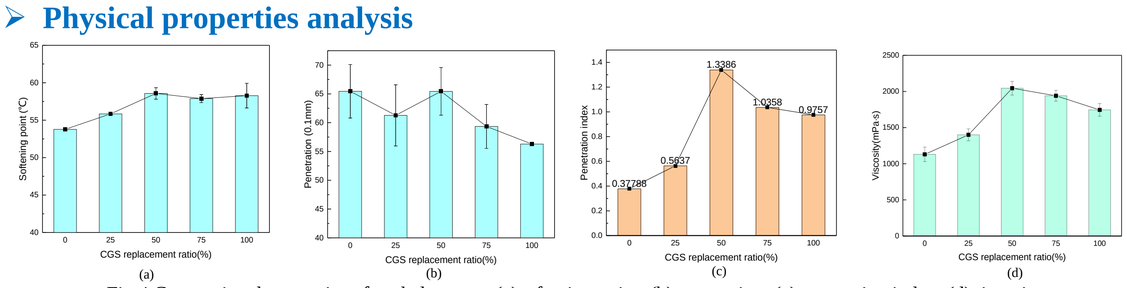

Fig.4 Conventional properties of asphalt mortar:(a)softening point; (b)penetration; (c)penetration index; (d)viscosity

High temperature performance	Improve the high temperature performance
Temperature stability $PI=\frac{1952-500\log(Pen_{25})-20SP}{50\log(Pen_{25})-SP-120}$	Decrease the temperature sensitivity; Improve the elasticity
Viscosity	Improve the shearing deformation resistance

CGS easier tend to have physical and chemical interaction with binder to obtain hardening effect

Temperature scanning test analysis

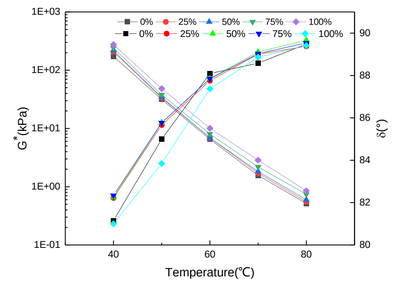

Fig.5 Complex modulus and phase angle of asphalt mortar under different CGS replacement ratio

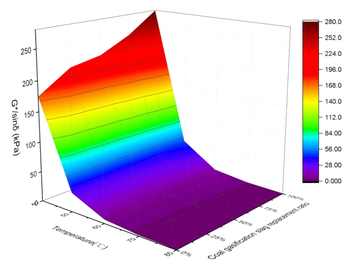

Fig.6 Rutting factor of asphalt mortar under different CGS replacement ratio

Obvious temperature dependence

◆ Temperature rise

- Decrease deformation resistance
- Decrease elasticity
- Reduce the improvement effect of the high temperature performance

MSCR analysis

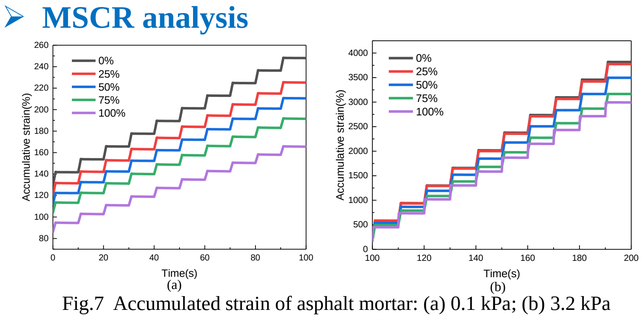

Fig.7 Accumulated strain of asphalt mortar: (a) 0.1 kPa; (b) 3.2 kPa

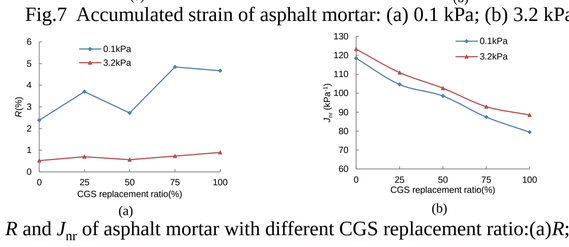

Fig.8 R and J_{nr} of asphalt mortar with different CGS replacement ratio:(a)R; (b) J_{nr}

- Increase permanent deformation resistance
- The effect of CGS replacement ratio on the accumulative strain of asphalt mortar was different under different stress levels

$$J_{nr}=\frac{\gamma_{nr}-\gamma_0}{\tau} \qquad R=\frac{\gamma_P-\gamma_{nr}}{\gamma_P-\gamma_0}\times 100\%$$

- Improve the elastic behavior of asphalt mortar
- Exhibit a better elastic recovery effect on asphalt mortar under low stress level
- Improve rutting resistance of asphalt mortar under high stress level

Findings and Conclusions

◆ CGS exhibited a wider particle size distribution than LM. The total particle size of CGS was smaller than LM. These characteristics potentially led to improve the cohesion between asphalt binder and CGS.

◆ The mineral main components of CGS were quartz, calcite, mullite, gypsum, and LM was calcite, implied that asphalt mortar with CGS was more stable than with LM.

◆ The increment of CGS replacement ratio led to increase in the accumulated strain of asphalt mortar at the same stress level, but presented different affecting level under different stress levels.

◆ CGS improved the elastic behavior and deformation resistance of asphalt mortar. CGS exhibited a better elastic recovery effect on asphalt mortar under low stress level and improved rutting resistance of asphalt mortar under high stress level. The increment of CGS replacement ratio had negligible effect on the R_{diff} of asphalt mortar, but led to an increase of $J_{nr\text{-}diff}$.

Low Carbon Technologies and Resilience for Long-Lasting Infrastructure

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