**## Carbonation-activated steel slag recycling for low carbon pavements**

**Materials Required**

The study used the following materials for the experiments:

* 70# Asphalt Binder: A standard highway-grade asphalt that meets ASTM standards and is typically used in road construction.
* Steel Slag: An alkaline by-product from a steel plant in Pingdingshan City, China, which was processed to meet the requirements for coarse aggregate.
* Carbon Dioxide (CO2​): Industrial-sourced gas, primarily captured from industries such as cement production or chemical plants, was used for the carbonation process.

**Aggregate Size and Carbonation Conditions**

* **Aggregate Size:** The steel slag was processed to control the particle size to **>4.75 mm** to meet the requirements for coarse aggregate.
* **Carbonation Conditions:** The accelerated carbonation treatment was conducted in a chamber with a controlled environment. The specific conditions were:
  + Humidity: 70%
  + CO2​ Concentration: 30%
  + Temperature: 25∘C
  + Pressure: Standard atmospheric pressure

**Carbonation Procedure**

The study used an accelerated carbonation process to treat steel slag samples. A carbonation chamber was connected to a carbon dioxide gas source with pressure-reducing and flow-control devices. The environment was regulated to maintain constant humidity,

CO2​ concentration, and temperature. Samples were treated for varying durations of 0, 10, 30, 45, and 60 hours to determine the effect of carbonation time on the product. The research found that a

30-hour treatment was optimal for improving the material's properties.

**Experimental Procedures and Determined Properties**

The research utilized a multi-scale approach to evaluate the effects of carbonation.

* *Pore Structure and Water Absorption:*
  + **Test: Immersion method** (following GB/T 17431.2-2010 standard) and volumetric method.
  + Properties Determined: Water absorption rate and porosity of the steel slag.
* *Interfacial Adhesion****:***
  + **Test: Boiling water test**.
  + Properties Determined: Adhesion properties and water resistance of the steel slag-asphalt interface by evaluating the percentage of peeled asphalt film.
* *Pavement Performance:*
  + **Test: Marshall test (JTG E20-2011 standard).**
  + Properties Determined: Marshall stability and flow value of the asphalt mixtures.
  + **Test: Immersion Marshall test.**
  + Properties Determined: Water stability of the asphalt mixtures by measuring residual stability after immersion in a 60∘C water bath for 48 hours.
  + **Test: Volume expansion test.**
  + Properties Determined**:** Volume stability and expansion rate of the asphalt mixtures.
  + **Test: High-temperature stability test using a rutting test system.**
  + Properties Determined: Rutting resistance and dynamic stability of the asphalt mixtures.
* *Microscopic Properties:*
  + **Test: X-ray diffraction (XRD**).
  + Properties Determined: Crystal structure, phase composition, and arrangement of the materials.
  + **Test: Scanning electron microscopy (SEM**).
  + Properties Determined: Surface morphology, microstructure, and elemental distribution of the samples.
* *Molecular-Scale Properties:*
  + **Test: Molecular dynamics (MD) simulations**.
  + Properties Determined: Interfacial binding energy, relative concentration, and mean square displacement (MSD) to understand the molecular-scale mechanisms of adhesion and diffusion