Materials:

- **Pyrogenic Silica**
  - Synthetic, hydrophilic, amorphous silica, produced via flame hydrolysis.
  - BET surface 175 - 225 m²/g
  - Density at 20 °C approx. 2.2 g/cm³

- **Aggregate**
  - Limestone 1 - Central Valley
  - Limestone 2 - North Pacific
  - River Gravel 1 - Central Caribbean
  - River Gravel 2 - North Pacific

Materials Characterization:

- **Atomic Force Microscopy (AFM)**
- **Differential Scanning Calorimetry Analysis (DSC)**

Effect of Modifier Content, Aging and Aggregate Source on Adhesion

Bitumen-aggregate adhesion was characterized based on the Bitumen Bond Strength (BBS) test. The test was performed following AASHTO TP-91 using the P.A.T.I. equipment.

- **Thermogravimetric analysis (TGA)**
  - The point of highest weight loss change rate is known as the inflection point.
  - It indicates when Pyrolysis occurs.
  - Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen (or any nitrogen).

- **DSC analysis of the neat bitumen and modifier**

Evaluation of the modifier content on the aggregate/binder interaction, Unaged

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>0.5% SiO₂</th>
<th>3% SiO₂</th>
<th>6% SiO₂</th>
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</thead>
<tbody>
<tr>
<td>Bitumen DSC properties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tg, °C</td>
<td>24.4</td>
<td>23.6</td>
<td>22.5</td>
<td>18.6</td>
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<tr>
<td>Tm, °C</td>
<td>31.7</td>
<td>30.9</td>
<td>30.1</td>
<td>26.9</td>
</tr>
<tr>
<td>δTg, °C</td>
<td>13.4</td>
<td>13.1</td>
<td>12.4</td>
<td>10.8</td>
</tr>
</tbody>
</table>

Conclusions:

- Higher particle interlock (AFM images texture) was accomplished by modification with nano-silica.
- Superior bitumen performance and higher thermal stability produced higher bond and tensile strength (from TGA and DSC analysis).
- Significant differences in strength of adhesion between the different aggregate-bitumen combinations were obtained. A minimum Bond Strength Ratio of 70% is recommended.
- An optimal adhesion/cohesion performance can be obtained for the studied modifier to maximize the adhesivity, and consequently moisture damage resistance at a concentration near 3%.
- RTFO aged bitumens showed a considerable increment in strength of adhesion which indicates that the affinity of aggregate and bitumen improves with short term aging.