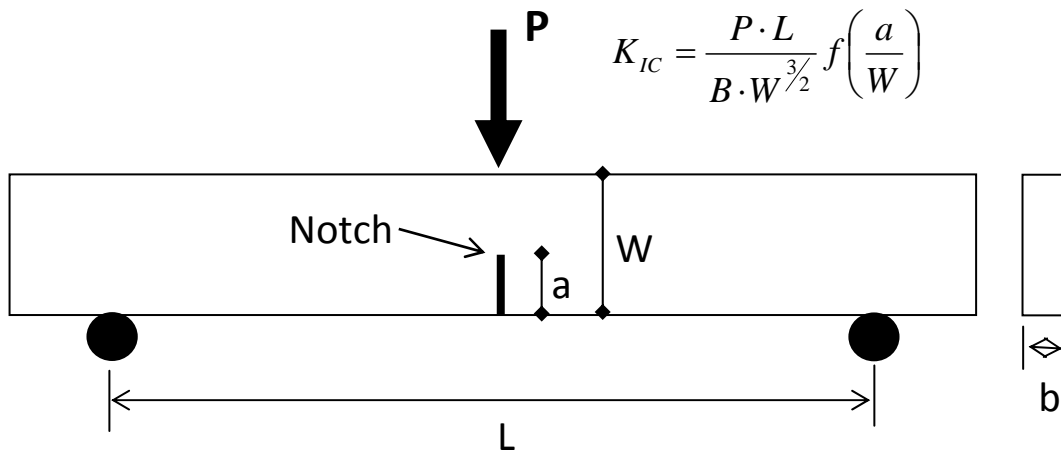


## Thermal Cracking Characterization Using the Single-Edge Notched Bending (SENB) Test

Current test methods to address low-temperature cracking, such as the Bending Beam Rheometer (BBR), characterize the material in the linear viscoelastic domain at small strain levels and therefore do not provide the whole picture for thermal cracking characterization. A more appropriate approach is to use the principles of fracture mechanics to minimize low-temperature cracking.

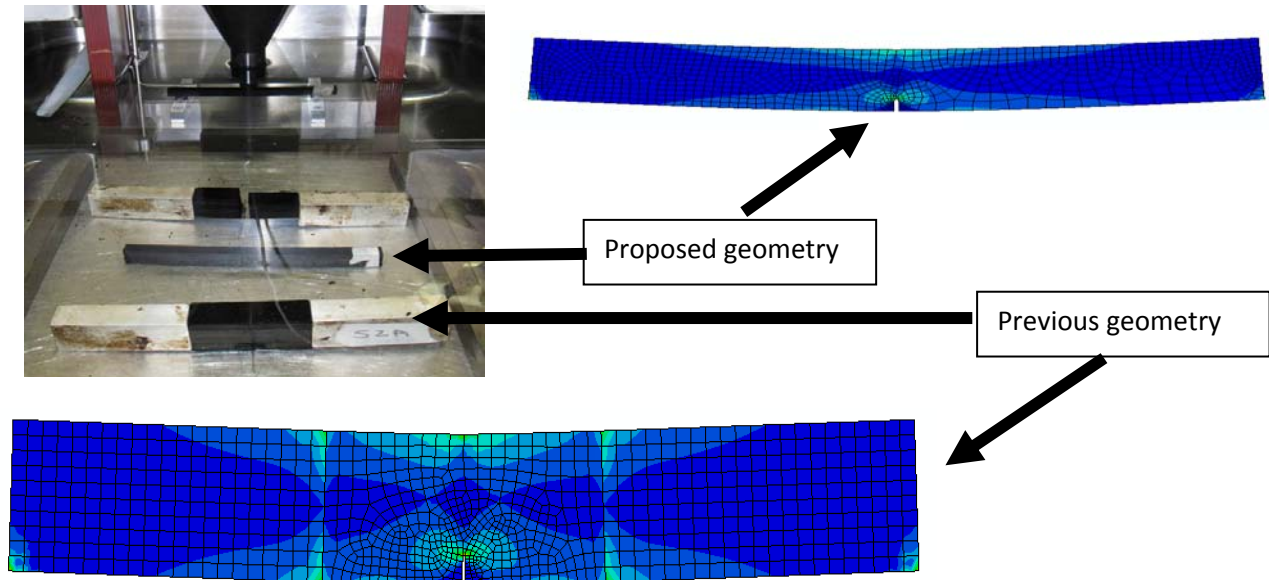
Previous researchers (Hoare and Hesp 2000, Hesp 2003, Chailleux and Mouillet 2006, Chailleux et al. 2007) have used the Single-Edge Notched Bending (SENB) Test, a fracture mechanics-based test commonly used in metals and other materials, to obtain the fracture properties of asphalt binders at low temperatures. They succeeded in grading a broad range of materials with different levels of modification. The SENB test follows ASTM E399 standard and assumes that linear elastic fracture mechanics (LEFM) conditions hold.



**Schematic of SENB test**

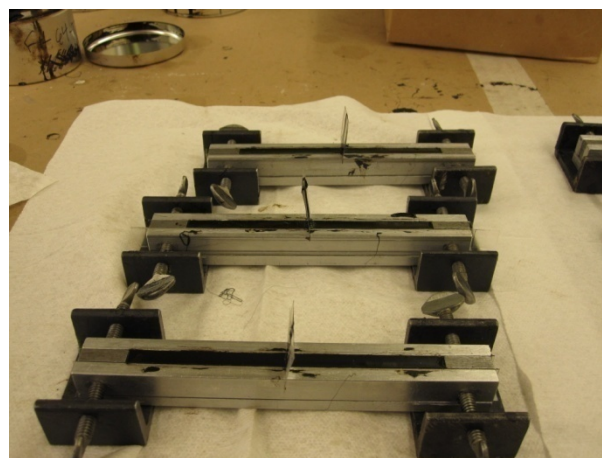
The research group at UW-Madison started development of a SENB system with the specimen geometry proposed by previous studies; however, they encountered problems with the adhesion between the asphalt binder and the metal bars during sample preparation and as the beams were handled before testing. This motivated the team to investigate other geometries.

The new geometry adds a notch to the beams made using common BBR molds, thus addressing the adhesion problem by eliminating the need for metal bars completely. Note that the sample preparation procedure is less time-consuming and simpler for the proposed BBR geometry. Finite element simulations of both geometries indicated that the stress distributions around the notch are very similar. Furthermore, the previous SENB geometry shows stress discontinuity in the interface between the metal bars and the binders that may have a significant effect on the results of the test.



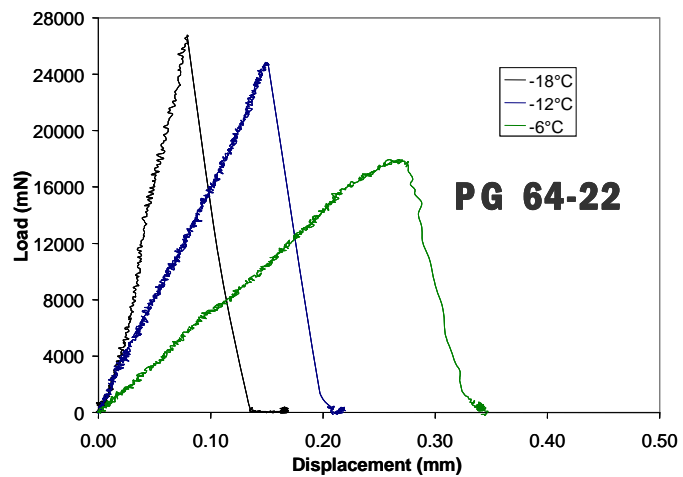
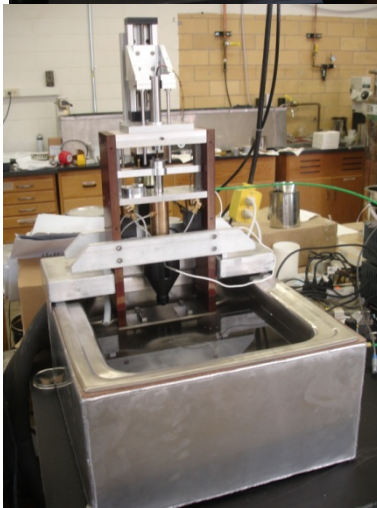
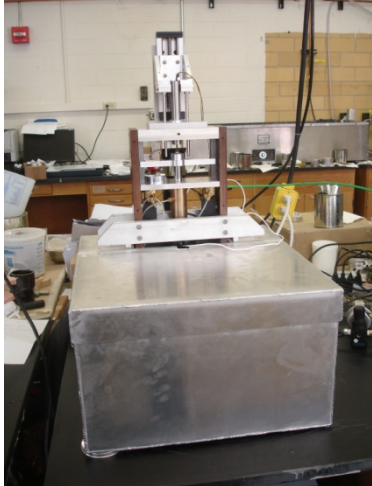
***Proposed and previous SENB geometry. FEM simulations indicate advantages of using BBR geometry with notch. No stress discontinuities are observed in the proposed geometry. The adhesion problem between binder and metal bars is avoided.***

The proposed SENB beams are prepared by introducing a notch of approximately 3 mm (corresponding to 20-25% of beam depth) in the width (12.7 mm) of the BBR mold side beams. The mold can still be used for regular BBR beam fabrication as the notch is very thin and it can be covered with plastic sheets used in molding.



**SENB specimens**

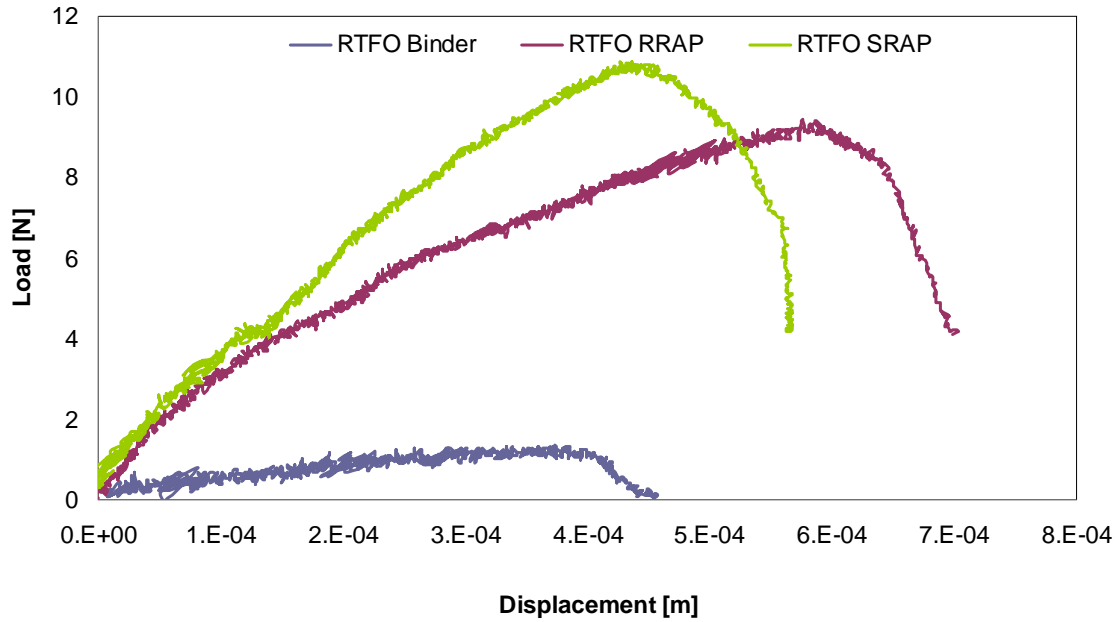
The ductile to brittle transition behavior of asphalt binders at low temperatures can be detected with the SENB system as it is observed in the Figure below. A PG 64-22 binder was tested at three temperatures (-6, -12, -18°C). It was observed how the ductility of the binder was significantly reduced from testing at -6°C to -18°C.



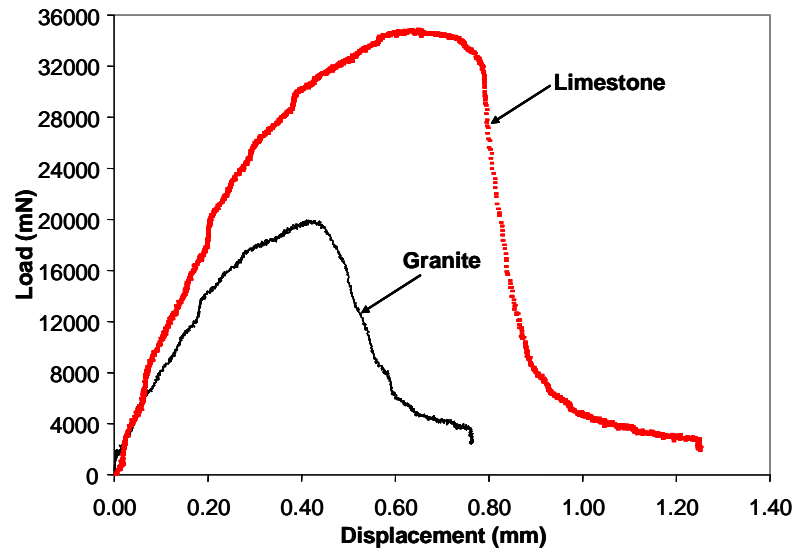
**SENB system: loading frame (displacement-controlled), cooling bath, and typical results for binders (as temperature increases the fracture behavior changes from brittle to ductile).**

Also, the SENB device with the proposed geometry has been used to test recycled asphalt pavement (RAP) materials. Significantly different fracture toughness and fracture energy were observed between binder and different mortars.

Preliminary results indicate that the SENB system also can be used to run fracture tests of thin asphalt mixture beams. Asphalt mixtures prepared with granite and limestone were successfully tested with the system. Specimens were obtained by cutting BBR-sized specimens from slab-compacted samples.



**SENB testing of RAP materials. System is capable of differentiating fracture properties (i.e., fracture toughness and fracture energy) of RAP materials. RRAP is binder containing burned RAP aggregates and RTFO-aged fresh binder. SRAP is binder containing sieved RAP material (aggregates plus RAP binder) that passes a #50 sieve and is retained on a #100 sieve mixed with fresh binder. RTFO is rolling thin-film oven.**



**SENB testing of thin asphalt mixture beams. Low-temperature fracture strength of asphalt mixtures can be estimated with the SENB device.**



**References:**

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