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Increased Highway Life via Electron Beam Initiated Polymer Modification

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Motivation

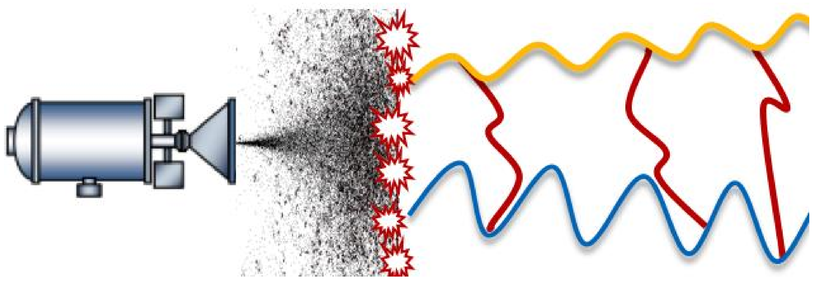
Current roads, constructed of bituminous asphalt, require maintenance and repair that costs over $50 billion per year while still facing application and longevity issues.

Efforts to improve roads by chemical modification have had only limited success because the resulting highways still suffer from rapid aging.

Enhancing strength properties of bitumen by means of electron beam induced polymer modification could reduce or prevent crack initiation and propagation in pavements due to various weather conditions and heavy loads[1,2].

E-beam modification

Electron beam initiated crosslinking and polymerization of materials leads to increased strength and toughness. The amount of crosslinking and subsequent material properties can be precisely controlled by the electron beam exposure time.



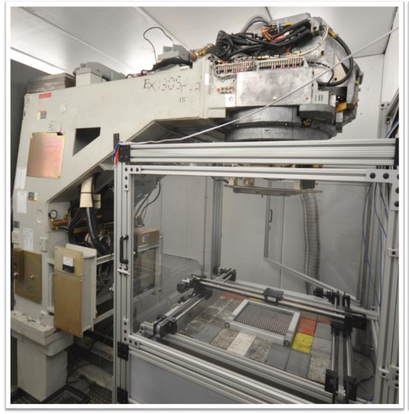
Electron beam initiated polymer crosslinking

The electron penetration depth in the product is determined by its energy which in asphalt is around 2 cm (for a 10 MeV beam). While the initial energy deposited is important, further electron interactions within the polymer would promote additional chemistry to be driven deeper in the system.

Experimental Facility & Treatment

Present work focuses on treating several bitumen-polymer formulations at various dose rates and total doses to improve material properties and produce feasible bitumen products for road use.

The Accelerator Applications Development and Demonstration (A2D2) electron beam accelerator is the tool used to treat the bitumen-polymer formulations.



Accelerator Applications Development and Demonstration (A2D2)

Bitumen-polymer sample prepared for electron beam treatment

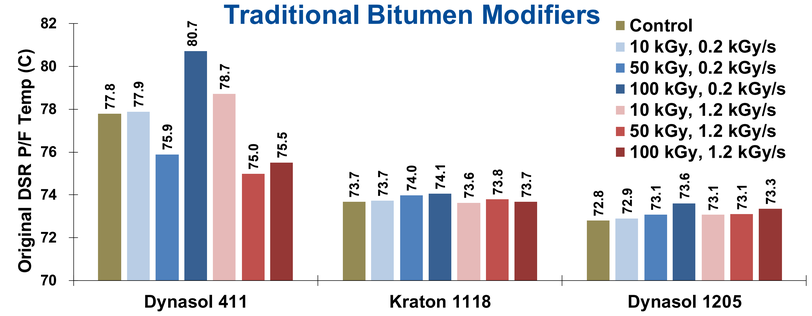
Treatments were carried out on different bitumen formulations and at varying experimental conditions. Characterization of both treated and original bitumen formulations were conducted by dynamic shear rheometer (DSR).

This method measures viscoelastic parameters such as the ratio of shear stress to maximum strain (complex modulus, G^*) and the phase difference between stress and strain in an oscillatory test (phase angle, δ). From the DSR a composite score to rate the overall suitability of the pavement called PG (performance grade) is given.

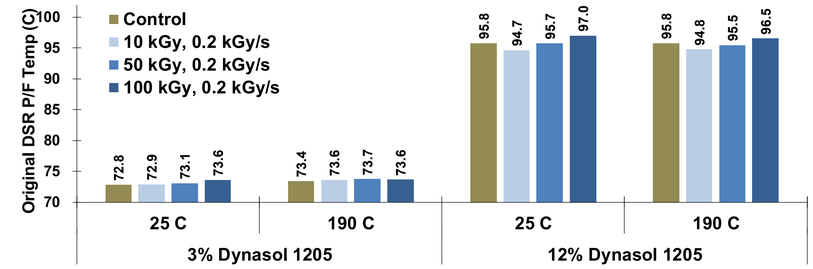
PG 64-22, a standard grade of asphalt, must meet performance criteria at an average 7 day maximum pavement temperature of 64°C and also at a minimum pavement temperature of −22°C. The high temperature relates to the effects of rutting and the low temperature relates to cold temperature and fatigue cracking.

Preliminary Results

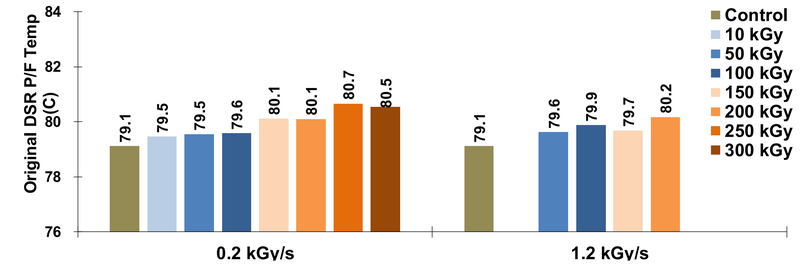
Traditional Bitumen Modifiers



Run #1 variables: Three bitumen-polymer formations – 3% polymer loading – room temperature – low and high dose rate – various total dose



Run #2 variables: One bitumen-polymer formation – 3% and 12% polymer loading – room and high temperature – low dose rate – various total dose



Run #3 variables: One bitumen-polymer formation (Dynasol 411)– 3% polymer loading – room temperature – low and high dose rate – various total dose

Summary

We have e-beam treated traditional bitumen modifiers at various experimental conditions. Future work will include treatment and examination of nontraditional bituminous chemistries.

Acknowledgements

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References

(1) Cardone, F.; Ferrotti, G.; Frigio, F.; Canestrari, F. Influence of Polymer Modification on Asphalt Binder Dynamic and Steady Flow Viscosities. Construction and Building Materials 2014, 71, 435–443.

(2) Becker, Y.; Méndez, M. P.; Rodríguez, Y. Polymer Modified Asphalt. Vision Tecnologica 2001, 39–50.