Assessing the Sensitivity of the IDEAL-CT and the I-FIT to Polymer Modification

As the asphalt pavement industry moves toward the implementation of balanced mix design (BMD), asphalt practitioners have been exploring innovative approaches to design asphalt mixtures with balanced rutting and cracking resistance. One potential approach is polymer modification to improve the quality of the asphalt binder. However, several existing studies found that using polymer modified asphalt (PMA) did not improve the cracking resistance of the mixture measured in the Indirect Tensile Asphalt Cracking Test (IDEAL-CT) and the Illinois Flexibility Index Test (I-FIT). This finding contradicts the superior cracking performance of many field projects using PMA versus unmodified asphalt mixtures, highlighting a potential limitation of the IDEAL-CT and the I-FIT as not being sensitive to polymer modification.

In a recently completed National Road Research Alliance (NRRA) study, researchers at NCAT and Mathy Technology and Engineering Services, Inc. (MTE) assessed two hypotheses for the lack of sensitivity of the IDEAL-CT and the I-FIT to polymer modification:

Hypothesis 1 is "Testing the IDEAL-CT and I-FIT at the volumetric optimum binder content (OBC) of the mixture is not sufficient to capture of the benefits of polymer modification." Many Superpave asphalt mixtures are lacking asphalt binder and thus have inadequate cracking resistance. Using PMA in these mixtures will improve the overall quality of the asphalt binder, but this improvement is not sufficient to affect the cracking resistance of the mixture. In other words, polymer modification alone cannot fix a "dry mix" issue. In this case, more asphalt binder would be needed to capture the benefits of polymer modification on improving the IDEAL-CT and the I-FIT results.

Hypothesis 2 is "The IDEAL-CT and I-FIT must be conducted at an equal stiffness condition to properly assess the cracking resistance of PMA versus unmodified asphalt mixtures." Currently, both tests are conducted at 25°C with a constant loading rate of 50 mm/min, and the final cracking index parameters [cracking tolerance index (CT_{Index}) for the IDEAL-CT and flexibility index (FI) for the I-FIT] are calculated based on the fracture energy (Gf) and the post-peak slope of the load-displacement curve. A high Gf and a moderate post-peak curve are desired for good cracking resistance. Polymer modification tends to stiffen the asphalt binder but while making it more ductile at the same time. As a result, the PMA mixture will have a higher Gf but a steeper post-peak curve, which could yield a similar or lower CT_{Index} and FI value than the unmodified mixture. This limitation could be addressed by running the test at an equal stiffness condition to better characterize the impact of the binder's elasticity and relaxation property on the cracking resistance of the mixture.

The study includes two mix designs (one from Alabama and one from Wisconsin) and four sets of virgin binders. As shown in Table 1, each set of virgin binders included an unmodified binder, a styrene-butadiene-styrene (SBS) modified binder, and a reactive ethylene terpolymer (RET) modified binder, where the two modified binders were formulated with the same unmodified binder to avoid the confounding impact of different base binders. The Alabama mix design was a 9.5 mm NMAS Superpave mixture with 20% RAP, and the Wisconsin mix design was a 12.5mm NMAS Superpave mixture with 23% RAP. The volumetric OBC of the two mix designs were 5.5% and 5.1%, respectively.

To assess the first hypothesis of the study, each mixture was tested with the IDEAL-CT and the I-FIT at three binder contents: volumetric OBC, + 0.3%, and + 0.6%. Both tests were conducted at 25°C following the current ASTM and AASHTO procedures. Test results were compared across the three virgin binders at each binder content to determine if increasing the binder content beyond the volumetric OBC could better capture the improved cracking resistance of the mixture due to polymer modification. Figure 1 presents the IDEAL-CT results of the Alabama mixtures with PG xx-22 binders for illustration purposes. Increasing the binder content consistently increased the CT_{Index} of all the mixtures, indicating improved cracking resistance. However, at all binder contents, the two PMA mixtures had statistically equivalent CT_{Index} results as the unmodified mix, which indicated that the CT_{Index} was not sensitive to polymer modification regardless of the binder content. The IDEAL-CT and the I-FIT results for the other combinations of mix designs and virgin binders showed similar trends. Therefore, Hypothesis 1 of the study was rejected.

To assess the second hypothesis of the study, additional IDEAL-CT and I-FIT testing at the volumetric OBC was conducted at an equal stiffness temperature (T=G*) in addition to 25°C. The T=G* was determined based on the Torsion Bar Modulus test, which varied from 22 to 25°C among the Alabama mixtures and 19 to 28°C

Table 1. Mix Design and Virgin Binder Summary

Mix Design	Virgin Binder	
Alabama	Set 1 (PG xx-22)	PG 64-22, PG 76-22 RET, PG 76-22 SBS
	Set 2 (PG xx-28)	PG 58-28, PG 64-28 RET, PG 64-28 SBS
Wisconsin	Set 3 (PG xx-28)	PG 58S-28, PG 58V-28 RET, PG 58V-28 SBS
	Set 4 (PG xx-34)	PG 52S-34, PG 58V-34 RET, PG 58V-34 SBS

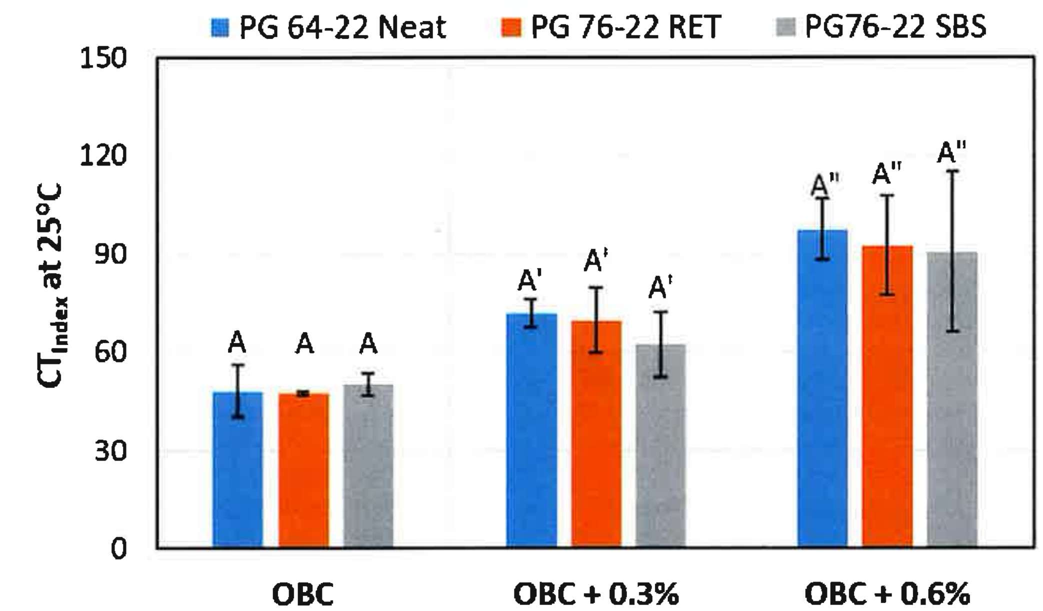

Figure 1. IDEAL-CT Results of Alabama Mixtures with PG xx-22 Binders at 25°C

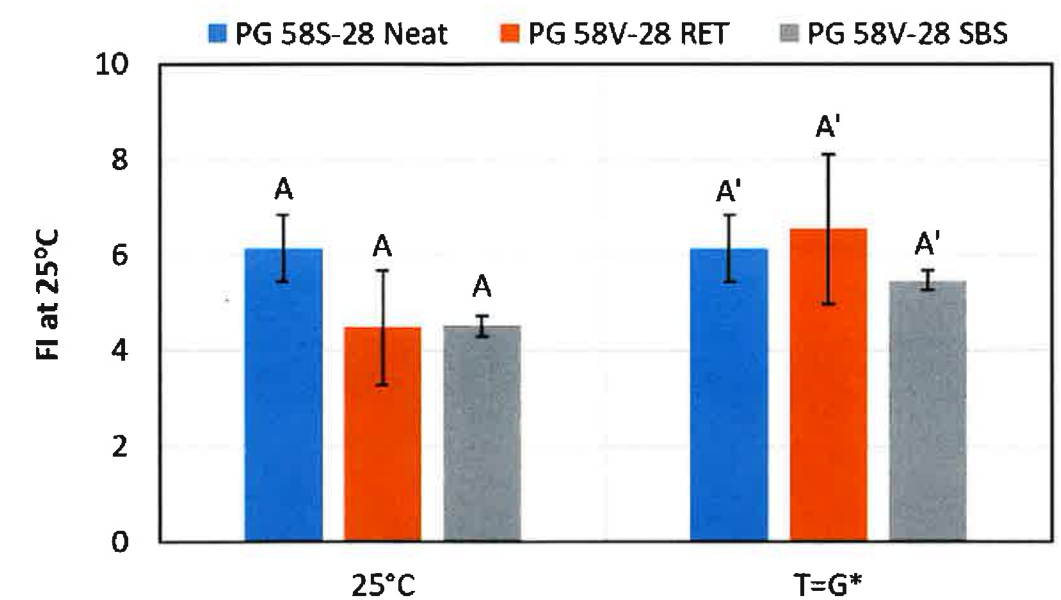

*Figure 2. I-FIT Results of Wisconsin Mixtures with PG xx-28 Binders at 25°C versus T=G**

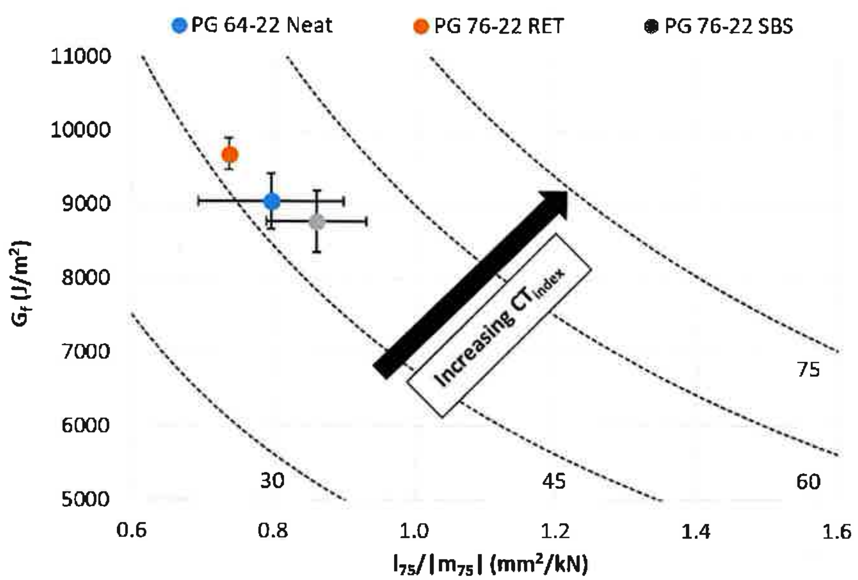

Figure 3. IDEAL-CT Interaction Diagram of Alabama Mixtures with PG xx-22 Binders at 25°C

among the Wisconsin mixtures. Figure 2 presents the I-FIT results of the Wisconsin mixtures with PG xx-28 binders at 25°C and T=G*. At both test temperatures, the two PMA mixtures had statistically equivalent FI results as the unmodified mixture when the test variability was considered. Similar findings were observed in the IDEAL-CT results, which indicated that adjusting the test temperature to T=G* did not help discriminate the cracking resistance of PMA versus unmodified mixtures. Therefore, Hypothesis 2 of the study was also rejected.

In addition to assessing the two hypotheses discussed previously, the IDEAL-CT and the I-FIT results were also evaluated using the interaction diagram analysis developed in Yin et al. (2023). The analysis showed that in most cases, polymer modification had a notable impact on the load-displacement curve, but its impacts on the fracture energy (Gf) and the post-peak parameters tended to offset each other on the CT_{Index} and the FI value. As shown in Figure 3, the direction of change in the IDEAL-CT and the I-FIT results due to polymer modification on the interaction diagram was almost perpendicular to the direction of increasing CT_{Index} or FI. As a result, the PMA and unmodified mixtures fell on similar CT_{Index} and FI contour curves despite having different Gf and post-peak parameters.

In summary, the study concluded that the current IDEAL-CT and I-FIT procedures and parameters are not sensitive to polymer modification. Future research was suggested to explore alternative parameters from the interaction diagram analysis that could discriminate PMA versus unmodified mixtures. In the meantime, SHAs were suggested to use the same IDEAL-CT and I-FIT criteria for asphalt mixtures containing PMA and unmodified binders with the same base binder grade. More detailed results and findings of the study can be found on the NRRA website.

Contact Fan Yin at f-yin@auburn.edu for more information about this research.

Cold Recycling Finally Has a Construction Guide Specification!

For years, readers of this newsletter have found interesting information and updates on Cold Recycling (CR) processes, such as Cold Central Plant Recycling (CCPR) and Cold In-place Recycling (CIR). With all the talk of great performance even on high-traffic volume roads (and the famed NCAT Test Track) there has been a deluge of State Departments of Transportation (DOTs) personnel, Federal Agencies, and even industry members looking to NCAT experts to provide insight into how to craft a specification to deliver a high-quality, reliable CR pavement. This has been especially important considering NAPA's The Road Forward plan, the industry's drive to net-zero emissions, and U.S. DOT grant opportunities (such as FHWA's Climate Challenge projects), which focuses on lowering greenhouse gas (GHG) emissions and energy associated with producing and constructing pavements.

In 2020, a team from NCAT led by Principal Investigator (PI) Dr. Benjamin Bowers, PE (that's me!) was awarded National Cooperative Highway Research Program (NCHRP) Project 14-43, Construction Guide Specifications for Cold Central Plant Recycling and Cold In-Place Recycling. Team members included Co-PI Dr. Brian Diefenderfer, P.E. at the Virginia Transportation Research Council (VTRC), Auburn/NCAT alumnus, Asphalt Recycling and Reclaiming Association (ARRA) technical director Dr. Stephen A. Cross of S. Cross & Associates, LLC, NCAT Associate Research Professor Dr. Adriana Vargas, and former Assistant Research Professor Dr. Fan Gu, PE. The objectives of this research project are to develop and produce a proposed AASHTO Construction Guide Specification, and develop a Best Practices Guide and training materials for the construction of CIR and CCPR.

You might ask: how do you go about putting together an AASHTO Construction Guide Specification? The first step was to assemble the right team: Our team consists of implementation-minded academics (Bowers, Vargas, Gu), agency representation (Diefenderfer), and industry representation (Cross) – the latter two who just happen to also be implementation-minded academics. Then, we gained insights from our NCHRP panel, findings from the literature review, and from feedback to a survey that went out to DOTs, counties, and municipalities. The information from these sources helped us gain an understanding of what was working and what wasn't in their CR specifications. Independent interviews were also conducted with DOT personnel identified in the survey, as well as experienced contractors who could speak to the construction process. This was critical because the team wanted to make a flexible specification that would suit the needs of the agency, as well as see these techniques grow in use, while not discouraging bids and competition due to a limiting specification.

The team then set out to draft the first specification. All five key elements of an AASHTO Construction Guide Specification were outlined and approved by the panel. Using experience from the team, input from DOT and industry experts, and drawing on some of the "top" specifications, the team drafted a CR specification. This iterative process included multiple panel reviews and a round of reviews from the team's Industry Technical Support Team – a team of industry experts who could provide insight into the challenges induced by the proposed specification language – we finally had a final draft. The draft specification was then submitted to AASHTO to begin committee reviews.

The final report contains a Best Practice Guide and training materials that will be useful for agencies and contractors interested in using CR. These guides will draw attention to many common questions, concerns, and will help troubleshoot challenges in the field. These guides are also an excellent complement to the commentary provided in the draft AASHTO specification. The training materials are intended to be complimentary materials that can be used in preparation for a project or for Just in Time Training right before construction commences. Publication of the final report is forthcoming, and the draft AASHTO Guide Specifications are in review. Keep an eye on TR News and NCAT social media for announcements of final publication, or simply search "NCHRP 14-43" in your favorite web search engine.

Contact Ben Bowers at bfbowers@auburn.edu for more information about this research.