Lessons Learned

BALANCED MIXTURE DESIGN

Improving Cracking Resistance in Illinois

This case study illustrates how a volumetric mix design (VMD) with inadequate cracking resistance was modified to meet the Illinois Department of Transportation's (IDOT) balanced mix design (BMD) specifications by using a softer virgin binder. See a summary of IDOT's BMD specifications.

Original Volumetric Mix Design

A 12.5mm nominal maximum aggregate size (NMAS) Superpave mix was designed with a PG 70-28 polymer modified asphalt (PMA) binder, granite aggregates, and 15% reclaimed asphalt pavement (RAP). The mix had a volumetric optimum binder content (OBC) of 4.7%, corresponding to 4.0% air voids and 14.6% voids in mineral aggregate (VMA) at 125 gyrations. Table 1 summarizes the performance test results at the volumetric OBC. As shown, the mix passed IDOT's Hamburg Wheel Tracking Test (HWTT) requirement but failed the Illinois Flexibility Index Test (I-FIT) requirement with an average flexibility index (FI) of 5.4 at the short-term aging condition. Therefore, the mix was expected to have good rutting resistance but inadequate cracking resistance.

BMD Modification

The BMD modification used to improve the cracking resistance of the original mix design was to use a softer PMA binder. This modification approach was selected for three reasons. First, IDOT's BMD specifications require the *Volumetric Design with Performance Verification* approach with no relaxation or elimination of the existing volumetric requirements. Second, using a softer virgin binder can improve the mixture cracking resistance while not affecting the volumetric properties. Third, the original mix design with a PG 70-28 PMA binder had very minimal rutting in HWTT, allowing for confidence that using a softer PG 64-34 PMA binder would likely pass IDOT's BMD rutting requirement. The modified mix design was identical to the original mix design except for using a softer virgin binder. As shown in Table 2, the original design binder was

Table 1. **BMD Test Results of Original Mix Design at Volumetric OBC**

BMD Test Parameter	Test Result (Average)	IDOT BMD Spec.	Pass/Fail
HWTT Rut Depth at 15,000 Passes (mm)	2.0	≤12.5	Pass
I-FIT FI	5.4	≥8.0	Fail

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National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Table 2. **Virgin Binder Performance Grade Results**

Binder ID	Critical Temperature Grade				ΔT_c	True Grade	Superpave PG
	High-temp.	Intermediate-temp.	Low-temp., Stiffness	Low-temp., m-value			
Original Design Binder	70.7	13.2	-33.1	-34	0.9	70.7-33.1	70-28
Modified Design Binder	67.5	10.3	-35.2	-35.7	0.5	67.5-35.2	64-34

graded as PG 70-28, while the modified design binder was graded as PG 64-34. Despite the 6-degree difference in the low-temperature PG grade, the two virgin binders had reasonably comparable low-temperature rheological properties as indicated by similar critical low-temperature grades and delta Tc (ΔT_C). Nevertheless, the modified design binder was approximately 3-degree softer than the original design binder at both the high-temperature and intermediate-temperature ends.

Table 3 presents the performance test results of the modified mix design at the volumetric OBC (4.7%). As shown, the mix with the softer PG 64-34 PMA binder met IDOT's HWTT and I-FIT requirements and thus was expected to have good rutting and cracking resistance. Additional volumetric testing of the modified mix design confirmed that changing the virgin binder did not affect the volumetric properties of the mix as expected.

Table 3. BMD Test Results of Modified Mix Design at Volumetric OBC

BMD Test Parameter	Test Result (Average)	IDOT BMD Spec.	Pass/Fail
HWTT Rut Depth at 15,000 Passes (mm)	2.7	≤12.5	Pass
I-FIT FI	9.3	≥8.0	Pass

Summary

Figure 1 compares the HWTT and IDEAL-CT results of the original versus modified mix designs on a performance diagram. The dashed lines in the performance diagram represent IDOT's test criteria. The two mix designs were identical, except that the modified design used a softer PMA binder than the original design (PG 64-34 vs. PG 70-28). As shown in Figure 1, the original mix design is located outside the 'balanced performance' zone on the performance diagram due to the failing I-FIT result. The modified mix design, on the other hand, falls within the 'balanced performance' zone with passing HWTT and I-FIT results and, therefore, is expected to have balanced rutting and cracking resistance.

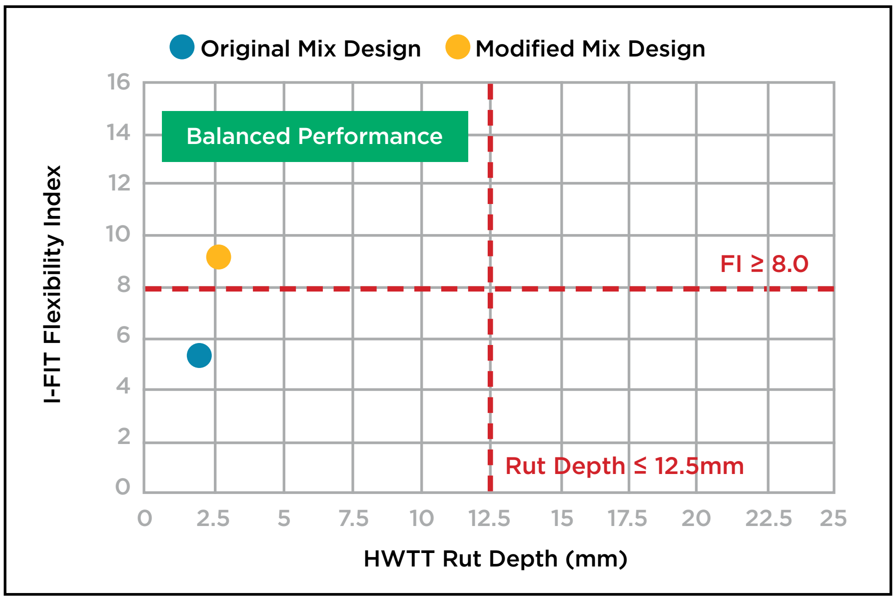

Figure 1. Performance Diagram of Mix Designs before and after BMD Modification