BALANCED MIXTURE DESIGN

Lessons Learned

Improving Rutting and Moisture Resistance in Wisconsin

This case study illustrates how a volumetric mix design (VMD) with inadequate rutting and moisture resistance was modified to meet the Wisconsin Department of Transportation's (WisDOT) balanced mix design (BMD) specifications by using a polymer-modified asphalt (PMA) binder and adding a liquid anti-strip (LAS) additive. See a summary of WisDOT's BMD specifications.

Original Volumetric Mix Design

A WisDOT-approved 9.5mm nominal maximum aggregate size (NMAS) surface mix with 35% reclaimed asphalt pavement (RAP) was obtained from an asphalt contractor in Wisconsin. The mix used a PG 52S-34 virgin binder and a blend of gravel and sand. It falls under WisDOT's Medium Traffic (MT) mix category, with design traffic between 2 and 8 million equivalent single axle loads (ESAL). The mix was designed following the Superpave volumetric approach but then modified to achieve 3% regressed air voids per WisDOT specifications. At 4.0% design air voids, the mix had 6.0% optimum binder content (OBC) and 16.5% voids in mineral aggregate (VMA) at 75 gyrations. At 3.0% regressed air voids, the OBC increased to 6.4%, but VMA remained at 16.5%. Table 1 summarizes the performance test results of the mix at the regressed OBC. As shown, it passed WisDOT's Indirect Tensile Asphalt Cracking Test (IDEAL-CT) requirement with an average cracking tolerance index (CT_{index}) of 60.6 at the long-term aging condition, which consists of additional loose mix aging for 6 hours at 135°C after short-term aging for 4 hours at 135°C. However, it failed the Hamburg Wheel Tracking Test (HWTT) requirements with an average number of passes to 12.5mm rut depth ($N_{12.5}$) of 6,400 passes and a stripping inflection point (SIP) of 4,250 passes at the short-term aging condition. Therefore, the mix was expected to have good cracking resistance but inadequate rutting and moisture resistance.

Table 1. BMD Test Results of Original Mix Design

BMD Test Parameter	Test Result (Average)	WisDOT BMD Spec.	Pass/Fail
HWTT $N_{12.5}$ (passes)	6,400	≥ 10,000	Fail
HWTT SIP (passes)	4,250	≥ 8,000	Fail
IDEAL-CT CT_{index}	60.6	≥ 30.0	Pass

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BMD Modification

The first BMD modification attempt to improve the HWTT results of the original mix design was to add an amine-based LAS additive. This modification approach was selected for two reasons. First, WisDOT's BMD specifications require the *Volumetric Design with Performance Verification* approach with no relaxation or elimination of the existing volumetric requirements.

Second, adding a LAS additive has the potential to improve the HWTT results from the moisture resistance perspective while not affecting the volumetric properties. The modified mix design was identical to the original mix design except that a LAS additive was added at a dosage rate of 0.5% by weight of total binder. Although the modified mix design slightly outperformed the original mix design in HWTT with improved $N_{12.5}$ and SIP values, it did not meet WisDOT's requirements as shown in Table 2. Therefore, adding a LAS additive alone was not sufficient for BMD modification in this case.

The second BMD modification attempt was to use a PG 58H-34 PMA binder. Compared to the PG 52S-34 binder used in the original mix design, the PMA binder has the potential to improve the HWTT results of the mix by improving its rutting resistance due to polymer modification. Furthermore, using a PMA binder is not likely to affect the volumetric properties of the mix. The modified mix design was identical to the original mix design except for using a PMA binder. As shown in Table 3,

Table 2. HWTT Results of Modified Mix Design with LAS Additive

BMD Test Parameter	Test Result (Average)	WisDOT BMD Spec.	Pass/Fail
HWTT $N_{12.5}$ (passes)	8,100	≥ 10,000	Fail
HWTT SIP (passes)	5,750	≥ 8,000	Fail

Table 3. HWTT Results of Modified Mix Design with PMA Binder

BMD Test Parameter	Test Result (Average)	WisDOT BMD Spec.	Pass/Fail
HWTT $N_{12.5}$ (passes)	11,400	≥ 10,000	Pass
HWTT SIP (passes)	8,100	≥ 8,000	Marginal Pass

Table 4. BMD Test Results of Modified Mix Design with PMA Binder and LAS Additive

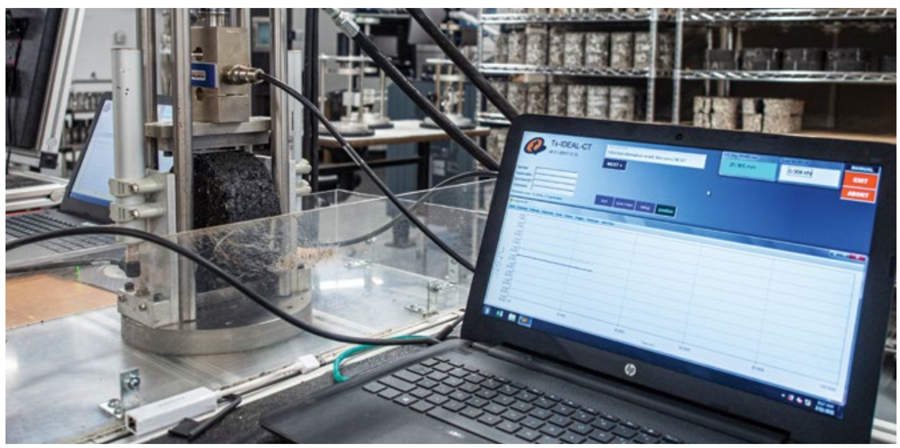
BMD Test Parameter	Test Result (Average)	WisDOT BMD Spec.	Pass/Fail
HWTT $N_{12.5}$ (passes)	12,600	≥ 10,000	Pass
HWTT SIP (passes)	9,000	≥ 8,000	Pass
IDEAL-CT CT_{index}	63.6	≥ 30.0	Pass

the modified mix design significantly outperformed the original mix design in HWTT with improved $N_{12.5}$ and SIP values. Furthermore, the modified mix design met WisDOT's HWTT requirements although the SIP result was marginally acceptable with only 100 passes above the minimum threshold (i.e., 8,000 passes).

Finally, a hybrid BMD modification approach used a PMA binder and a LAS additive. This approach was anticipated to improve the HWTT results of the original mix design from both the rutting resistance and moisture resistance perspectives. As shown in Table 4, the hybrid-modified mix design significantly outperformed the original mix design in HWTT. It had an average $N_{12.5}$ of 12,600 passes and a SIP of 9,000 passes, which met WisDOT's requirements. The mix also passed WisDOT's IDEAL-CT requirement with an average CT_{index} of 63.6 at the long-term aging condition. Therefore, the hybrid modification approach significantly improved the rutting and moisture resistance of the original mix design while maintaining cracking resistance.

Summary

Figure 1 compares the HWTT ($N_{12.5}$ only) and IDEAL-CT results of the original versus hybrid-modified mix designs on a performance diagram. The dashed lines in the performance diagram represent WisDOT's test criteria. The two mix designs were identical, except that the modified design used a PMA binder and a LAS additive. As shown in Figure 1, the original mix design is located outside the 'balanced performance' zone on the performance diagram due to the failing HWTT result. On the other hand, the hybrid-modified mix design falls within the 'balanced performance' zone with passing HWTT and IDEAL-CT results and, therefore, is expected to have balanced rutting and cracking resistance. Note that although using PMA and LAS for BMD modification in this case study will increase the material cost of the mix, it has the potential to improve the performance and life span of the pavement, which will likely justify the higher material cost from a life-cycle cost perspective.



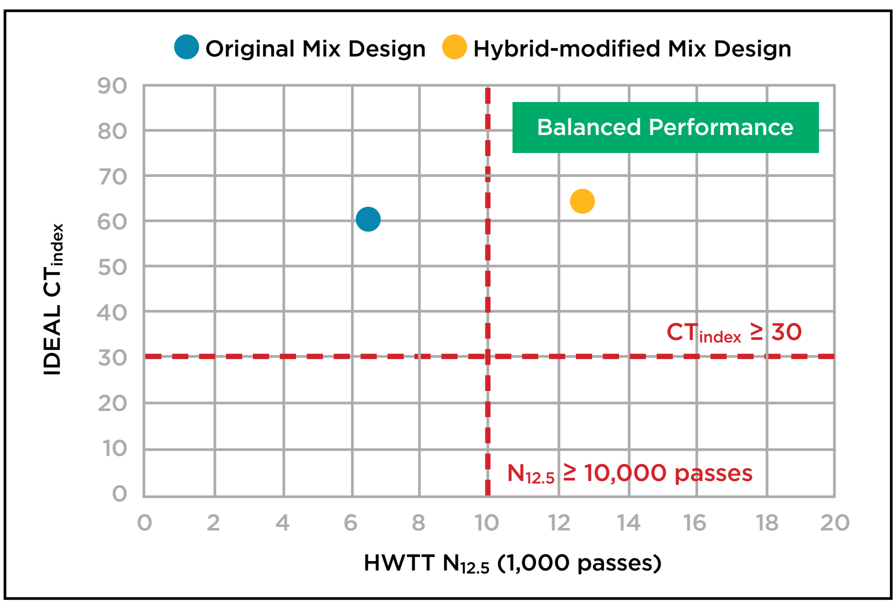


Figure 1. Performance Diagram of Mix Designs before and after Hybrid BMD Modification