
# Back at it

## After FHWA pause, IDOT study presses industry to continue moving forward

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**Pavements continue to be among the most recycled materials on the planet.**

**Table 1a. Allowance of ABR Levels in District 1**

| HMA Mixtures | Maximum % ABR | | |
|---|---|---|---|
| Ndesign | Binder/Leveling Binder | Surface | Polymer Modified |
| 30L | 50 | 40 | 30 |
| 50 | 40 | 35 | 30 |
| 70 | 40 | 30 | 30 |
| 90 | 40 | 30 | 30 |
| 4.75 mn N-50 | | | 40 |
| SMA N-80 | | | 30 |

**Table 1b. Allowance of ABR Levels in Districts 2 Through 9**

| HMA Mixtures | Maximum % ABR | | |
|---|---|---|---|
| Ndesign | Binder/Leveling Binder | Surface | Polymer Modified |
| 30L | 50 | 40 | 10 |
| 50 | 40 | 35 | 10 |
| 70 | 40 | 30 | 10 |
| 90 | 40 | 30 | 10 |
| 4.75 mn N-50 | | | 30 |
| SMA N-80 | | | 20 |

Over the past several decades, the asphalt industry has successfully innovated the use of reclaimed asphalt pavement, or RAP. This has inarguably led to significant environmental and economic benefits. To move the needle further in this direction, recent innovations in the area of warm-mix asphalt (WMA) have been shown to reduce the required energy associated with asphalt production and laydown, the fractionation of RAP (FRAP) and the use of recycled asphalt shingles (RAS) to push asphalt mixtures to even higher levels of asphalt binder replacement (ABR). The movement to WMA turned out to be relatively straightforward. WMA is now used extensively in certain regions of the U.S., for environmental and economic reasons. It also is a means to facilitate compaction, extend haul range and increase available time for compaction.

On the other hand, the use of FRAP and RAS to achieve higher ABR levels has proven to be a much bigger challenge and has even stirred up some controversy in the industry in recent times. So what are the sticky widgets? High fines content, partial blending of virgin and recycled binder and moreover, the relatively high stiffness of the field-aged recycled binder—all factors that have challenged mix designers who seek to balance mixture

**Table 2. Results of Projects Studied in District 1**

| Investigated Projects in District 1 | Mix Type | Asphalt Binder Replacement (ABR) (%) | Allowed by Statewide BDE spec | Max. Allowable ABR (%) (Current D-1 spec) | Max. Allowable ABR (%) (Current Statewide BDE) | Difference Between Maximum Allowable ABR of D-1 and Statewide BDE |
|---|---|---|---|---|---|---|
| Edens Expressway - Let 8/3/07 (Virgin Mix) | N80 SMA | 0 | Yes | 30 | 20 | 10 |
| I-55 between Jefferson St. and Plainfield Rd. - Let 6/15/07 (Virgin Mix) | N80 SMA | 0 | Yes | 30 | 20 | 10 |
| Bishop-Ford Expy - Let 4/1/09 (5% RAS) | N80 SMA | 16.7 | Yes | 30 | 20 | 10 |
| IL Rte. 83 from IL 64 to IL 19 - Let 4/26/13 (14.2% FRAP, 3.1% RAS) | N80 SMA | 27.6 | No | 30 | 20 | 10 |
| US 6/159th St. in Oak Forest - Let 4/26/13 (8% FRAP, 5% RAS) | N90 | 29.1 | No | 30 | 10 | 20 |
| US 52/Jefferson St. - Let 4/26/13 (N50 Binder: 30.5% FRAP, N90 Surface: 2.4% RAS, 14% FRAP) | N50 | 23.7 | Yes | 40 | 40 | 0 |
| | N90 | 30.0 | No | 30 | 10 | 20 |
| Illinois Rte. 58 - Dempster St. - Let 5/15/09 (10% FRAP) | N90 | 10.0 | Yes | 30 | 10 | 20 |
| Green Bay Road south of Tower Rd. in Winnetka - Let 4/23/10 (20% FRAP) | N70 | 14.5 | Yes | 30 | 30 | 0 |
| Wolf Rd. north of Roosevelt Rd. - Let 4/26/13 (30% FRAP) | N70 | 20.0 | Yes | 30 | 30 | 0 |
| Harrison Rd. north of Roosevelt Rd. - Let 4/26/13 (TRA mix, 53% FRAP, 5% RAS) | N50 | 57.0 | No | 60 | - | - |
| Jefferson St. downtown - Let 4/3/09 (20% FRAP) | N70 | 18.9 | Yes | 30 | 30 | 0 |
| State St. in Thornton - 4/26/13 (2.5% RAS, 17.5% recycled agg) | N70 | 29.8 | Yes | 30 | 30 | 0 |

economy and sustainability with mixture rut resistance and crack resistance.

In most cases, mixtures with high ABR have not displayed rutting issues or presented any challenges in passing rutting performance tests, such as the Hamburg wheel tracker. Therefore, pavement cracking is the primary concern with high ABR mixes. Until recently, the industry was without a reliable, standardized cracking test that could be used to control cracking in asphalt mixtures. In the meanwhile, the use of high ABR mixtures has led to mixed results in the field. This has in turn led to some back-tracking on recycling rates by the Federal Highway Administration (FHWA), pointing to pavement cracking problems in the Midwest on projects where high ABR mixtures were used. However, a number of local practitioners disagree with the source of pavement cracking, and vehemently resist backpedaling on recycling rates in the absence of rigorous scientific evidence.

This article presents a case study involving a forensic pavement-cracking investigation on high ABR mixes in and around Chicago, and presents a cracking test and specification that was used to determine if the use of high ABR mixtures was the cause behind observed field cracking. Suggested use of the new cracking specification for mixture design is presented, as well. Greener-yet-durable asphalt pavements are now possible with a modern design tool.

## Not convinced

In the Chicagoland area, designated by the Illinois Department of Transportation as District 1 (D1), a special provision has been used in recent years (Table 1) allowing the use of higher ABR levels as compared to the rest of the state (Districts 2 through 9) for polymer-modified mixtures. Following pressure from the FHWA to address pavement cracking in the Chicagoland area, IDOT proposed to have D1 revert to the statewide specification for RAP/RAS mixtures. However, local practitioners were not convinced about the source of observed cracking and commissioned a study by the University of Illinois at Urbana-Champaign to take a closer look in light of a modern cracking performance test and two decades of experience with various types of asphalt-pavement-cracking studies. The study involved on-site pavement investigation in Districts 1 and 2, evaluation of selected projects using a state-of-the-art data collection vehicle, fracture testing and density assessment of cores obtained from projects in D1, and evaluation of associated plans and specifications.

## Taking a pounding

The projects studied in the main investigation (pavement sections in D1) are shown in Table 2. Sections were selected in order to compare pavement sections in three different traffic categories, following both D1 and statewide specifications.

From field investigations, the predominant mode of pavement deterioration (distress) observed was determined to be reflective cracking, caused by traffic-induced movement of underlying portland cement concrete (PCC) slabs, which constituted the main pavement structure in all sections investigated. This finding was supported by a number of identifying factors, including:

1. Existence of regularly spaced transverse cracks, reflective of typical PCC joint spacing;
2. Existence of longitudinal cracks in the typical location of underlying PCC longitudinal joints;
3. Alignment of transverse cracks with observed joints and cracks in PCC curbs and pavement shoulders (Figure 1);
4. Existence of underlying PCC slabs in each project investigated as documented in IDOT plans and specifications;

Figure 1. Alignment of transverse cracks with observed joints and cracks in PCC curbs and pavement shoulders.

Figure 2. Existence of crack patterns resembling utility cuts in PCC pavement.

Figure 3. The disk-shaped compact tension cracking test, or DC(T).

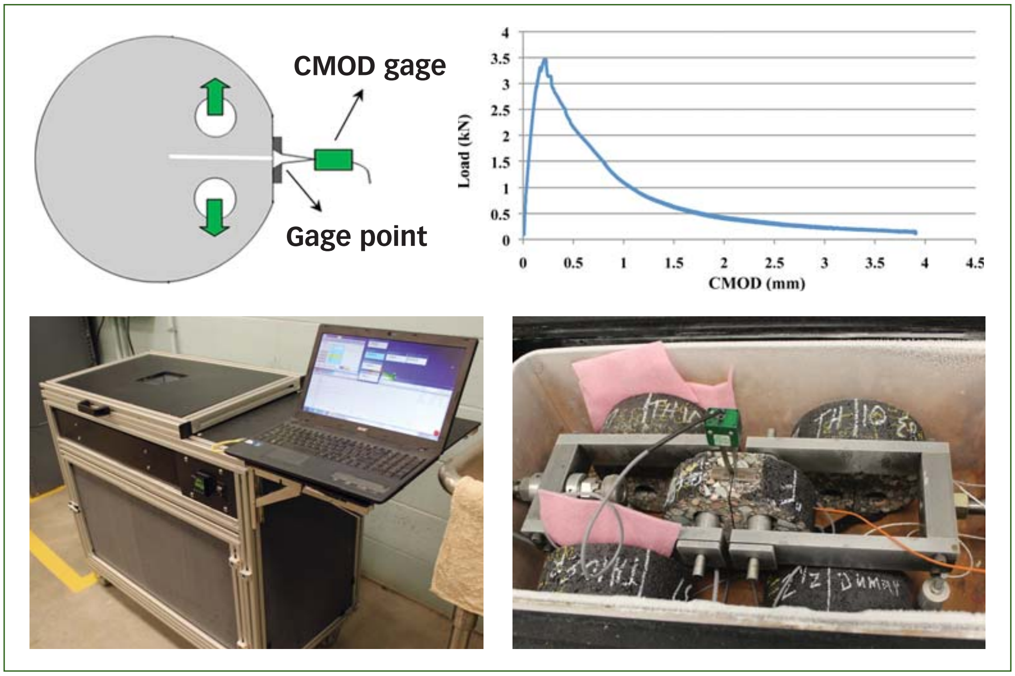



Table 3. Recommended Fracture Energy Thresholds (Minimums)

| | Project Critically/Traffic Level | | |
|---|---|---|---|
| | High (>30M ESALS) | Moderate (10–30M ESALS) | Low (<10M ESALS) |
| Fracture Energy, minimum (J/m$^2$), PGLT + 10°C | 690 | 460 | 400 |

5. Existence of reflective crack patterns matching typical PCC joint patching geometry;
6. Existence of crack patterns resembling utility cuts in PCC pavement (Figure 2); and
7. Existence of deposits of fine material pumped to the surface of the pavement, which is typically caused by the vertical deflection and pumping of water from joints and cracks in deteriorated PCC pavements.

Although low temperatures can accelerate reflective cracking, research has shown vehicular traffic to be the primary driver of this cracking form. In comparison to reflective cracking, other distresses observed in the D1 sections were relatively minor and infrequent, including slippage, cracking, bleeding and segregation/raveling. Common distresses that were not observed on pavements investigated were traditional thermal cracking, block cracking or rutting. Similar reflective cracking patterns and amounts were observed in both D1 and D2, which included a number of projects designed according to the statewide specification for RAP/RAS, which calls for lower levels of asphalt binder replacement through the use of RAP and/or RAS as compared to the D1 special provision for RAP/RAS.

## Special provision

Fracture tests were conducted to determine the fracture resistance of pavement surfaces following the D1 special provision for RAP/RAS, selected control sections following the statewide specification for RAP/RAS, and selected control sections using only virgin materials (no recycled asphalt binder replacement).

Fracture testing and specification levels used were those developed over the past 12 years by the University of Illinois and partnering universities, particularly under an FHWA pooled fund study involving a number of Midwest states, including Illinois. The recommended cracking-performance tests have been recently implemented by the Minnesota DOT and the Chicago DOT, respectively. Figure 3 displays the disk-shaped compact tension cracking test, or DC(T), which is specified in ASTM D7313-07 and commercially available (the Test Quip portable DC(T) was used in this study). The test measures the resistance of an asphalt mixture to cracking in terms of mixture fracture energy. Fracture energy is simply the work involved in creating a crack surface, which is calculated by dividing the area under the load versus CMOD (crack mouth opening displacement) curve by the area fractured (specimen thickness multiplied by the length of the crack produced). Table 3 presents the recommended fracture energy thresholds (minimums) as a function of project traffic/criticality. More conservative levels (higher fracture energies) are specified for projects where repairs and traffic closures are expected to be more expensive/critical.

A representative result is shown in Figure 4, where for high traffic sections the higher ABR D1 pavement section was in compliance with the DC(T) specification and performed well as compared to the mixtures with lower ABR following the statewide specification for RAP/RAS. Combining all mixture types and comparing ABR specifications, for the statewide specification, five of eight sections met cracking criteria (62.5%), while for the D1 Special Provision, three of four sections met cracking criteria (75%). Additionally, in each traffic category considered, mixtures following the D1 Special Provision for RAP/RAS had a higher percentage of compliance with recommended fracture energy levels than mixtures following the statewide specification. The lowest fracture energy of all sections tested was in fact one that adhered to the statewide specification (lower recycling rate). In summary, fracture testing results demonstrated that mixtures following the D1 Special Provision can be designed to exceed recommended fracture energy thresholds for thermal-cracking resistance, having similar fracture energy levels as mixtures produced under the statewide specification and a better overall percentage of compliance with recommended levels when viewed in aggregate. The presence of mixtures not meeting minimum recommended fracture energy levels in each category is perhaps not surprising, since these mixtures were required to pass the Hamburg wheel rut test, but not required to pass a mixture cracking test.

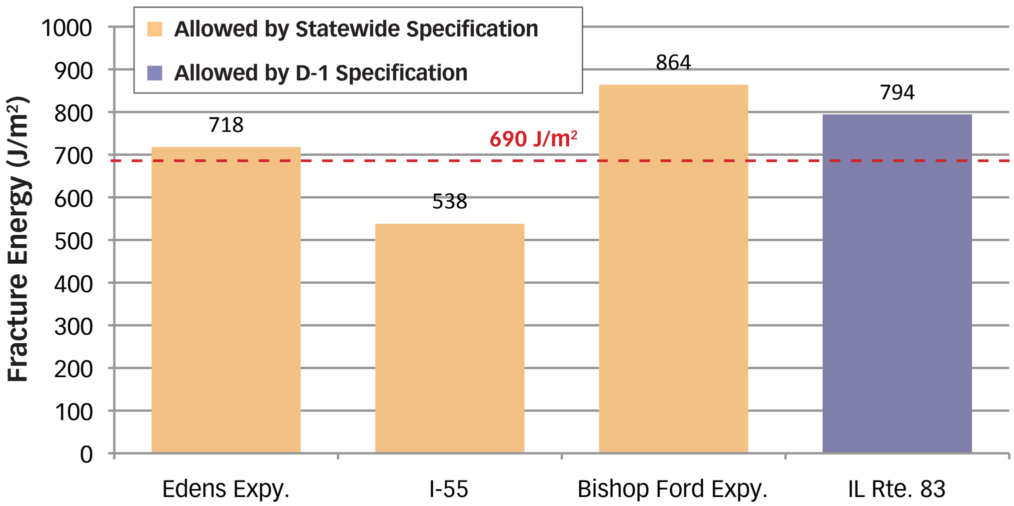
## The real cause

Based on the results of this investigation, the District 1 Special Provision for RAP/RAS was not found to be the cause of the observed cracking in the pavements investigated in the Chicagoland area. The cause of early age cracking in asphalt overlays in the pavements investigated in D1 and D2 was clearly attributable to the mechanism of reflective cracking, emanating from the movement of underlying deteriorated PCC pavement and likely accelerated by the severe winter of 2013-2014.

Considering the results of this investigation, the following recommendations were made:

1. Continue the sustainable practice of allowing higher recycling rates in asphalt overlays, such as that specified in the D1 Special Provision;
2. Calibrate expectations for pavements that are in fact designed to concede reflective cracking (i.e., expect cracking to appear in one to three years depending on traffic level and severity of winters);
3. Require a cracking performance test as part of overlay mixture design (e.g., the DC(T), i.e., ASTM D7313) to control thermal and block cracking, and to open the door for even higher recycling rates; and
4. Conduct research to fine-tune the recommended thermal-cracking specification to investigate alternatives for reflective crack control in light of new materials and analysis techniques (such as ultra-high fracture energy overlay systems), and to determine appropriate applications and design methods for asphalt mixtures with even higher recycling levels to promote enhanced pavement sustainability.

**Figure 4. Five of the eight high-traffic sections met cracking criteria.**




## Bright green

None of the pavements investigated, including those surfaces designed under the statewide specification for RAP/RAS, had sufficient fracture resistance to combat the high strain induced by rocking PCC panels. Past research has indicated the difficulty in preventing reflective cracking over PCC pavement in colder climates, with solutions limited to more expensive repairs including: 1) removal and reconstruction of deteriorated PCC slabs; 2) extensive concrete pavement repair (such as dowel bar retrofit or doweled patches); 3) rubblization of PCC slabs to eliminate concentrated movements at joints and cracks; or 4) the use of at least two ultra-high fracture energy overlay lifts (reflective cracks have been found to "jump over" a single crack resistant lift). Currently, most overlays are designed to "concede" to the occurrence of reflective cracking, since funding for more expensive repairs has been scarce in the era of declining infrastructure state-of-repair. For such designs, dozens of studies have indicated that reflective cracking will eventually occur, with a crack initiation time of one to three years in moderate-to-cold climates depending on factors such as underlying PCC condition, overlay thickness, overlay fracture energy, climate, traffic loading and use of interlayers.

That notwithstanding, it is recommended that the asphalt overlay be designed to withstand thermal cracking in order to retard the rate and severity of reflective cracking and to avoid denser crack patterns, such as thermal and block cracking between reflective cracks.

The DC(T) specification shown in Table 3 can be used to achieve this goal. For new mix designs, specimens should be short-term oven-aged, as the specification is calibrated to this aging condition for mix-design specimens. As with any new specification, demonstration projects and local calibration will produce the best results in the long run, accounting for local variations in materials, climate, underlying pavement and traffic. As for the aforementioned two-layer, ultra-high fracture energy mixtures—preliminary research shows promise, but a more precise solution is still under development and beyond the scope of the current article. Current results indicate that fracture energies in the 1,500-2,500 range will likely be required for these layers.

The bottom line is by employing a mixture cracking performance test along with sound engineering experience, the future is bright (green?) for achieving even higher pavement sustainability without sacrificing durability and ride quality. **R&B**

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