TECHNICAL NOTE

University of Pittsburgh

Guidelines for Bonded Concrete Overlays of Asphalt: Beginning with Project Selection and Ending with Construction

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Bonded Concrete Overlays of Asphalt Pavements (BCOA)

1. Introduction

Bonded concrete overlays of asphalt (BCOA) pavements are typically between 3 to 6 inches thick. The bond between the asphalt and the concrete is critical to ensure that that the pavement behaves as one structure, especially for very thin concrete overlays. This monolithic behavior results in reduced stresses and deflections. The purpose of the BCOA is to increase the structural capacity, eliminate surface defects and/or improve surface friction, noise, and rideability of the existing asphalt pavement. The overlay can be placed on an existing asphalt pavement or a composite pavement (asphalt on top of concrete), as shown in Figure 1.

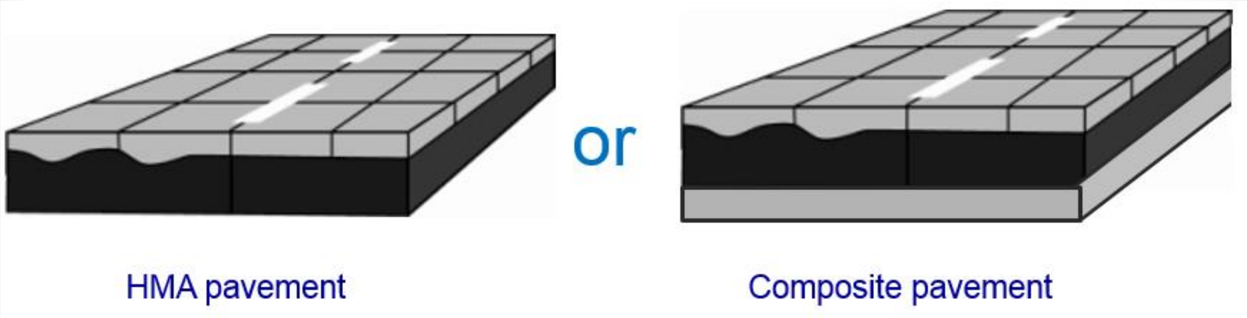

Figure 1. Pavement types suitable for BCOAs.

2. Suitable Candidates

BCOAs are a good rehabilitation alternative for pavements that are currently in good to fair structural condition, as shown in Figure 2, but structurally insufficient to carry the projected future traffic. If the condition of the HMA pavement can be improved to fair or good condition with a reasonable amount of repair, this is also a good candidate for a BCOA, as shown in

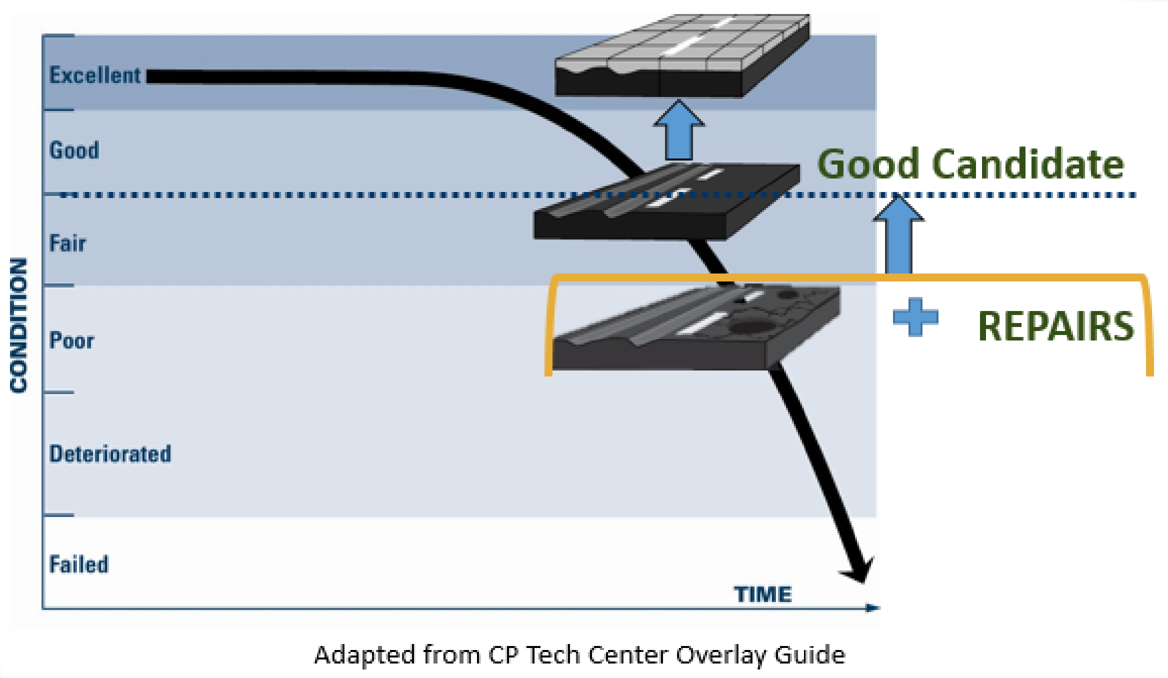

Figure 2. Suitable HMA pavement conditions for a BCOA.

Figure 2. BCOAs are also ideal in heavily trafficked areas that are susceptible to chronic rutting as well as HMAs with other functional distresses (e.g. loss of friction, noise, etc.). The characteristics of good and poor BCOA candidates are provided in Table 1.

Table 1. Characteristics of a good and poor BCOA candidates.

GOOD CANDIDATE	POOR CANDIDATE
Stable support conditions (Localized weak area can be strengthened)	Significant structural deterioration
Surface distresses	Stripping of lower HMA layers
Temperature cracking	Poor drainage
Minimum of 3 to 4 inches of HMA remaining after milling	Inadequate or uneven support conditions

Some of the distresses that can be addressed with a BCOA are provided in Figure 3. Many of the surface distresses illustrated in Figure 3 are typically removed during the milling process done prior to the placement of an overlay.

Figure 3. Distresses in the HMA pavement.

The flowchart in Figure 4 is a tool developed by the National Concrete Pavement Technology Center (CP Tech Center) that can be used for determining if a BCOA is a good rehabilitation alternative for a distressed HMA pavement, with consideration to the characteristics listed in Table 1.

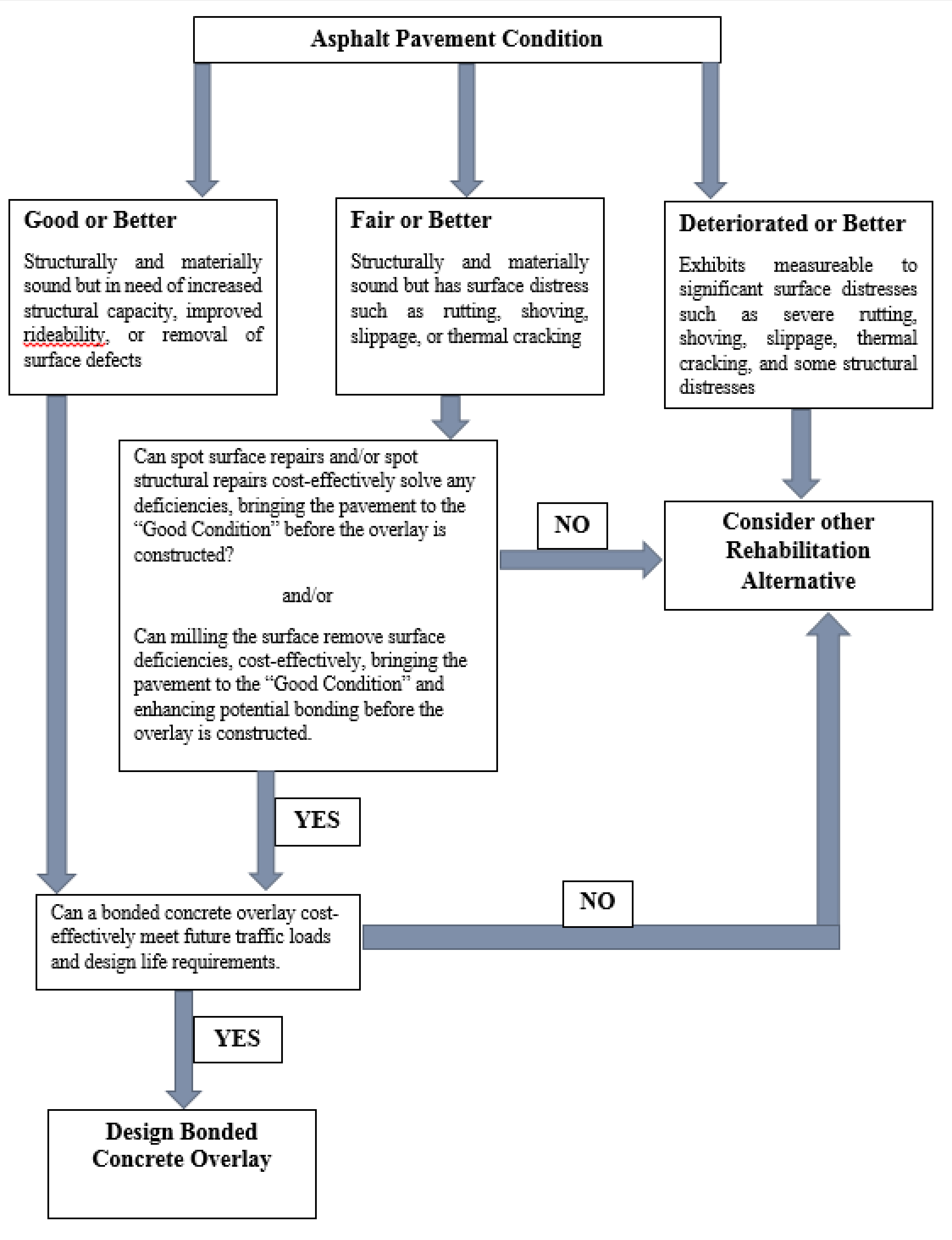

Figure 4. Flowchart for determining if a BCOA is a good rehab alternative [1].

3. Pre-Design Activities

Once it is determined that the BCOA is a good rehab alternative, there are several pre-design activities that should be performed prior to designing the overlay. These activities are described below.

I. Gather Historical Records for Existing Pavement

Historical records that should be gathered include the following:

- Original design, construction, and material testing records
- Traffic data
- Performance data
- Previous maintenance and repair records

II. Site Visit

The site visit should include the following:

- Conduct a distress survey documenting the type, severity, and quantity for each distress observed. This information can be obtained from the National Concrete Pavement Technology Center (CP Tech Center) Guide to Concrete Overlays [1].
- Determination of minimum vertical clearance and sight and grade restrictions
- Identification of drainage issues and shoulder condition
- Identify locations for coring

III. Coring and Material Sampling

Coring is highly recommended for the following reasons:

- Establishing the depth and severity of distresses in the asphalt
- Determining the thickness of the asphalt layers as well as the location and depth of the lifts in the asphalt
- Determine if there is the stripping within or at the bottom of the HMA layers
- Material characterization

IV. Falling Weight Deflectometer (FWD) Testing (optional)

FWD testing is not essential but, if preferred, can be used for establishing the elastic modulus of the layers beneath the asphalt. The estimated moduli will be used to establish the composite modulus of subgrade reaction (k-value) in the design procedure. The layer moduli can also be estimated based on correlations with other known or measured material properties (e.g. CBR, R-value, etc.). The overlay thickness is not very sensitive to the k-value, and therefore an estimate of the elastic moduli for each layer based on correlations is sufficient. In the BCOA-ME design procedure, the elastic modulus of the HMA layer is established based on the percent fatigue cracking, and therefore does not need to be established with FWD data. More information providing guidance on FWD testing and results can be found in the BCOA-ME theory manual [3].

4. Design Considerations

The thickness of the overlay can be determined using the BCOA-ME design procedure and can be accessed at www.engineering.pitt.edu/Vandenbossche/BCOA-ME. Several other factors must be considered in the design process. These factors, along with considerations that should be made while addressing each of these factors in the design process, are provided below.

Joint design

A square joint pattern should be used with panel sizes ranging between 3 to 8 feet, to reduce curling and warping stresses. When selecting the slab size, if at all possible, avoid slab sizes that result in longitudinal joints near the wheelpath. The slab sizes should be established based on economics. While thickness reduction is possible with smaller slabs, more sawing and sealing is required, due to the increase in lineal feet of joints. Other project specific conditions might also dictate the panels size. If vertical clearance issues exist, a smaller slab size should be considered to reduce the design thickness. On the other hand, if a thick milling depth is required to remove surface distress, larger slab sizes can be accommodated when the existing pavement elevation must be maintained.

Dowels and Tie bars

The use of tie bars and dowel bars is typically not necessary when the panel sizes are small. However, the use of dowel bars and tie bars can be considered for heavily trafficked roadways when the overlay thickness is 6 inches or greater.

Sawing and sealing

Joints should be sawed to a depth of 1/3 the thickness of the overlay. It is recommended that the joints be sealed for overlays less than 5 inches thick. A 1/8 to ¼ reservoir can be sawed and sealed with an asphalt sealant. The success of very thin overlays relies on the bond between the HMA and the overlay, to allow the pavement to carry the load as a monolithic structure. Allowing water to infiltrate into an unsealed joint can contribute to stripping and raveling of the HMA, and therefore degradation of the bond between the two layers.

Fiber in concrete mixture

The use of fibers can be considered for overlays 4 inches thick or less. Only structural grade fibers should be considered, which improve the toughness and post-cracking behavior of the concrete. The structural fiber chosen should provide a residual strength of 20 percent or more. Insufficient evidence exists at this time to support using fiber reinforced concrete in BCOAs for the purpose of increasing the panel size.

5. Pre-overlay Repairs

Some HMA pavements might require pre-overlay repairs prior to the placement of the BCOA. A list of the distresses that should be repaired are provided in Table 2, along with suggested repairs. All full and partial depth patching should be completed after milling. When patching is required, concrete should be used, as new asphalt does not bond well with concrete overlays. After milling, the patch can be placed either by itself or monolithically with the overlay. A separate panel should be created over the location of the concrete patch, to keep it separate from nearby asphalt that provides different underlying support conditions.

Table 2. Distresses to be repaired prior to the placement of the overlay.

HMA DISTRESS	POSSIBLE REPAIR
Rutting $\geq$ 2 in	Milling
Corrugations & slippage	Milling
Transverse cracking	Clean and fill or localized debonding
High or med. severity fatigue cracking	Full-depth concrete patch
Pothole	Full-depth concrete patch

Repair of Transverse Cracks

There are two methods available for repairing transverse cracks prior to the placement of the overlay, based on the severity of the crack. If the crack width is greater than the maximum aggregate size in the concrete overlay, then the crack must be filled prior to paving. This will prevent interlocking or "keying" of the overlay into the HMA. The crack can be filled with an emulsion, a slurry or sand prior to placing the overlay.

If the crack width is less than the maximum aggregate size in the overlay and it is a working crack, it is possible that the crack may reflect through into the overlay. A reflection crack has the potential to develop in the overlay if the flexural stiffness of the concrete is less than the flexural stiffness of the asphalt, as seen in Figure 5. The flexural stiffness, D, is defined in Equation 1.

$$Flexural\ Stiffness = D = \frac{Eh^3}{12(1-\mu^2)} \qquad \text{(Eq. 1)}$$

E is the elastic modulus of the material, h is the thickness of the layer and μ is the Poisson's ratio. A localized area along the crack should be debonded, if there is potential for reflective cracking to occur. The debonding material is placed over the crack on top of the asphalt and can consist of any thin material that would break the bond, such as duct tape or roofing paper, as shown in Figure 6. Only cracks identifiable as major working transverse cracks should receive such treatment. In colder climates, some lower percentage of reflective cracking in the BCOA should be expected.

Figure 5. Transverse crack in the HMA (left) reflecting up into the BCOA (right).

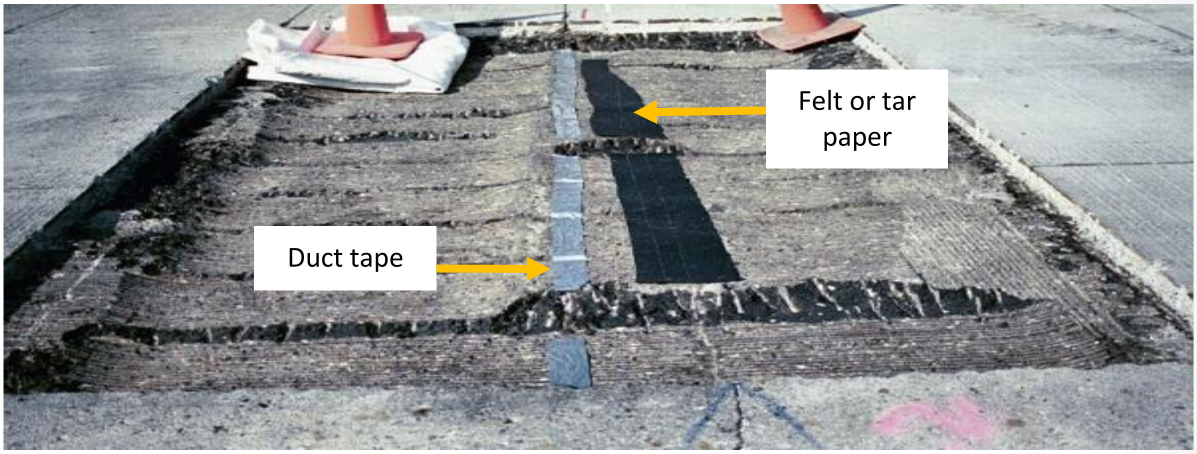

Figure 6. Pre-overlay repairs and measures taken to reduce reflective cracking.

6. Construction

The construction of a BCOA is accomplished through the following steps.

I. Milling (See Figure 7.)

- Milling of the existing HMA is optional, but highly recommended for very thin BCOAs. Milling enhances the bond between the concrete and asphalt, which is especially critical to the performance of thin concrete overlays.

- When possible, try to leave an inch of HMA between the HMA surface and the nearest asphalt lift, so that debonding is unlikely between the lifts.
- Changes in grade requirements or the cross slope should be made by adjusting the concrete overlay thickness, rather than when milling across lifts in the asphalt, which can be detrimental to a good bond.
- The depth of milling is established based on the thickness of the overlay and the following:
  - The depth needed to remove surface distortions greater than 2 inches
  - Thickness required to match curb or existing structure elevations
  - Thickness required to meet minimum vertical clearance requirements

Figure 7. Asphalt milling operation and the HMA surface after milling.

II. Surface Cleaning

- Before placing the overlay, the asphalt surface needs to be cleaned to ensure proper bonding. Cleaning is typically accomplished by sweeping the surface or using compressed air.

III. Mist surface

- It is imperative that the existing asphalt temperature be maintained at a temperature below 120 ^{o}F when placing the concrete overlay to decrease the potential of fast set shrinkage cracking. The surface can be misted with water to reduce the temperature of the asphalt.

- Misting the surface will bring the surface of the HMA up to a saturated surface dry condition, so that it is not pulling moisture from the concrete mixture.

- Water should not be puddled on the surface when placing the overlay, or localized high water to cementitious ratios, and therefore reduced bond strengths can develop at the interface.

IV. Place and finish concrete

- The overlay can be placed with a slip-form paver, using forms or, at times, through a mill and fill method, as shown in Figure 8. More information on the mill and fill method can be found in the BCOA Rehabilitation Strategies Tech Note [4].
- If structural fibers are used in the mix, ensure that they are uniformly distributed throughout the concrete during placement.

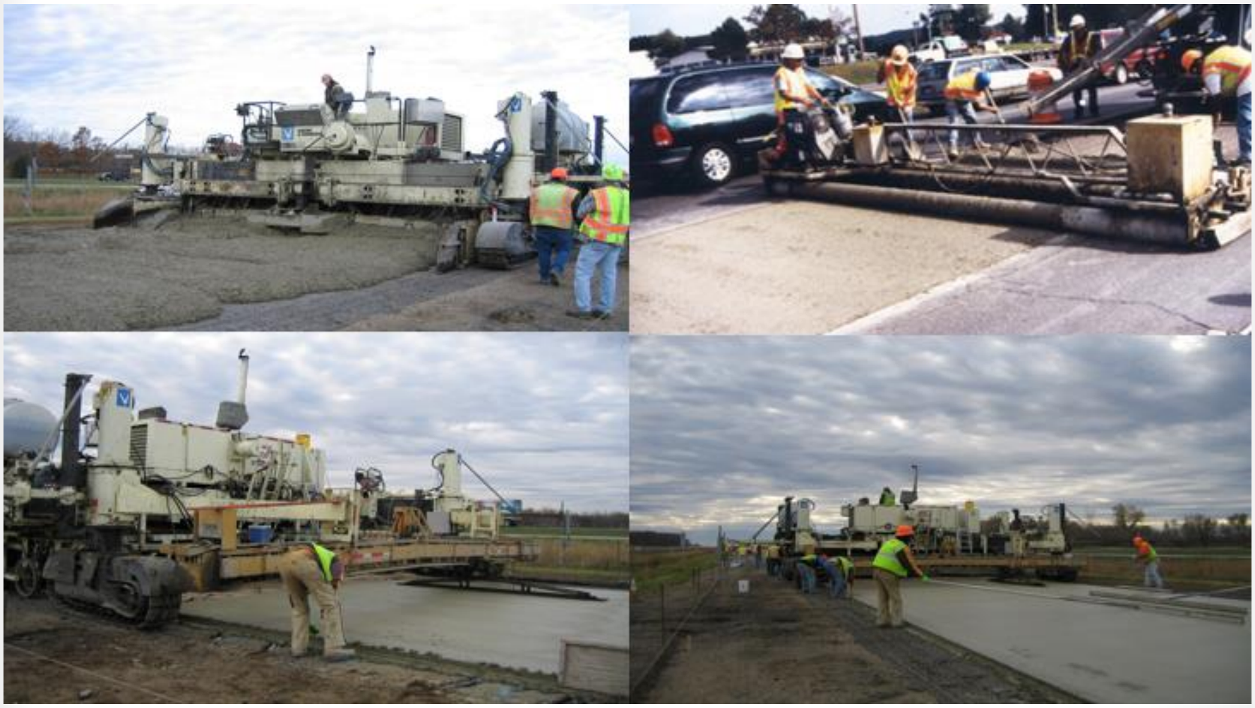

Figure 8. Placing and finishing the BCOA.

V. Curing

- Curing is critical for bonded resurfacing projects because their high surface area–to-volume ratio makes them more susceptible to rapid moisture loss.
- When at all possible, a cure cart should be used over insure a uniform distribution across the pavement surface. See Figure 9.
- Caution should be taken not to spill curing compound onto an area of the HMA yet to be resurfaced, because it will deter bonding between the two layers [1].
- Curing compound should be sprayed on all exposed edges, as well as the surface of the overlay, as shown in Figure 9.

Figure 9. Application of a curing compound.

VI. Sawing and Sealing Joints

- Joints should be sawed to 1/3 the depth of the overlay.
- Joints should be cleaned and sealed as quickly as possible to prevent uncontrolled cracking. See Figure 10.
- A 1/8 to ¼ inch wide reservoir is sufficient if an asphalt sealant is to be used. Backer rod should not be used for these narrow joint widths.

Figure 10. Sawing and sealing joints.

VII Opening to traffic

- The most important factor in determining when to open a BCOA to traffic is the concrete strength. The minimum concrete opening strength is related to the load carrying capacity and can also provide an sign of the bond strength.

- Distress will develop quickly if the structure is loaded before the bond between the HMA and overlay has had time to fully developed. Measuring the strength (compressive or flexural) or the use of maturity measurements before opening to traffic will help to confirm that sufficient concrete strength has developed to ensure a good bond.

- More detailed information and recommendations in regards to opening the overlay to traffic can be obtained from the National Concrete Pavement Technology Center (CP Tech Center) Guide to Concrete Overlays [1].

Acknowledgments
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References

1. National Concrete Pavement Technology Center. *Guide to Concrete Overlays: Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements.* 2nd Edition, September 2008.

2. FHWA. *Distress Identification Manual for the Long-Term Pavement Performance Program.* Fourth Revised Edition, 2003. FHWA-RD-03-031. Washington, DC.

3. Li, Z., N. Dufalla, F. Mu, and J.M. Vandenbossche. *BCOA-ME Theory manual*. FHWA Pooled Fund study, TPF 5-165, August 2013.

4. Vandenbossche, J. M. and S. Sachs. *Rehabilitation Strategies for Bonded Concrete Overlays of Asphalt Pavements.* FHWA Pooled Fund study, TPF 5-165, August 2013.