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TechBrief

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Continuously Reinforced Concrete Pavement: Improved Transition Designs

A transition between a continuously reinforced concrete (CRC) pavement and any other type of pavement or structure needs to accommodate a gradual change in either the configuration or the structural capacity of the pavement cross section to maintain rideability, minimize or facilitate slab end movements, and minimize the potential for drainage-related issues to be a factor in performance. In CRC pavements, transitions are design measures to accommodate a uniform or gradual change in slab thickness, width, restraint, or movement (either vertically or horizontally) at a specific location with the intent of preventing early deterioration and minimizing the need for maintenance over the design life.

The junction between a CRC pavement and any other type of pavement such as jointed concrete (JC) or asphalt concrete (AC) pavement or a bridge structure (figure 1) all require a reconfiguration of the pavement typical section to provide an acceptable transition (particularly in light of the magnitude of movements that potentially can take place). A variety of joint configurations and movements can be included in transitions, but those such as jointing details, tie bars, and dowels, along with other details of each transition type, are discussed in this document, which addresses the important factors that must be considered for transition design.

The objective of a transition involving segments of CRC pavement is to maintain uniformity of both support and cracking across the transition segment. Performance-wise, one function of reinforcing steel in CRC pavement is to maintain the stiffness and tightness of transverse cracks, as well as, for instance, transverse header joints (as one type of transition). The capability of maintaining the necessary aggregate

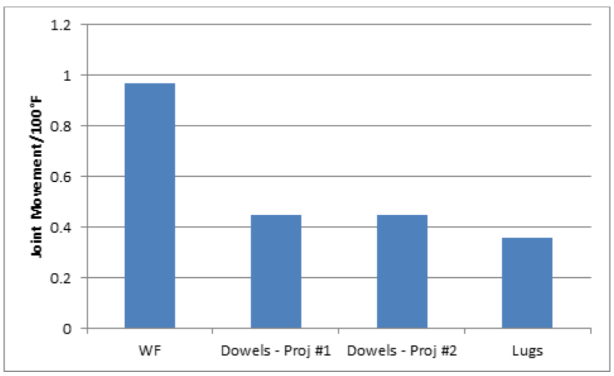

FIGURE 1. Summary of joint movement at different transition joints and sites. (WF = wide flange)

interlock and sufficient load transfer may depend upon the use of additional deformed steel (of a larger diameter) or smooth dowel bars as part of the transition. For instance, to supplement the load transfer capability of the reinforcing steel, a certain amount of doweling may provide a sufficient level of load transfer in a CRC-to-CRC transition, subsequently elaborated.

For the sake of consistency, table 1 outlines a classification system and notations for a range of joint types typically detailed in transition designs. Contraction, construction, and isolation joints are defined as Type A, B, and C, respectively. These basic joint types form the basis for a wide variety of joints when associated with combinations of modifiers that define them with respect to specific design features included in the transition. Elaborating further, deformed bars tie the transition components together and provide load transfer, while smooth dowels transfer load without restraining the opening of the joint. Thickened edge, wide flange, and sleeper slabs are used in cases where wide-opening joints are expected at such transitions as between CRC and bridge approach slabs, where it is important to ensure a minimum level of load transfer. As an example of how these designations can be used, a header joint with deformed bars only would be designated as "Transverse Type A (DB)," a header joint with dowels would be "Transverse Type B (SD)," and a transverse isolation joint with a wide flange would be "Transverse Type C (WF)."

Table 1. Classification and Notations of Joint Types

Type	Joint Description	Joint Type Modifiers	Abbreviation
A	Contraction joint	With smooth dowel	SD
B	Construction joint	With deformed bar	DB
C	Isolation joint	Thickened edge	TE
		Wide flange	WF
		Sleeper slab	SS

TRANSITIONS BETWEEN CRC AND CRC PAVEMENTS

A joint of this type is typically used at header joints. Figure 2 shows the arrangement of reinforcing steel associated with a CRC-to-CRC construction joint. The wheel path can be assumed to be an area 2 ft (0.6 m) wide positioned 1 ft (0.3 m) from the longitudinal edge. As a minimum, three deformed bars (or dowel bars) can be installed in each wheel path to provide for additional load transfer. If an extended amount of time transpires before placing the adjacent CRC pavement, an isolation joint with deformed bar

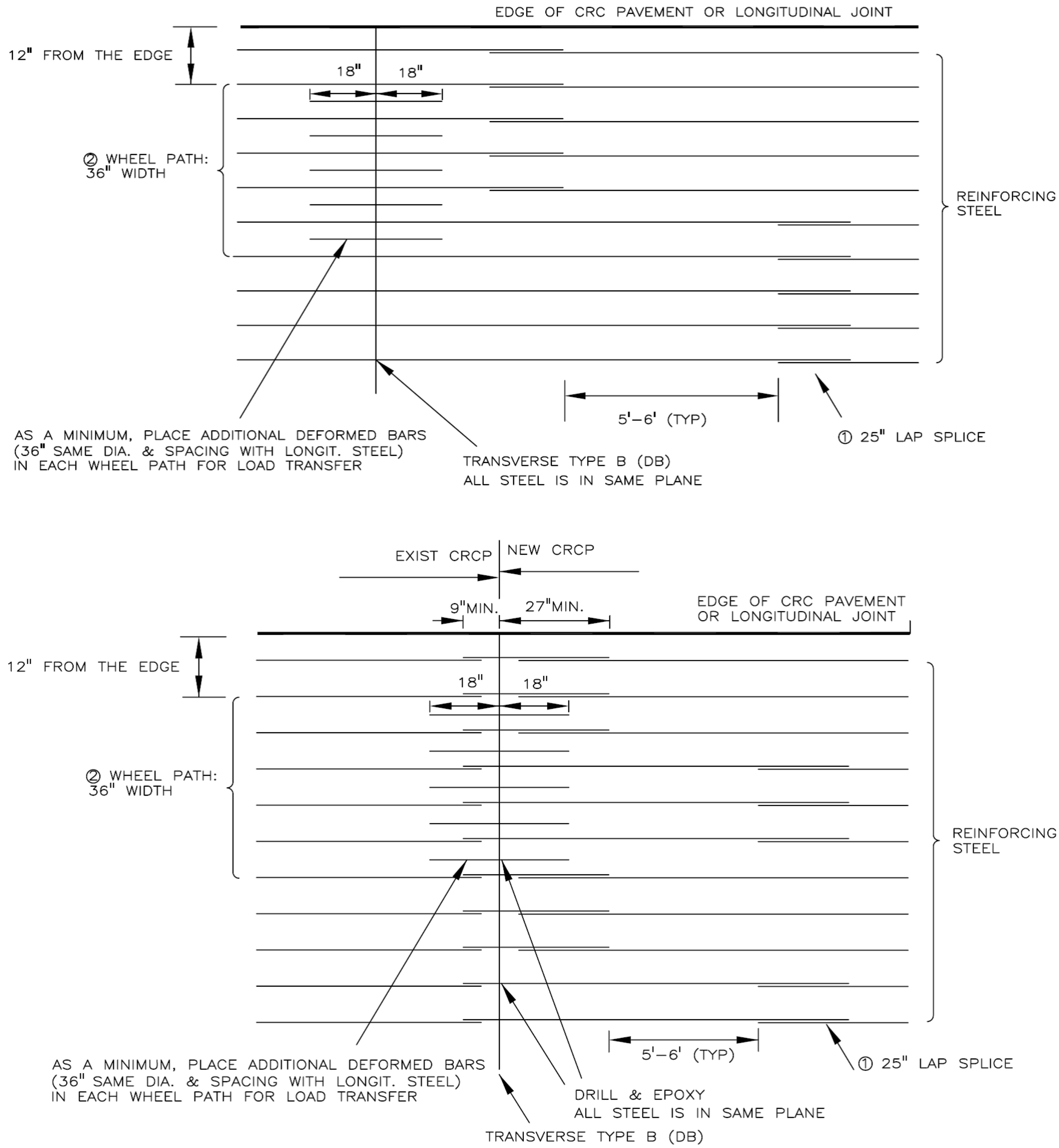

FIGURE 2. Wheel-path reinforcing details of a CRC pavement construction joint. (1 inch = 25.4 mm; 1 ft = 0.305 m)

(Type C (DB)) that includes an expansion joint filler material should be installed to minimize damage due to differential thermal movement (aggravated by differences in concrete set temperatures). Design of the joint to designate the features to be specified typically entails the determination of bar size, spacing, and length based on traffic level, slab thickness, and the size and spacing of the existing reinforcement. Additionally, the supplemental doweling may adversely impact the spacing requirements between the steel bars and the dowels, possibly causing consolidation problems of the concrete during paving. To limit the area where consolidation may be an issue, doweling should be limited to the wheel-path area of the slab along the transverse joints, particularly if the dowels are placed at mid-depth.

A key feature of a portland cement concrete (PCC) pavement thickness transition is achieving continuity of support and deflection. When a thickness transition occurs abruptly at a construction joint, it may actually involve a blockage to subbase drainage paths that may eventually create support problems that can, if load transfer is insufficient, create deflection differences across the joints between two slabs, which may lead to erosion damage. The use of a graduated thickness transition would help improve continuity. Figure 3 shows such a thickness transition facilitation for a change in pavement thickness. Dowels/tie bars can be positioned, drilled, and epoxied into the existing pavement to be compatible with the transition between the two pavement thicknesses. The tapered transition area should be at least 20 ft (6.1 m) long where the length of the lap splices should be 33 times the steel bar diameter. The reinforcing steel splice can be made in the thickness transition area if it is necessary to make splices. It is also important to achieve proper consolidation of the concrete placed in the transition area.

TRANSITIONS BETWEEN CRC AND JC PAVEMENTS

The objective of this type of transition is to allow the movement of the joint and isolate the movements of the CRC relative to the JC slab. Good performance with this type of transition depends on keeping the joint area clear of incompressible debris and maintaining the opening of less than 1 inch (25 mm) to preserve the integrity of the joint seal. However, wider openings can and have been accommodated but may

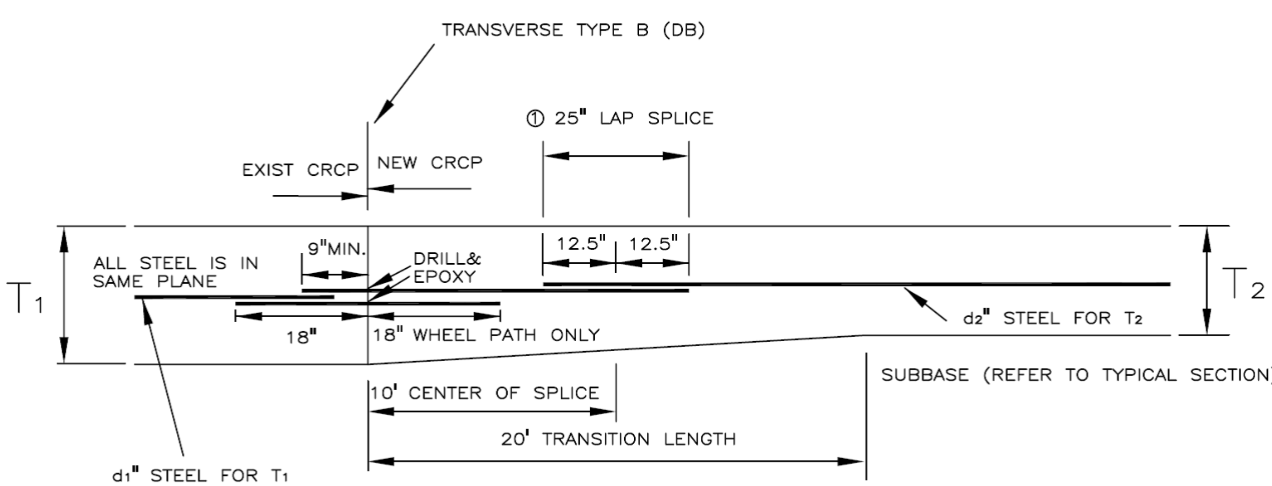

FIGURE 3. Thickness transition detail for CRC pavement.

involve special consideration for deflection or support continuity at the joint requiring the use of a sleeper slab. Additionally, the expansion joint may include a filler material that results in the joint being wider than 1 inch (25 mm), suggesting other options subsequently discussed may be more appropriate. Furthermore, dowels may also be used and interspersed within the pattern of the reinforced steel.

For this transition type, four options are available. In recent years, however, the use of anchor lugs has diminished, and this option is not included with those discussed below. Although more difficult to keep sealed, the four options allowing free movement of the joint have been used for transitions between CRC and JC pavements, as follows:

- Sleeper slab and wide flange (figure 4).
- Modified wide flange (figure 5).
- Doweled joint (figure 6).
- Steel transition and saw cuts (figure 7).

Option 1

Shown in figure 4, the first option details a sleeper slab with an embedded I-beam section. A 2-inch (51 mm) poly foam compression seal is inserted at the interface of the CRC pavement and the I-beam to accommodate any expected end movement. The embedded 5-inch-wide (127 mm) I-beam is tied to the JC slab by bars 0.75-inch (19 mm) in diameter (#6 bars), fabricated as 8-inch (203 mm) studs at 18-inch (457 mm) centers. The width of the sleeper slab is 60 inches (1.5 m) with a minimum thickness of 10 inches (254 mm). This detail is applicable where movement is restricted to one side of the joint only and the interest is to eliminate the need to install joint seals. Drawbacks to this option pertain to a nonwatertight system (perhaps requiring galvanization of the I-beam) and the potential for problems on snowplowed routes such as effects from impact loading to the I-beam and rutting due to studded tire wear. A variation would be to omit the I-beam and only use a sleeper slab.

Option 2

The second option, shown in figure 5, refers to a modified wide flange for stability purposes with dowels instead of the standard I-beam and sleeper slab. This design option can be applied effectively between previously placed CRC and new JC pavement since a sleeper slab is not involved. This design is useful to simplify con-

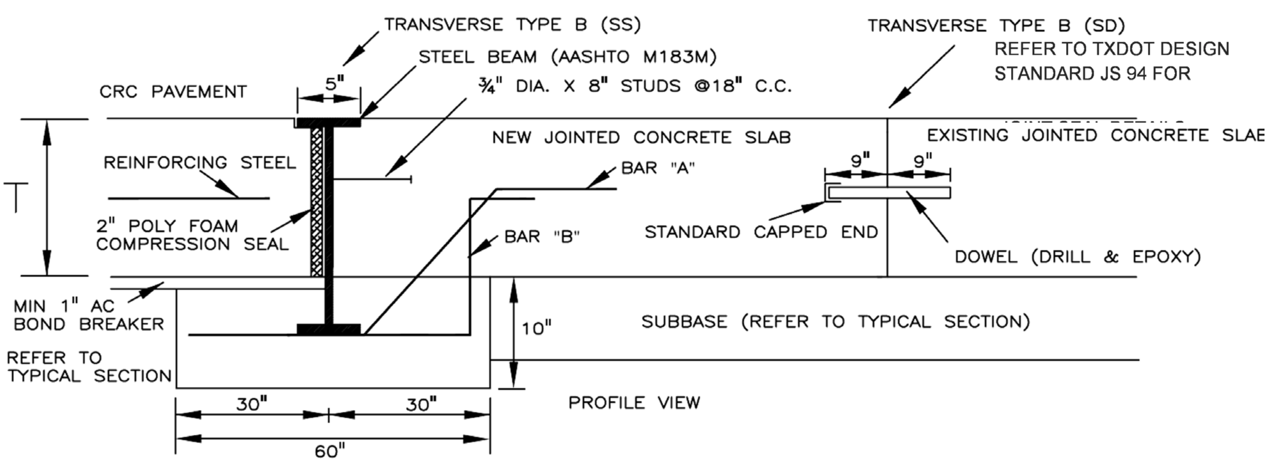

FIGURE 4. Transition details between CRC and JC pavements using a sleeper slab and a wide-flange I-beam.

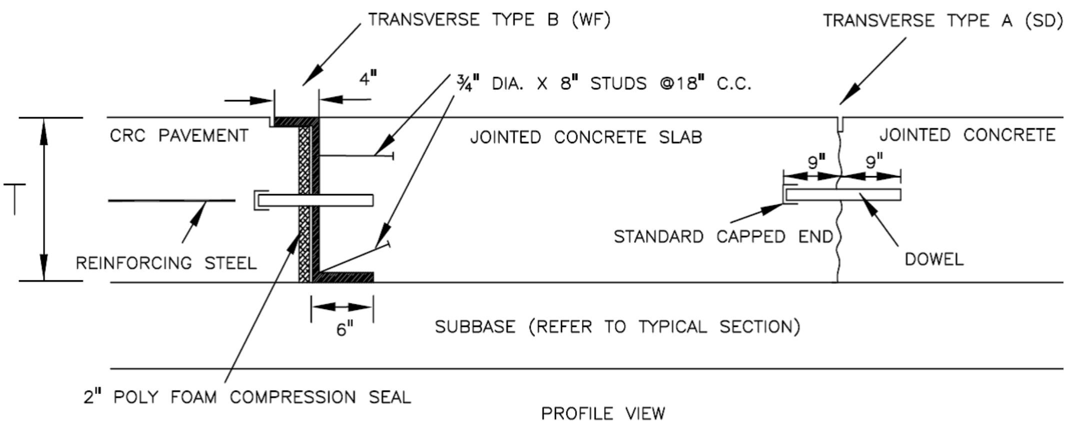

FIGURE 5. Transition details between CRC and JC pavements using a modified wide flange.

struction and eliminate the need for an I-beam and a sleeper slab as long as the subbase is of sufficient shear strength. It uses the same type of compression seal that is used with option 1, which allows for movement on the CRC pavement side of the joint. The width of the flange at the surface is recommended to be 4 inches (102 mm), but it can be varied based on field conditions. The same size and spacing studs as described with option 1 are used to tie into the concrete slab. Dowel size and spacing would be determined by design to achieve appropriate load transfer efficiency (LTE) between the CRC and JC pavements. The same type of advantages and disadvantages described in option 1 exist with this option.

Option 3

A third option, shown in figure 6, entails using a dowelled joint to transition from a CRC pavement to either a JC pavement or a terminal connection such as an approach slab. This design would require sealing to inhibit incompressible materials entering the joint but may be difficult to seal for an extended period of time since the dowelled joint is expected to accommodate the movement between the CRC and the jointed segment. As a consequence, this design includes a poly foam compression component, as noted in the figure, to minimize the accumulation of incompressible materials, and substitutes a stabilized subbase for a sleeper slab. The advantages of this design are its simplicity and ease of construction, and in some climates, less maintenance.

The dowelled joint is presumed to accommodate all the movement between the CRC and the JC pavements, eliminating the need for additional expansion joints to accommodate any of the movement generated by the CRC pavement. The bridge approach and terminal transitions are unique in that designs typically include an expansion joint that can be combined with a sleeper slab element, but the joint opening should be minimized to the extent possible. Figure 6 represents the simplest configuration for terminal connections that effectively meets most of the above-noted objectives. However, the expected amount of movement of the joint in this configuration would make it difficult to maintain a seal for an extended period of time.

Option 4

The fourth option, shown in figure 7, is presented in concept only and involves a 240-ft-long (73.2 m), gradually reduced, reinforced seg-

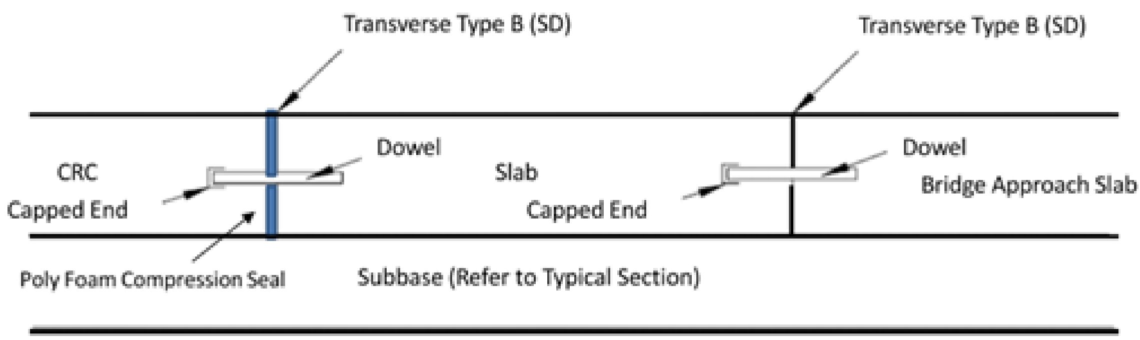

FIGURE 6. Transition detail between CRC and JC pavements using a doweled joint.

ment of CRC pavement that potentially eliminates the need for annual maintenance of the joint sealing. The first 120-ft (36.6 m) section, which includes the terminal end, is reinforced at approximately 30 percent of the design steel content; the next 120-ft (36.6 m) section is reinforced at 60 percent of the design steel content. Saw cuts spaced at 12-ft (3.7 m) intervals are employed in the 30-percent reinforced zone with the option of providing dowels to compensate for the expected wider openings. The 60-percent design steel content section is saw cut at 6-ft (1.8 m) (or the designed) intervals to induce a uniform crack pattern. Saw cuts are

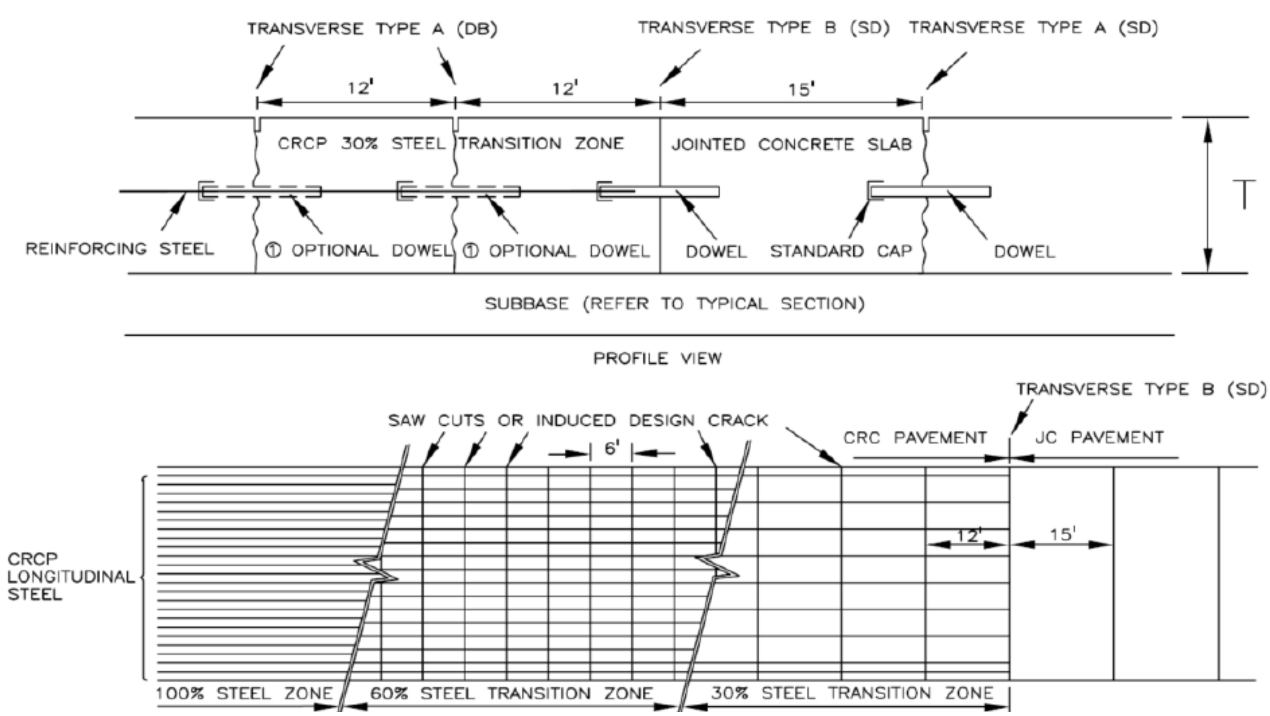

FIGURE 7. Transition between CRC and JC pavements using steel transition and saw cuts.

made soon after initial setting of the concrete. The reduction in steel content and the induction of joints would require consideration of load transfer to ensure that sufficient stiffness at the joints is provided, but one purpose of this transition is to better and more uniformly distribute the cracks and their movement over the length of the transition rather than concentrating the movement at a single location.

TRANSITIONS BETWEEN CRC AND AC PAVEMENTS

The transition of CRC to AC pavement has similarities to the transition between CRC and JC pavements since the detail incorporates a jointed transition segment; such a feature is useful to minimize the separation at the interface between a JC slab and an AC pavement. The incorporation of a slab segment in this regard facilitates the transition from CRC to AC and the sealing of the transition while keeping movement to a minimum.

The objective of a CRC-to-AC transition is to reduce the edge deflection between the CRC and the AC pavements to deflections interior to the slab with a concomitant reduction in subgrade stress. A JC slab should be employed as a buffer between a CRC and an AC pavement. Figure 8 shows the preferred option for this

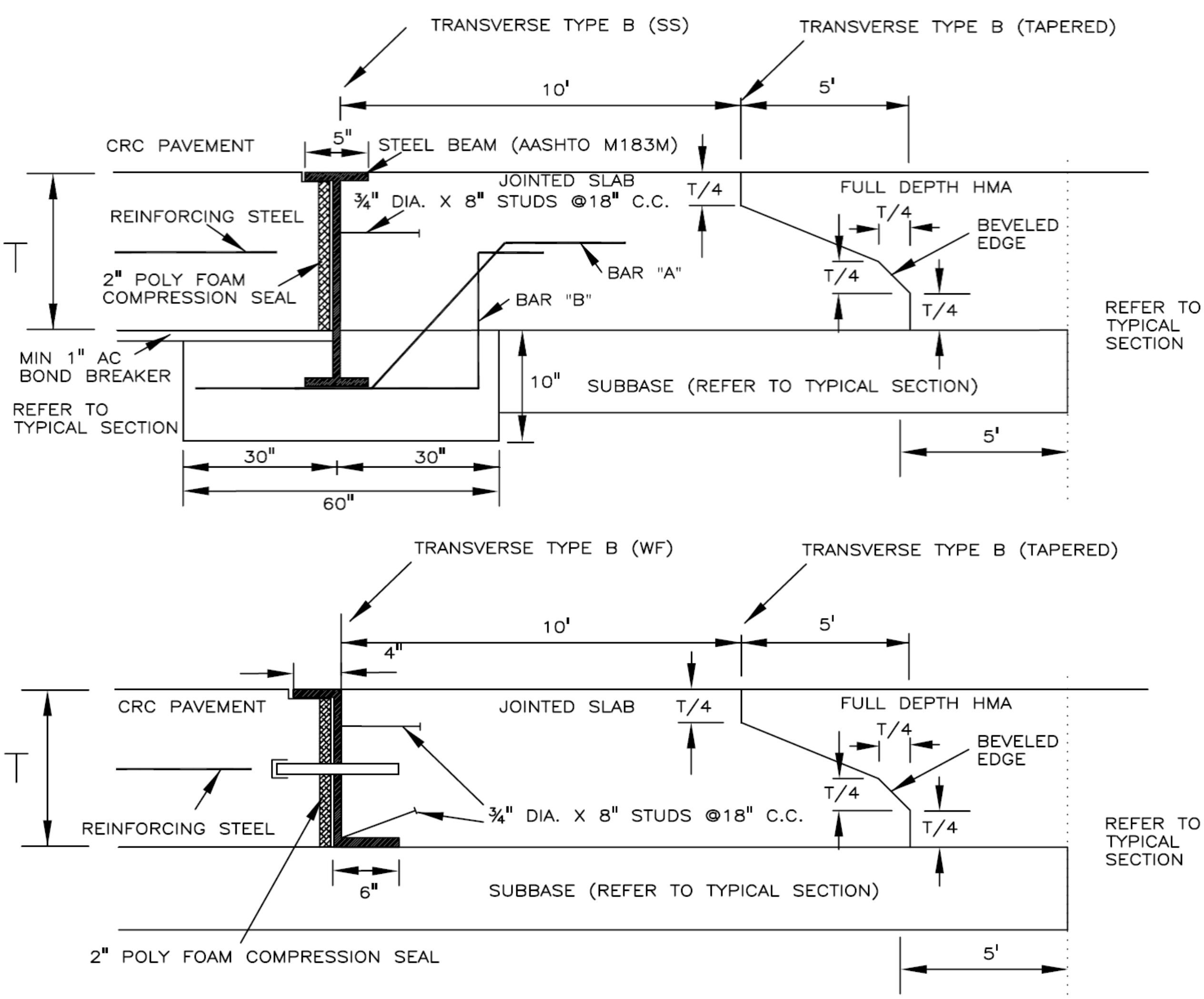

FIGURE 8. Transition between CRC and AC pavements using a tapered slab.

type of transition; it uses a specially tapered JC slab and the AC pavement section. The desirable features of the transverse joint between the PCC and AC pavement are the gradually reduced thickness of the tapering JC pavement and the increasing of the AC thickness, as seen in figure 8. The jointed slab should accommodate larger movements accompanying the end of a CRC pavement section. Load transfer with isolation between CRC and JC may be addressed through the use of a sleeper slab or, where appropriate, combined with a wide flange in the sleeper slab or an elastomeric concrete joint between the PCC and the AC materials (figure 9).

Option 1

Figure 8 shows the preferred option for this type of transition, which uses a tapered slab between a single JC slab and an AC pavement. As previously noted, a beveled edge should be placed at the end of the tapered section to minimize crack reflection in the AC; a treated subbase should be incorporated in the section and should extend into the AC section for a distance of at least 5 ft (1.5 m). The Texas Department of Transportation typically uses a 6-inch-thick (152 mm) cement-treated base with a 1-inch-thick (25 mm) AC bond breaker for the treated subbase layer in CRC pavements; a 4-inch (102 mm) AC or asphalt-stabilized base is also commonly used. The following are recommended construction practices:

- Compaction of hot-mix asphalt and subgrade materials to 100-percent and 95-percent theoretical density, respectively.
- Subgrade may be either cement- or lime-stabilized.

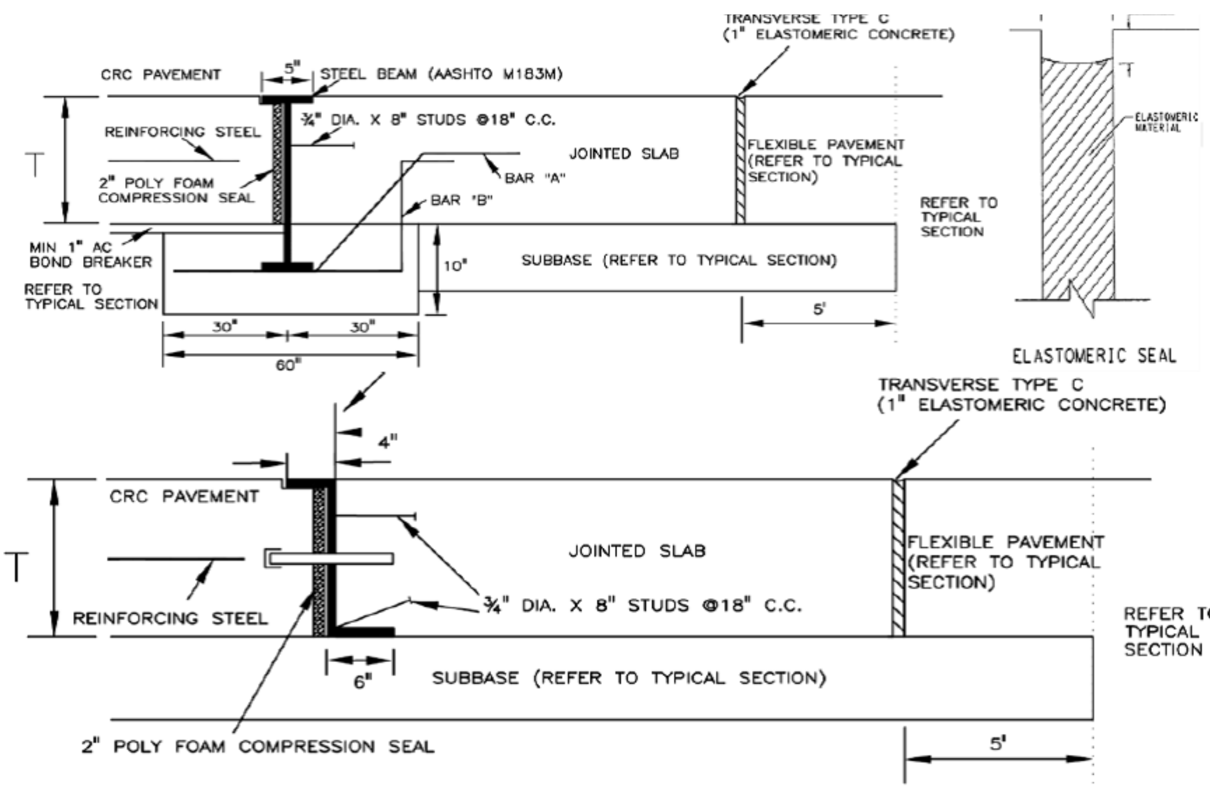

FIGURE 9. Transition between CRC and AC pavements using elastomeric concrete and a JC pavement slab segment.

- The tapered concrete section should be rough-finished with a beveled edge.

Option 2

Figure 9 shows a variation of the above option that uses an elastomeric concrete joint material to transition the vertical movement between the JC slab and the AC section. This option also incorporates a treated subbase extension into the AC section at least 5 ft (1.5 m), and a sleeper slab or wide-flange joint type should be constructed between the CRC and the JC slab. Dowel size and spacing for the wide flange joint would be determined by design to achieve the appropriate LTE between CRC and the JC pavement section. Table 2 shows the guidelines for the elastic modulus of elastomeric concrete. The order of placement in the construction is PCC first, AC material next, and, finally, cutting a slot for placing the elastomeric concrete that essentially toughens the interfacial transition from PCC to AC material.

The objective of these transitions is to ensure deflection or support continuity across the joint, which may, under certain traffic and subgrade strength combinations, pose no performance issues. Elaborating further, this transition promotes deflection continuity between the CRC and AC pavement sections to maintain the riding quality and the longevity of the transition. To this end, the isolation joint allows the single JC segment to remain in contact with the AC pavement section. It is also pointed out that the doweled expansion joints in the transitions shown in figures 8 and 9 could also be constructed more simply with the doweled joint depicted in figure 6.

TRANSITIONS TO TERMINALS AT BRIDGE ABUTMENTS

Typical details shown in figures 4 through 7 are applicable pavement transitions between CRC and the approach slab at bridge abutments, as follows:

- Sleeper slab and wide flange (figure 4).
- Modified wide flange (figure 5).
- Doweled joint (figure 6).
- Steel transition and saw cuts (figure 7).

The simplest and perhaps most practical transition option is shown in figure 6. Use of a treated subbase through the transition area will promote continuity of load-induced deflection. Although the transition design in figure 7 is presented in concept only, a transition of this nature between the CRC pavement and the bridge approach slab offers the potential for reduced long-term maintenance if it can provide deflection as well as frictional continuity at the end of the CRC pavement section to minimize end movement. The pavement thickness transition may be needed when the bridge approach slab thickness is greater than the CRC slab thickness.

SEAMLESS PAVEMENT DESIGN

Another promising concept, used in Australia, is the seamless pavement (Griffith and Bryce 2006). The objective of the seamless design is to improve constructability and eliminate the

TABLE 2. Transition Between CRC and AC Pavement Using Elastomeric Concrete and a JC Pavement Slab Segment: Properties of Elastomeric Concrete

Brand Name (Manufacturer)	Compressive Strength (lbf/in^2)	Tensile Strength (lbf/in^2)	Elastic Modulus (lbf/in^2)
Pro-Crete (Capital Services)	2,800	900	3.01×10^6
Delcrete™ (D.S. Brown)	800	600	1.61×10^6
Pro-Crete NH (Capital Services)	4,200	2,250	3.69×10^6

need for transition joints at bridge abutments. The approach slab is tied to the deck slab; however, a closure joint is placed between the approach slab and the CRC to prevent the development of contraction cracks in the approach slab during the construction process. Once the closure joint has been placed, the restraint provided by the bridge deck serves to maintain the position of the CRC pavement, much as intended in the anchored designs shown in figures 4 through 7.

SUMMARY

This document provides a variety of options to address key transition types typically used in the design of CRC pavements. Over the years, some transitions, such as those at terminal connections, have tended to be cluttered with extraneous features and slab configurations to enhance a specific aspect of the transition. Although not all types of transitions are addressed here, when transitions are included in a pavement design, the following objectives and requirements should be kept in mind:

- Accomodate freedom of movement at critical locations.
- Reduce movement at the end of a CRC slab.
- Minimize extraneous features that unnecessarily complicate the construction process, recognizing that transitions typically require the design of two separate joints and possibly a sleeper slab.
- Accommodate a uniform change in slab dimension and configuration between CRC, JC, and AC pavements.
- Minimize the potential for premature failure and the need for extensive maintenance over the long term by providing deflection continuity with satisfactory support between pavement type transitions.

REFERENCES

Griffiths, S., and C. Bryce. 2006, February. Design and Construction of Seamless Pavements on Westlink M7, Sydney. Highlights of Colorado 2005 Concrete Pavement Workshops, Colorado–Wyoming Concrete Conference, Greeley, CO.

Jung, Y., D. G. Zollinger, and S. D. Tayabji. 2007, April. Best Practices of Concrete Pavement Transition Design and Construction (Research Report 5320-1). Texas Transportation Institute, Texas A&M University, College Station, TX.

Contact—For more information, contact the following:

Federal Highway Administration (FHWA)
Office of Pavement Technology
Sam Tyson, P.E.—sam.tyson@dot.gov

ACPT Implementation Team
Shiraz Tayabji, Ph.D., P.E., Fugro Consultants, Inc.—stayabji@aol.com

CRSI Cooperative Agreement Contact
Gregory E. Halsted, P.E., Concrete Reinforcing Steel Institute—ghalsted@crsi.org

Research—This TechBrief was developed by Dan Zollinger, Ph.D., P.E., and Youn su Jung, Ph.D., Consultants, under FHWA's Cooperative Agreement with the Concrete Reinforcing Steel Institute. The TechBrief was processed as part of FHWA's Advanced Concrete Pavement Technology Program and is based on research cited within the document.

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