Tech Brief

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Selection of Pavement Types for Roundabout Intersections

U.S. Department of Transportation
Federal Highway Administration

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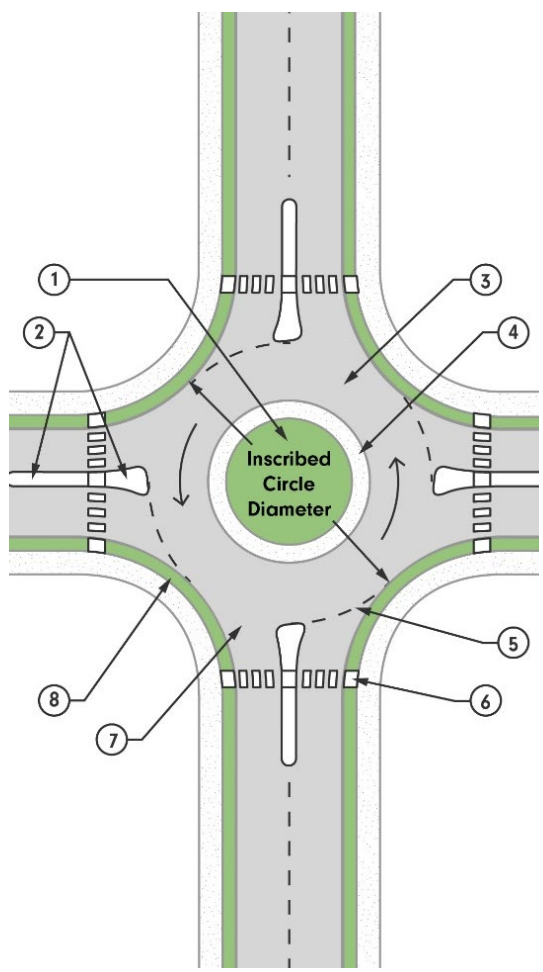
INTRODUCTION

A roundabout is a form of circular intersection in which traffic travels counterclockwise (in the United States and other right-hand traffic countries) around a central island and in which entering traffic yields to circulating traffic (Rodegerdts et al. 2010). Compared to signalized and stop-controlled intersections, modern roundabouts typically provide better overall safety performance, shorter delays and shorter queues, better management of speed, and lower management and operation costs while also adding aesthetic value (FHWA 2010). Figure 1 presents a general schematic of a roundabout, along with a brief description of some of the key design features.



1. Central Island – Raised area around which the traffic circulates.

2. Splitter Island – Raised or painted area on the approach used to separate entering and exiting traffic, control entering traffic, and accommodate pedestrians crossing the roadway.

3. Circulatory Roadway – Curved path used by vehicles to travel around the central island in a counterclockwise direction.

4. Truck Apron – Part of central island that facilitates wheel tracking of large vehicles.

5. Entrance/ Yield Line – Marks the point of entry to the circulatory roadway. Also functions as a yield line in the absence of a separate yield line.

6. Accessible Pedestrian Crossings – Provided before the entrance/ yield line. The splitter island is cut to allow access for pedestrian, wheelchairs, strollers, and bicycles in accordance with ADA requirements.

7. Exit – Marks the point of exit from the circulating roadway.

8. Landscape Buffer – Separates vehicular and pedestrian traffic and guides pedestrians to designated crossing locations.

Figure 1. Key roundabout design features.

Roundabouts are typically classified into three categories: mini, single lane, and multilane (FHWA 2010). Most roundabouts constructed in the United States are single lane (roughly 70 percent) and multilane (28 percent) (Rodegerdts 2017). As shown in figure 2, a cross slope of 2 percent away from the central island is typical for the circulatory roadway on single-lane roundabouts (WSDOT 2019). This not only helps in surface drainage, but also promotes safety by raising the height of the central island and improving its visibility, encourages lower circulating speeds, and minimizes breaks in the cross slopes of the entrance and exit lanes (FHWA 2010).

Various pavement types can be used in the construction of roundabouts, including hot-mix asphalt pavement (HMAP), jointed concrete pavement (JCP), continuously reinforced concrete pavement (CRCP), and precast concrete pavement (PCP). The FHWA has prepared separate Tech Briefs on each of those pavement types when used in roundabout intersections (Seeds and Smith 2021; Van Dam, Stempihar, and Medina 2021; Tayabji 2021a; Tayabji 2021b), all of which are available on the FHWA Pavement Publications webpage.

This Tech Brief presents a summary of each of those four pavement types and highlights information on their use, applicability, and selection.

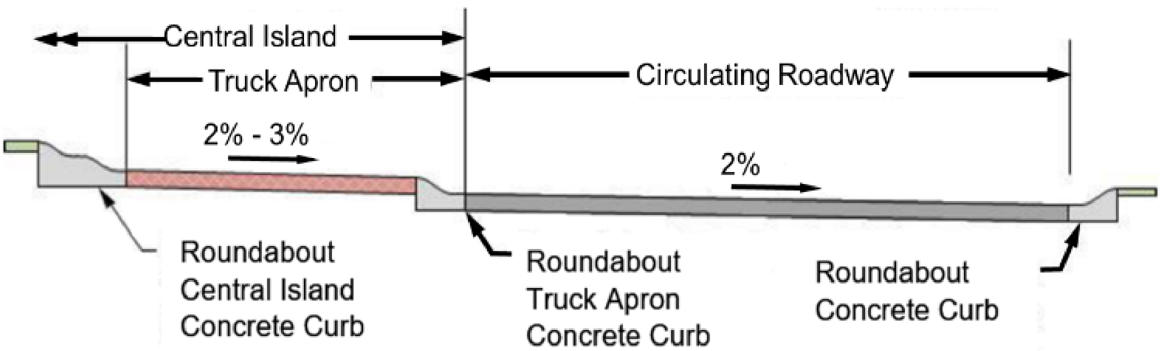


Figure 2. Typical circulating roadway section with truck apron.

OVERVIEW: HMAP ROUNDABOUTS

Like the majority of paved streets and highways, most roundabouts nationally and internationally are paved with hot-mix asphalt (HMA) (KDOT 2003). A photo of a typical HMAP roundabout is shown in figure 3.

Figure 3. Aerial view of HMAP roundabout.

HMAP Typical Applications

HMAP has been used in all three major roundabout types (mini, single lane, and multilane) under a range of traffic loading conditions. If the characteristics of the roundabout are considered in both the structural design and the mixture design stages, HMAP may be considered for use in any roundabout application. In multilane roundabouts, some States may consider factors beyond structural design and the asphalt mixture that suggest HMAP for an application. For instance, the Virginia Department of Transportation (VDOT) design criteria distinguish the truck apron through color, texture, and material to differentiate it from the circulatory roadway (VDOT 2014).

HMAP Advantages/Disadvantages

Like conventional paving applications, factors that make HMAP attractive for use in roundabouts include (Rodegerdts et al. 2010):

- Low initial cost. HMAP generally has a low initial construction cost.

- Ease of construction and rehabilitation. The curvature of a roundabout does not create any significant issues in the construction of the HMAP, with only a few minor deviations from the construction of tangent sections. HMAPs can also be readily constructed under active traffic and are easily and rapidly rehabilitated through conventional mill-and-fill operations.
- Satisfactory performance. HMAP provides a durable and smooth-riding pavement surface.

As a viscoelastic material, however, the use of HMA in a roundabout application could pose performance issues. For example, vehicles negotiating the circular pattern produce outward (shear) forces in the pavement surface. Similarly, braking forces in the roundabout's approach portions could create excessive shear stresses. The result of these shear stresses is shoving of the asphalt and potentially cracking or tearing of the surface layer. In addition, a high percentage of heavy trucks moving at slower speeds because of the roundabout geometry could lead to the increased potential for permanent deformation. Many of the potential performance problems for HMAP roundabouts can be addressed through the proper selection of materials and the development of effective HMA mixture designs.

OVERVIEW: JCP ROUNDABOUTS

A 2016 survey of State practices revealed that JCP roundabouts are considered and implemented in many U.S. States (Pochowski et a. 2016). Figure 4 shows a JCP roundabout intersection.

Figure 4. JCP roundabout intersection.

JCP Typical Applications

Typical applications of JCP roundabouts include both single-lane and multilane configurations that experience significant traffic from commercial vehicles and buses. JCP is chosen for its ability to withstand demanding loading conditions while being a familiar option from its use for conventional road building. For roads, JCP is generally considered an effective and long-lasting pavement option (Rens 2013).

JCP Advantages/Disadvantages

Two major advantages of JCP roundabouts are the load-carrying capacity and durability of concrete pavement. Furthermore, JCP roundabouts can offer long-term solutions with minimal future maintenance, resulting in cost savings and less traffic disruption (McMullen 2016).

While JCP's advantages are in its durability and performance in demanding traffic constraints, there are several potential disadvantages. First, rapid opening times can be a challenge due to the time needed to construct and cure the concrete pavement. Moreover, the planning of JCP roundabouts is complicated by factors such as utility integration, jointing layouts and panel sizing, and reinforcement considerations (ACPA 2005). Effective jointing patterns should be established to account for varying lane widths and the curvature of the roundabouts, which could otherwise potentially lead to cracking and reduced performance. Finally, relative to expectations from conventional roads, joints in JCP roundabouts may be susceptible to deterioration under the unique traffic loading forces. Maintenance plans for JCP roundabouts should include regular monitoring and repair of joint distresses (e.g., cracking, spalling) if they arise.

OVERVIEW: CRC ROUNDABOUTS

CRC pavements are heavy-duty pavement structures used by several highway agencies on their heavily trafficked roadways. Unlike JCP, CRC is "continuous" in that it does not include transverse contraction or expansion joints except at bridges and pavement ends. CRC has been widely used by several European countries in roundabouts (Rens 2013), and recently Texas has constructed several CRC roundabout projects, one of which is depicted in Figure 5.

Figure 5. Completed CRC roundabouts in Texas (El Paso District).

CRC Typical Applications

CRC roundabouts are typically used for high-traffic intersections, especially those experiencing heavy truck traffic and need minimal disruptions to traffic flow. They are commonly used in multilane roundabouts and may be used for the reconstruction of an existing roundabout with poorly performing pavement. In Europe, CRC roundabouts have been successfully used for entrances to industrial areas, freeway exits, and other high-volume roadway intersections (Debroux, Dumant, and Ployaert 2010; Rens 2013). In the United States, Texas has constructed several CRC roundabouts to improve safety, relieve traffic congestion, and reduce the need for frequent maintenance activities (TxDOT 2014).

CRC Advantages/Disadvantages

Given the demonstrated performance of CRC pavements in conventional applications, it follows that CRC roundabouts can handle high volumes of truck traffic without significant deterioration. CRC pavements are ideal for multilane roundabouts expected to carry heavy wheel loads and volumes from commercial vehicles and buses. Furthermore, like other CRC pavement structures, CRC roundabouts should provide long-term service with only limited maintenance. Also, the use of CRC eliminates the need for complicated jointing patterns and accommodations. Finally, CRC roundabouts may not necessarily need a full closure of the intersection. Lane-at-a-time construction can be used for multilane roundabouts, allowing partial opening during the construction period.

The performance advantages of CRC roundabouts are accompanied by their demands in terms of planning effort, construction time, and initial construction cost. The design process involves various considerations, including slab thickness, longitudinal steel content, base type, and edge treatment (Roesler, Hiller, and Brand 2016). Design planning and associated complexity may call for additional engineering expertise and planning, particularly in urban areas where utilities may also need to be accommodated. CRC roundabout construction may need several weeks to several months, which could cause temporary disruptions and inconvenience for road users. Both the delay to opening and construction materials are associated with considerable costs for CRC roundabouts, which agrees with CRC applications for other pavement structures.

Overall, while the planning and construction of CRC roundabouts can be time-consuming and expensive, their application may lead to decades of service with only minimal maintenance under heavy and unusual traffic loading conditions.

OVERVIEW: PCP ROUNDABOUTS

PCP typically are used to repair pavements in high-traffic, high-profile circumstances where time restrictions and road-user interruptions are demanding (Tayabji, Buch, and Ye 2013). These structures can also be used to repair and replace existing roundabouts.

Figure 6. Completed PCP truck apron of roundabout.

PCP Typical Applications

PCP technology makes use of panels that are placed under controlled conditions at a precast plant and then hauled to the project site for placement. PCP may be a candidate for any project where a JCP is viable, and it may be particularly applicable for the rapid rehabilitation of the circulating roadway and the truck apron in existing distressed roundabouts. PCP is suggested for heavily trafficked roundabouts where the roundabout pavement rehabilitation work can only be performed during short nighttime (i.e., off-peak) closures (partial or full). They can also be applied to small segments, allowing flexibility in construction phasing and corridor-wide pavement rehabilitation/reconstruction.

PCP Advantages/Disadvantages

An advantage of PCP technology is the rapid construction of long-lasting repairs with minimal traffic disruptions (Tayabji 2019a). The use of precast concrete ensures that each panel, through controlled fabrication and quality assurance processes, performs consistently and predictably in terms of strength and durability. Construction staging processes for roundabouts are also simplified with PCP, as off-site fabrication limits staging to delivery and placement. In terms of the advantages JCP roundabouts, PCP roundabouts provide similar long-term performance while needing far less planning and construction time than their JCP counterparts.

However, the upfront costs associated with PCP may limit the ability to with other pavement alternatives. PCP roundabout costs are likely to be much higher than HMAP and JCP methods due to the need for specialized formwork and equipment for panel fabrication. While on-site placement of PCP panels is relatively straightforward when performed by an experienced contractor, PCP panels are still subject to special planning and logistical factors that are not relevant to other alternatives (Tayabji 2019b). For instance, the transportation of large precast panels to the construction may involve procuring special permits and equipment.

PCP roundabout designs should also consider the dimensions of the prefabricated panels, which limits the ability of the designer to make last-minute changes during construction (Smith and Snyder 2019). Also, as noted above, contractor experience is critical as long-term joint performance relies on precise alignment and leveling of panels and proper reinforcement installation between panels. PCP joints can become a long-term maintenance concern if panel misalignment or improper installation of dowel bars occurs.

In conclusion, PCP roundabouts offer benefits such as faster construction and improved concrete properties. However, they also come with challenges, including high initial costs and transportation logistics, which need to be carefully considered during the project planning phase.

PAVEMENT TYPE SELECTION CONSIDERATIONS

Selecting the pavement type for a roundabout intersection depends on factors that include local preferences and experience, pavement type used in the approach roadways, traffic classification and volume, and closure restrictions and opening times. In addition, the decision is influenced by project context, with factors such as complex staging, traffic management, and multilane or intricate lane configurations each favoring certain pavement types over others.

Table 1 summarizes some of these factors in a selection criteria matrix for pavement type in roundabouts. This table is based on the four FHWA Tech Briefs (Seeds and Smith 2021; Tayabji 2021a; Tayabji 2021b; Van Dam, Stempihar, and Medina 2021), and expands on considerations introduced in a recent report (NCHRP 2023). In addition to the factors summarized in table 1, the road owner and designer should also consider climatic conditions, applicable local practices, locally available materials, and contractor experience in the selection of a pavement type for their specific roundabout intersection.

The factors discussed throughout this brief, some of which are detailed in table 1, are by no means comprehensive in terms of both the number of factors and discussion of each individual factor by pavement type. For example, a major consideration alluded to but not explicitly discussed is cost. Material costs, labor costs, and road user costs (i.e., costs to the traveling public due to construction) are all important factors that should also be considered in the selection process. Additionally, another factor not explicitly addressed is the development of sustainable pavement infrastructure, which may be described as infrastructure that achieves the engineering goals for which it was constructed, preserves and restores surrounding ecosystems, and uses financial, human, and environmental resources economically (Van Dam et al. 2015). Overall, these kinds of nuanced factors should be considered for each pavement type in the selection, planning, design, and construction of a roundabout.

Table 1. Considerations in selecting specific pavement types for roundabout intersections.

Consideration	HMAP Roundabouts	JCP Roundabouts	CRC Roundabouts	PCP Roundabouts
Applications	Suitable to all locations	Suitable to all locations	Best suited to high-volume traffic locations with minimal long-term maintenance needs	Best suited for locations needing minimal closure times and long-term performance
Pavement Materials	HMA mix design should consider improved rutting and shear resistance	Conventional JCP paving materials are sufficient	Conventional CRC paving materials are sufficient	Conventional concrete materials through prefabrication. Panels placed on cement-sand or grout leveling course.
Structural Design	Conventional HMAP design processes are sufficient	Conventional JCP design processes are sufficient	Conventional CRC design processes are sufficient	Conventional JPC thickness designs can be used to approximate PCP panel thickness
Other Design Features	Concrete-paved truck aprons may be incorporated to limit damage to heavy trucks	Joint layout and reinforcement planning, including accommodation of the truck apron	Special isolation joints/transitions may be needed between roadway and roundabout	Panel layout and reinforcement should consider both project needs and panel manufacturing characteristics
Construction Factors	Many factors similar to conventional HMAP placement practices	Longer construction time than JCP roads due to relative increase in joints and panels	Special reinforcement needs; longer construction time relative to CRC roads due to staging	Panel prefabrication should account for roundabout geometry, in addition to other special planning and delivery needs
Initial Consequences for Road User	Similar to HMAP in disruptions; rapid construction (weeks)	Delays during construction, similar to conventional JPC projects (months)	Delays during construction, similar to conventional CRC projects (months)	Similar to HMAP roundabouts with needed planning for construction staging; rapid construction (weeks)
Performance	Rutting and shoving may be accelerated by demands specific to roundabouts (e.g., turning forces, traffic)	Expect performance similar to conventional JCP projects, with consideration of joints due to panel layout	Expect performance similar to conventional CRC projects	Expect performance similar to JCP roundabouts
Maintenance & Rehabilitation	Higher anticipated maintenance needs but repairs rely on familiar processes (e.g., mill and overlay)	Increased joint monitoring and maintenance relative to JCP roads	Least anticipated long-term maintenance of all options	Similar to JCP roundabouts

SUMMARY

Recent considerations of roundabout design, construction, and performance show that pavement type selection is driven by factors beyond matching the pavement type of approach roads. Instead, roundabout pavement selection should consider the needs of the pavement to serve the public while resisting challenges unique to roundabout traffic. Continued attention to the special needs of roundabouts in design and long-term performance should help ensure that these structures outlast the approach roads they connect and that they provide road users with high levels of serviceability and minimal delays.

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