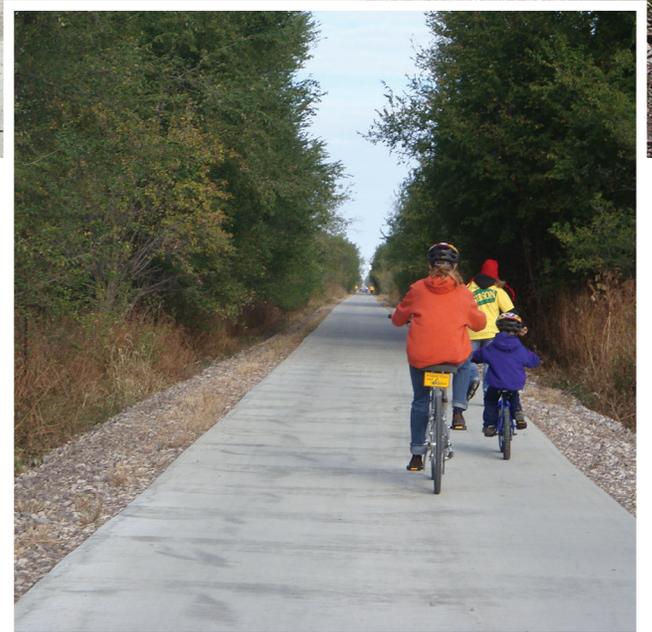
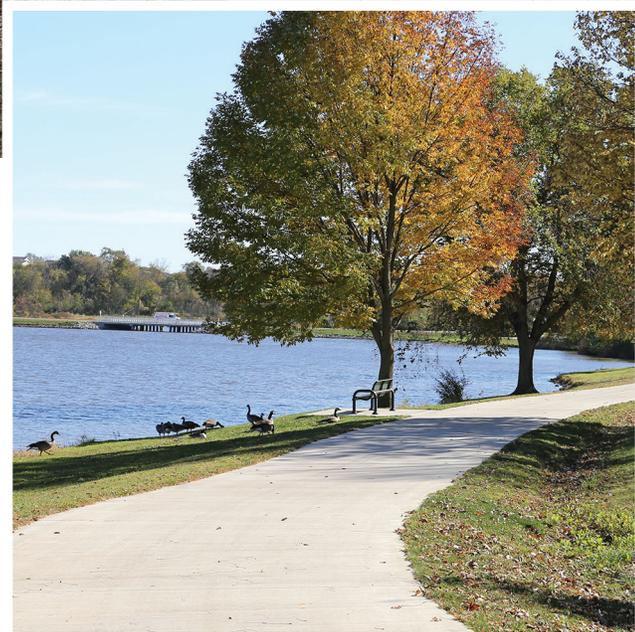


GUIDE TO

Concrete Trails



IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Pavement
Technology Center



AUGUST 2019

About the National CP Tech Center

The mission of the National Concrete Pavement Technology (CP Tech) Center at Iowa State University is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

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Guide to Concrete Trails

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About This Guide

The purpose of the *Guide to Concrete Trails* is to provide guidance to the ready-mixed concrete industry, contractors, design professionals, decision makers, practitioners, and public agencies on the design, construction, and maintenance of concrete trails and paths that help to improve the transportation and recreation opportunities of the general public.

The guide focuses on the development steps, design parameters and options, important elements of construction from subgrade preparation to delivery, use of various and sometimes innovative construction equipment, as well as concrete trail maintenance and repair. Finally, the guide offers case studies from projects located throughout the country on concrete trails of all ages, including various construction methods.

This guide is a product of the National Concrete Pavement Technology (CP Tech) Center at Iowa State University's Institute for Transportation. The guide's goal is to provide comprehensive guidance at a national level. Such guidance is useful for construction of all types of paved recreational trails, including those for biking, running, and walking, and of other pathways such as cart paths on golf courses.

Introduction

The History of Trails

Trails provide opportunities for healthy lifestyle activities such as walking, jogging, biking, and skating for people of all ages, abilities, and backgrounds. Trails constructed within parks and greenways provide an escape from the stresses of urban life and improve mental well-being (CDC 2013.)

Communities that have robust trail networks attract residents and tourists who want to bike, walk, or run for transportation, recreation, or fitness. Special events on trails can attract thousands of tourists to a community. Popular trail routes often lead to economic development in the form of restaurants, hotels, bike shops, and campgrounds. These, among other reasons, have led to a high demand for trail development across the country since the 1980s.

Trail development surged in the 1990s due to federal and state funding for alternative transportation and the development of rail trails. However, the funding is highly competitive, and new construction (expanding the system) is often favored over maintenance of old trails. A properly designed and constructed concrete trail can be a sustainable amenity for the community.

Trail Types

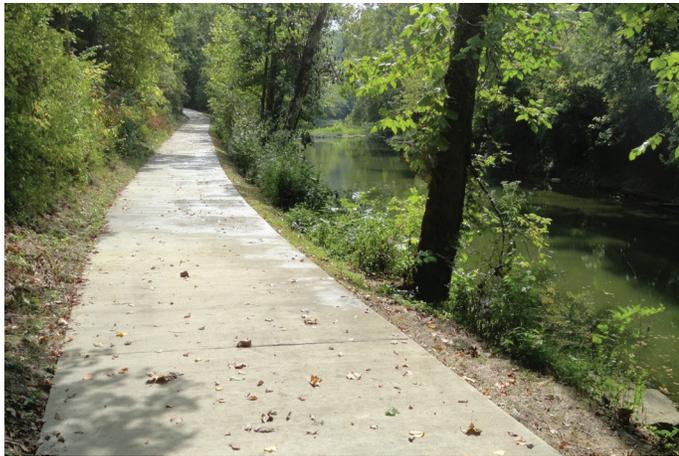
There are several types of trails that are constructed utilizing available right of way or a strategically designed alignment:

- Former railroad rights of way have been preserved by conversion to trail use and often provide a connection between small towns (Figure 1).
- Park and riverside trails provide public access to natural areas (Figure 2).
- Trails around bodies of water provide exercise and recreation as a looped system (Figure 3).
- Urban sidepaths are the most common multipurpose trail accommodation. They provide good connectivity typically within existing roadway corridors (Figure 4).
- Rural sidepaths are successful with minimal crossings for driveways and intersections (Figure 5).
- Utility corridors can often be a beneficial corridor for trail transportation, while also affording utility companies good access to their facilities (Figure 6).

The following images represent some of the typical locations where multipurpose trails provide transportation and recreational benefits.



Figure 1. Rail trail



Greg Smith, Kentucky Concrete Pavement Association

Figure 2. Greenway (follows a waterway) or park trail



Figure 3. Circumferential lake trail



Figure 4. Urban sidepath



Figure 5. Rural sidepath



Figure 6. Utility corridor trail



Background

Funding Legislation

The Federal-Aid Highway Act of 1956 created the Highway Trust Fund to help pay for the development and modernization of the US transportation system that focused primarily on highways. Later, it was expanded to include other modes of transportation, such as public and freight transit, bicycle, and pedestrian projects.

In 1991, when the Intermodal Surface Transportation Efficiency Act was signed into law, federal aid expenditures shifted from highway development to maintenance and rehabilitation. The law included a new emphasis on multimodal transportation activities by establishing the Surface Transportation Program (STP). This allocated federal money to local and regional transportation projects for the first time. STP included the Transportation Enhancements and Federal Recreational Trails programs.

In 1998, the Transportation Equity Act for the 21st Century (TEA-21) continued and expanded the Transportation Enhancements and Federal Recreational Trails programs. The follow-up to this bill was the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) that increased total funding for trails to \$370 million. The subsequent 2012 bill, Moving Ahead for Progress in the 21st Century (MAP-21), consolidated previous programs and replaced the Transportation Enhancements, Safe Routes to School, and Federal Recreational Trails programs with the Transportation Alternatives Program.

In 2015, MAP-21 was replaced with the Fixing America's Surface Transportation Act. This five-year expenditure bill converted STP funds into the Surface Transportation Block Grant program, which required a specific suballocation for projects and programs that fall into the category of transportation alternatives, including on- and off-road bicycle facilities, recreational trails, and safe routes to school.

Rails-to-Trails

In 1968, the National Trails System Act called for establishing trails in both urban and rural settings for people of all ages, interests, skills, and physical abilities. Helping to support those efforts, in 1976, the Railroad Revitalization and Regulatory Reform Act included a Rails-to-Trails Grant Program.

The Staggers Rail Act of 1980 allowed the discontinuation of unprofitable rail routes. Struggling railroad companies then began abandoning 4,000 to 8,000 mi of rail lines each year. In response, Congress amended the National Trails System Act to allow railbanking, which permits a trail agency to contract with a railroad company to lease-purchase an unused rail corridor. Railbanking is a preabandonment procedure that prevents the railroad resource from being lost or removed (Figure 7). Since the railroad corridor is not officially abandoned, the lease-purchase agreement between the railroad and the trail agency preserves the railroad's right to the corridor should they decide to resume service on that line in the future.



Figure 7. Former railroad converted into trail

Trail Development

Planning

A successful trail project begins with thorough planning (Figure 8). Input from an experienced professional is useful so that process, costs, and potential challenges can be identified early.

Funding

There are numerous funding sources for trail construction. They can range from national and state funding programs all the way down to grassroots and corporate donations. State agencies often have guidance available on potential funding sources.

Environmental Review

An environmental review is needed to determine the impacts the trail project may have. Most funding sources carry specific requirements. State and federal codes also apply. This review will identify any permits required from regulatory agencies. It is important to identify these needs early in the project as the various clearance and permit processes can take time.

Land Acquisition

Most trail projects require either temporary or permanent right-of-way acquisition from adjacent properties. It is important to understand and follow your state's regulated process when acquiring land. The process typically includes public notification, public meetings and fair-market value compensation provided to property owners in return for the rights to use the land for a trail.

Engineering/Design

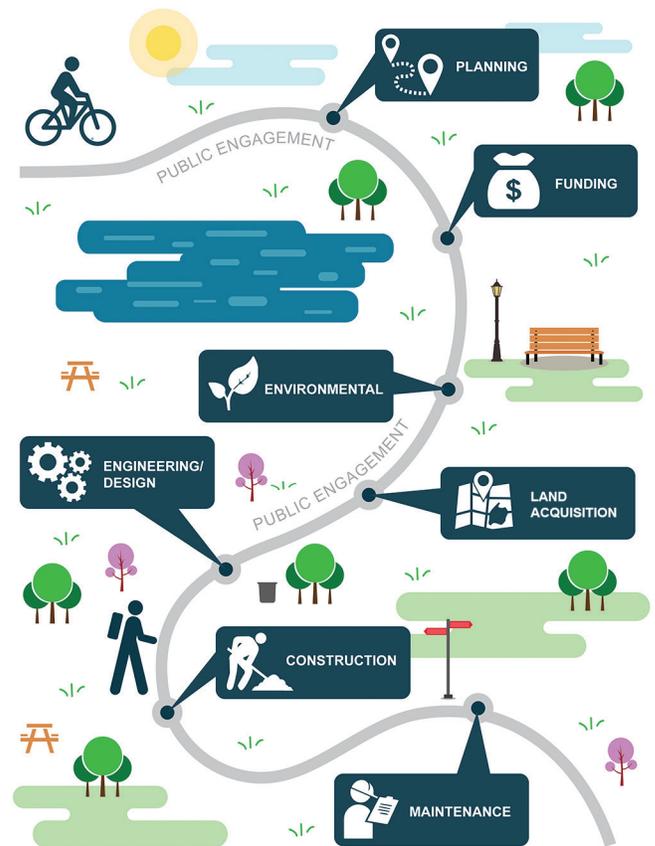
Trails can be simple and straightforward; however, an experienced trail designer can save construction costs with good design practices. Most states require public improvements to be designed with plans sealed by a licensed professional engineer or landscape architect. These professionals can optimize the design for constructability while meeting requirements of various funding sources and following applicable design standards, including Americans with Disabilities Act (ADA) compliance. A complete set of construction drawings allows multiple contractors to be able to easily understand and competitively bid on the construction project.

Preconstruction Meeting

A preconstruction meeting is recommended to discuss the schedule and other specifics of trail corridor access for subgrade preparation and paving operations. Often, the project corridor is narrow and a planned staging operation should be communicated between the contractor and adjacent property owners.

Maintenance

For the long-term management of the trail, it is recommended to plan for future maintenance activities. This is accomplished by annual pavement reviews and maintenance budget allocation.



Illustrator: Mindy Sauer, Snyder & Associates, Inc.

Figure 8. Trail development steps

Choosing Concrete for Trail Paving

Concrete is commonly used as a construction material for infrastructure projects. Agencies, engineers, and landscape architects who have selected concrete as a paving material cite the following benefits:

1. **Durability**—Concrete offers long-term durability even in harsh freeze/thaw environments. With proper design, quality materials, and quality construction methods, concrete will provide long-life service to the public. A *Guide for Maintaining Pedestrian Facilities for Enhanced Safety* (Huber et al. 2013) suggests that a concrete sidewalk can last as long as 80 years.
2. **Competitiveness**—Concrete production from ready-mix plants is a competitive market throughout the country.
3. **Ease of Construction**—Concrete trails can be built in a variety of ways. From fixed-form construction, to a variety of slipform pavers, concrete is easy to place. This allows large and small contractors the opportunity to be successful at building trails.
4. **Minimal Maintenance**—Concrete trails require minimal maintenance. With proper subgrade preparation and proper joint placement, shrinkage cracks can be controlled. Of the maintenance required, local agency staff can handle the repairs without needing to outsource the work to larger contractors.

Other Considerations

A concrete trail pavement has some key differences from other types of conventional concrete pavement construction.

No Steel Reinforcement in Mainline Trail Pavement

With a uniform subgrade, a trail will perform well without the cost of steel reinforcement. Reinforcing steel may be used in special situations where loss of support is possible, such as trail bridge approach slabs.

Subgrade Support

With adequate and uniform subgrade support, a trail will likely deliver acceptable long-term performance. Subgrade scarification and recompaction are the most common methods for slab-on-grade construction. Moisture and density control may also be incorporated into the design when necessary. Drainable rock subbase is often not necessary for trail construction and nonpermeable support materials are preferred.

Life-Cycle Value

Concrete can be competitive in most markets. When designed and constructed properly, it is not uncommon for a concrete trail to be in service for over 30 years while maintaining a good overall pavement condition. The maintenance activities performed over this lifespan are simple, low in cost, and can be performed by local-agency labor with local materials. Figure 9 illustrates the condition of existing concrete trails at different ages.

New



Constructed in 2018



Constructed in 2018

10 years



Good condition for 99% of the trail length—Constructed in 2008



Fair condition for 1% of the trail length—Constructed in 2008

20 years



Good condition for 95% of the trail length—Constructed in 1998



Fair condition for 5% of the trail length—Constructed in 1998

30 years



Good condition for 90% of the trail length—Constructed in 1988



Fair condition for 10% of the trail length—Constructed in 1988

Figure 9. Concrete trail conditions over time

Concrete Trail Design

The Guide for the Development of Bicycle Facilities (also referred to as the AASHTO Bike Guide) is available for design guidance. AASHTO defines a shared-use path as a bikeway that is physically separated from motorized vehicular traffic by an open space or barrier (AASHTO 2012). For the purpose of this document, trails shall be synonymous with AASHTO’s definition of shared-use paths.

The following design information expands upon the AASHTO Bike Guide for concrete trails.

Trail Width

The AASHTO Bike Guide identifies a minimum width of 10 ft for a paved, two-directional trail. Typical paved trail widths range from 10 to 14 ft, with the wider trails used in locations of high traffic volume. A width of 8 ft can be used when peak traffic is very low, pedestrian use is minimal, and maintenance vehicle traffic loading will not cause edge damage. For trails that are 8 to 12 ft wide, a centerline longitudinal joint is not required. For trails wider than 12 ft, a centerline longitudinal joint tied with deformed bars is recommended. The deformed bars minimize the potential for the slabs to separate. If a trail width over 14 ft is desired, consideration should be given to a corridor with separated directional paths. Table 1 lists the recommended trail width based on trail use.

Trail Thickness

The strength and uniformity of the subgrade is key to determining necessary trail thickness. Tables 2 and 3 list minimum trail thickness based on various subgrade conditions. Subgrade strength is identified by the modulus of subgrade reaction (k) and the California Bearing Ratio (CBR).

Typically, a jurisdiction with the resources to maintain a system of trail paving can achieve successful performance with a 5 in. thick concrete trail under most subgrade conditions.

However, many jurisdictions rely on grants and other funding streams for trail construction. This money is available for initial construction but rarely available for pavement maintenance or replacement. This situation may justify a pavement that is slightly thicker than the minimum.

Table 1. Recommended trail widths

Trail width	Trail use
8 ft	<ul style="list-style-type: none"> • Neighborhood connector trails • Low bicycle traffic • Occasional pedestrian use • No regular maintenance vehicles
10 ft	<ul style="list-style-type: none"> • Two-way bicycle traffic • Maintenance vehicle use
12 to 14 ft	<ul style="list-style-type: none"> • Higher capacity trails • Maintenance vehicle use • Bicycle passing use, while allowing room for oncoming traffic • High user volume (>300 in peak hour) and high pedestrian use (≥30%)

Data source: *Guide for the Development of Bicycle Facilities* (AASHTO 2012)

Table 2. Subgrade soil and support values

Type of soil	Support	k, psi/in.	CBR
Fine-grained soils with high amount of clay and silt	Low	75 to 120	2.5 to 3.5
Sands and sand-gravel mixtures with fair amount of clay and silt	Medium	130 to 170	4.5 to 7.5
Sands and sand-gravel mixtures with low amount of clay and silt	High	180 to 220	8.5 to 12

Data source: *Guide for the Design and Construction of Concrete Parking Lots* (ACI-330R-01/ACI 2008)

Table 3. Minimum trail thickness based on width and support condition

Trail width	Support condition		
	Low	Medium	High
Less than 10 ft	5.5 in.	5.0 in.	4.0 in.
10 ft or greater	6.0 in.	5.5 in.	5.0 in.

Minimum 28-day compressive strength: 4,000 psi

The AASHTO Bike Guide suggests a minimum trail thickness of 6 in. for portland cement concrete. A thicker concrete pavement is suitable for loading from maintenance vehicles, such as mowers, trucks with snow or debris removal equipment, and utility vehicles. A 6 in. thick trail can also withstand occasional heavier loads, such as emergency vehicles and construction traffic for repairs and trail extensions. Figures 10 through 13 show typical maintenance equipment in urban and rural locations.



Figure 10. Ditch maintenance



Figure 11. Utility potholing



Mike Wallace, Dallas County Conservation Board, Iowa

Figure 12. Edge mowing



Figure 13. Directional boring

Concrete Overlays on Asphalt Trails

Concrete overlays on existing asphalt trails can be a successful method of major rehabilitation. Properly designed and constructed concrete overlays on roadways have performed for 20 years or more without further major rehabilitation (Gross et al. 2017). The *Guide to Concrete Overlays of Asphalt Parking Lots* (Harrington et al. 2012) can be referred to for design consideration on trail applications. Figure 14 shows a concrete overlay constructed over an existing distressed asphalt trail in Guthrie County, Iowa.



Joe Hanner, Guthrie County Conservation Board, Iowa

Figure 14. Concrete overlay on asphalt trail

If considering a concrete overlay over an asphalt trail, it is recommended that a thorough review of the existing asphalt pavement is performed. If the existing pavement has fatigue-related alligator cracking or potholes, then a full-depth repair is needed to correct potential subgrade conditions. A feasibility study should be performed to determine if an overlay is an economically beneficial alternative. Additional information can be found in Appendix A.

Cross Slope

Trails are designed mainly for transportation, recreation, and fitness purposes. There are critical design items, including cross slope, drainage, accessibility, stopping sight distance, speed, connection points to roadways, other trails, and railroad crossings that are important to the safety of the user.

A minimum of 1% cross slope is recommended for drainage, as well as for accessibility. This also helps prevent standing water and slick patches during cold months. The Public Right-of-Way Accessibility Guidelines (USAB 2011) require the cross slope for a shared path to be 2% or less. To allow for construction tolerance, a 1.5% design cross slope is typical (Figure 15).

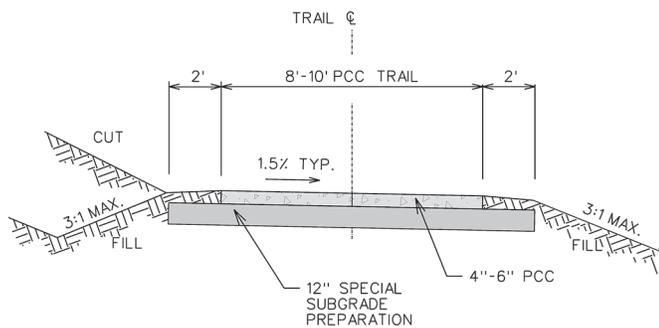


Figure 15. Typical concrete trail detail

The cross slope is recommended to follow the same path as the existing terrain or be directed toward a drainageway or curb and gutter. Typically it is recommended to avoid a crown so that surface runoff is maintained in one direction (AASHTO 2012). In situations where cross slope needs to transition to connect to a horizontal curve or an existing slope, a minimum transition length of 5 ft for each 1% cross slope change should be used (AASHTO 2012).

Longitudinal Profile

Rail trails are popular since they offer the shallow profile grades that the railroads needed for safe and efficient operation. A trail with a flat (0%) profile can be acceptable but is not recommended for areas that would develop drainage issues, such as the low point of a sag vertical curve (where the downward grade meets the upward grade). In these instances, positive cross slope with proper ditching is critical for drainage.

Since trails are built for different users, including people with disabilities, they need to be comfortable and easy to use. Trails with grade or longitudinal slope over 5% are undesirable due to the major speed changes associated with the steeper grades and the need for users to maintain control. Proper warning signs, wider trail sections, higher design speeds for curves, extended clearances, and other measures may be warranted if the longitudinal grades need to be more than 5%. Refer to the AASHTO Bike Guide for design speed considerations.

Designers should also keep in mind the line-of-sight obstructions for horizontal curves. The lateral clearance

can be obtained from the radius of the curve and the stopping sight distance (see Table 5.10 in the AASHTO Bike Guide [AASHTO 2012]). Stopping sight distance is necessary for the user to avoid any sudden and unexpected situations and conflicts. The distance needed to bring a user to a fully controlled stop is a function of the user's perception and braking reaction times, the initial speed, the coefficient of friction between the wheels and the pavement, the braking ability of the equipment, and the longitudinal grade. Stopping sight distance is required for both horizontal curves and vertical curves.

Clear Zone

Separation of the trails from other natural and artificial structures should be provided for the safety and comfort of the users. To separate the trail from obstacles like trees, rocks, bridge piers, poles, and abutments, a minimum of 2 ft graded area with a maximum cross slope of 6:1 should be maintained. If a trail runs alongside a roadway and the offset from the curb edge is less than 5 ft, or the trail runs alongside a water body or downward slope of 3:1 or steeper and less than 5 ft of separation is present, then a safety barrier or railing is needed (Figure 16). The railings should be at least 42 in. high. A minimum vertical clearance of 10 ft is typical for tunnels, under-bridge crossings, as well as other overhead obstructions.

Other objects placed outside the clear zone include signs and lighting. Signs should be installed according to the Manual on Uniform Traffic Control Devices (MUTCD).



Figure 16. Barrier along the trail installed for safety

Trail Crossings of Roadways

Several factors should be considered when designing trail crossings of roadways. Items such as intersection geometry, signage, crossing type, and access restrictions are reviewed to suit the needs and safety of the users.

Intersection geometry is critical to review for assessment of sight distance for both the trail users and oncoming traffic, while considering the terrain on approach to the intersection. Skewed crossings should be minimized. Perpendicular crossings are preferred. Skewed crossings lengthen the exposure of trail users to roadway traffic and may impede sight distance at acute angles.

Gravel road crossings (and field entrance crossings) should be paved to reduce trail user accidents due to the change of surface materials and potential windrows of loose material at the roadway edges (Figure 17). The paved crossing can have either curved or squared off headers, as preferred by the jurisdiction that maintains the roadway.

A thickened section is recommended to withstand heavier loading from vehicles or farm equipment at trail crossings of roadways or field entrances. Crossings that carry traffic should be designed similar to a paved roadway thickness to follow local jurisdictional specifications. These crossings can be placed during the construction of the main trail or completed later by hand placement.

The width of the trail can be widened to help delineate the location of the thickened slab for the intended crossing (see Figure 18).

Intersection signage on trails is a critical safety factor. Trail regulations may be noted at each access point to restrict motorized vehicle usage or other unwanted activities. The signs should be sized and placed in such a way as to discourage unintended uses. The Manual on Uniform Traffic Control Devices should be followed for installation of signage.

Bollards and other restricted access items such as gates, planters, and ornamental decorations may be used to deter unintended trail use by motor vehicles (Figure 19). The use of rigid barriers in the trail path should be avoided. If bollards must be used, visibility of the bollards is important. Extended pavement markings should be used to aid in distinguishing the lanes of travel, and the bollards should be of contrasting color from the surroundings and marked with reflectors. Flexible bollards are often specified as they allow for a less severe collision if struck by a trail user.

For trails crossing residential driveways, a 6 in. trail thickness is considered satisfactory. For major commercial or industrial accesses or roadway crossings, the crossing depth should match the design of the roadway or driveway thickness.



Figure 17. Paved crossings of gravel roads



Figure 18. Thickened/widened section on field entrance crossings



Figure 19. Sign and bollard installed at intersection/crossing

Subgrade Preparation

Subgrade is the in situ earthen material that, when improved, provides support for the concrete trail. Concrete trails are typically built on a compacted subgrade, as shown in Figure 20.

The condition of the support system is critical for the performance of the concrete trail. At a minimum, the soil should be free of high organic content (topsoil), and the underlying subgrade should be scarified to a specified depth and recompact with moisture and density control. Where poor soils are encountered, crushed rock can be mixed in during the scarification process to create a soil-aggregate subgrade. This is common on recently rail-banked rights of way where the ballast from the railroad track is still present.

Table 4 lists recommended subgrade preparation based on the quality of the existing subgrade.

Proof rolling is recommended to evaluate freshly-compacted subgrade. It is conducted by driving a fully

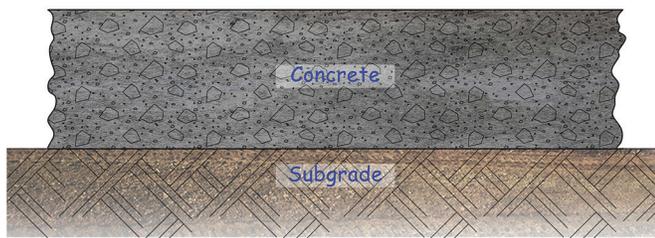


Figure 20. Concrete trail cross section

Table 4. Recommended subgrade preparation for different qualities of subgrade

Existing subgrade quality	Subgrade preparation
High (sand and gravel)	Strip topsoil, scarify to 6 in. depth, and recompact with moisture and density control
Good to fair (silt and nonexpansive clay)	Strip topsoil, scarify to 12 in. depth, and recompact with moisture and density control
Poor (weak, expansive clay)	Strip topsoil, scarify to 12 in. depth, and recompact with moisture and density control. If further improvements are needed in isolated wet areas, options include a 6 in. soil-aggregate subbase along with geosynthetic or chemical treatment.

loaded, single-axle or tandem-axle dump truck over the subgrade and observing the deflection or rutting of the compacted surface.

Poor subgrade can be improved by replacing the weak areas with geosynthetics (geogrids and geotextiles) and aggregate subbase. These improvements minimize the probability of localized shear failure, thus improving bearing capacity (Gross et al. 2014). Poor subgrade can also be improved by treating it with cement, fly ash, or lime.

The following cross sections are shown to illustrate what can occur with the presence of a drainable subbase under a trail pavement that does not have a drainage outlet. If a drainage outlet is not present, the subbase layer can trap water (Figure 21). In colder climates with freeze-thaw cycles, the trapped water can freeze, creating faulting and pavement cracking (Figure 22).

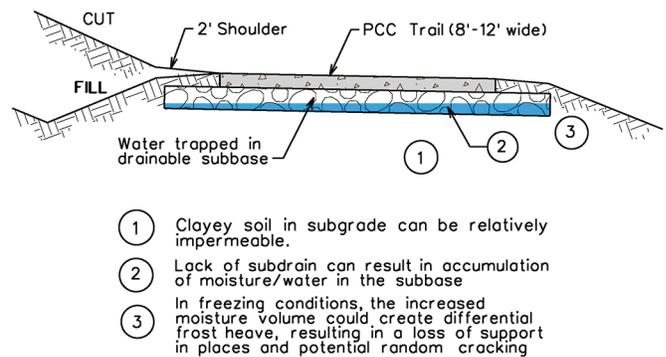


Figure 21. Water can collect in the bottom of drainable subbase without proper drainage

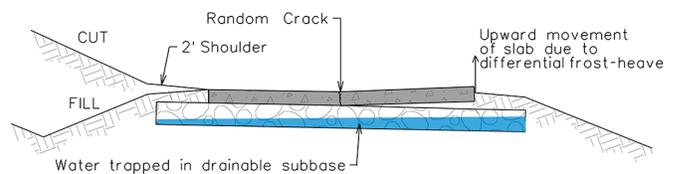


Figure 22. Differential frost heave conditions can lead to random cracking or panel displacement

Fiber Reinforcement

Fibers are used in concrete pavements to improve toughness and help keep cracks tight. Fibers may increase the ability of concrete to retain loadbearing capacity after cracking. Fibers can also increase concrete's resistance to plastic shrinkage cracking.

Because fiber types vary in size and material, fiber manufacturers should be consulted to determine dosage rates. Additional information on fibers can be found in Appendix B.

Edge Details and Drainage

Pavement backfill and shouldering are important to the safety of the user. Both shoulders should shed rainfall runoff away from the pavement. Sheet flow across the trail should be avoided if possible by incorporating a shallow ditch or swale on the high side and draining that longitudinally to a culvert under the trail. When sheet flow across the trail is unavoidable, extra attention to the downstream shoulder is required to ensure positive drainage off, and away from, the slab edge. The eventual buildup of organics (leaves, silt, and grass) on an earthen shoulder can block the drainage and cause ponding on the trail edge. Periodic maintenance may be necessary to ensure edge drainage.

Paving Details at Structures

Bridges

At bridges, a paving notch on the back of an abutment can be placed to support a reinforced approach slab (Figures 23 and 24). The reinforced approach slab will support a void that can be created as the trail pavement moves up and down with frost, while the bridge remains in place due to its deep foundation.

Shallow Culverts

Culverts with less than two feet of cover over the structure are considered shallow. The presence of a shallow culvert can alter the longitudinal subgrade uniformity.

To prevent cracking or failure of the trail paving section over the culvert, thickened concrete sections and/or reinforcing can be utilized. Material between the culvert and trail may be disrupted more easily by storm water

and settling, which can create flexural cracks within the concrete. Reinforcement will assist in preventing shifts in the concrete panels.

Paving equipment crossing shallow culverts can easily disturb the base material and potentially cause failure of the culvert. Heavy loading should be avoided if there is a potential for collapse of the culvert. Heavy loading may also be from delivery of concrete in trucks utilizing the trail bed as a supply route. Low-load paving methods (e.g., fixed form, extension screeds, truss screeds) may be the most effective methods of paving for sections extending over these shallow structures.



Figure 23. Pedestrian bridge over a stream

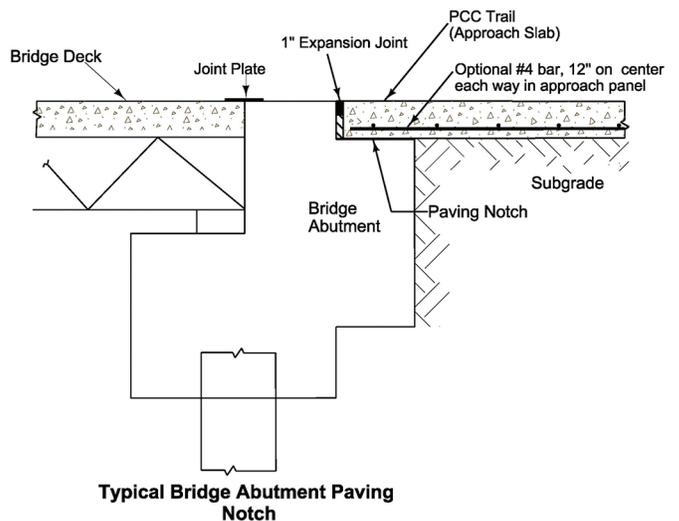


Figure 24. Typical bridge abutment paving notch and reinforced approach slab



Figure 25. Combined retaining wall and trail

Retaining Walls

There are situations where a retaining wall is needed to accommodate trail construction in certain terrain. The trail and wall can be combined into a single system. The wall can be on either side (with approved safety railing) as best suits the design (Figure 25).

The concrete mix design for a combined retaining wall and trail is typically a structural concrete mix.

Planning for Construction

Narrow Corridors

Convenient access for trail paving is not always possible. Trail rights of way can be narrow and are constructed to create a path suitable for pedestrians and small vehicles rather than large construction equipment. It is recommended to plan for the construction limits and staging areas to allow for the most economical construction with the smallest footprint possible (Figure 26).

Paving operations can complicate staging plans due to the limitations of the equipment, construction limits, and cure time for pavement. Concrete paving starting at bridge structures and directed outward tends to be more effective than paving towards bridge structures, unless the structure is wide enough and capable of handling the loading.

Construction planning and project design should include consideration for stockpiling of shoulder material along the edge of the corridor in regular intervals prior to paving. This will avoid the need of hauling shoulder material on a recently placed trail pavement. The staging areas can also be used as turnarounds for concrete delivery.



Figure 26. Concrete trail construction

Trail Construction

Concrete Mixtures

Concrete mixtures should incorporate quality materials and appropriate mixture proportions to provide long-term performance. Durable aggregates are critical and should be assessed for potential alkali reactivity and D-cracking. In cold climates, an air content of 5% to 8% is recommended along with a water/cement ratio of no more than 0.45. A mix design resulting in a 28-day compressive strength of 4,000 psi is typical for concrete trails.

The *Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual* (Taylor et al. 2019) provides comprehensive guidance on concrete mixtures.

Concrete Delivery

Concrete delivery is an important aspect of trail paving and may provide a challenge to the contractor, depending on the terrain and features of the corridor. In tight corridors, ready-mixed concrete trucks will need to back up the grade when using the traditional rear discharge trucks. With front discharge trucks, the delivery is simplified. However, they would need to back out of the grade. If the corridor has sufficient width and suitable subgrade quality, ready-mix trucks can deposit material from alongside the grade.

Restrictive corridors, narrow bridges, and subgrades that are not suitable for loaded concrete trucks require an alternative method of concrete delivery. Buggies, as shown in Figure 27, can navigate efficiently along the proposed trail alignment without disrupting the compacted subgrade. They are also able to turn around easily and maneuver for loading and unloading.



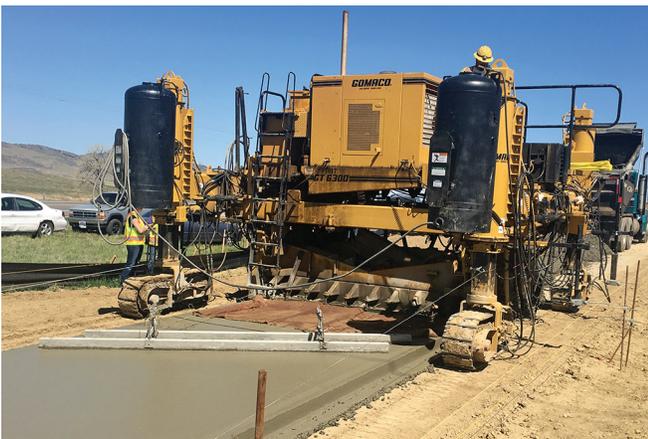
Figure 27. Buggies provide efficient concrete delivery

Fixed-Form Paving

Fixed-form paving is a concrete placement method using wood or steel side forms that hold the concrete in place until hardened. Consolidation is accomplished using vibratory screeds or portable devices. Fixed-form paving is necessary for small areas, including intersections, tight corridors, and ADA curb ramps.

Slipform Paving

Slipform paving is a concrete placement method where a paving machine uses vibration to spread and consolidate the material onto the grade without the use of side forms (Figure 28). With this method, the concrete mix is designed such that the material holds a vertical edge without slumping. The use of slipform paving equipment is becoming more common for concrete trails. Some agencies require the use of slipform paving for trails over 200 ft in length.



Jamie Johnson, ACPA, CO/WY Chapter

Figure 28. Slipform paving produces trails of uniform thickness and width

The reliability, economy, and speed associated with slipform paving equipment allows contractors improved productivity.

A slipform paver generally produces better quality pavement, particularly over a long distance. A talented handwork crew using fixed forms can create equivalent results, but the production rate is typically slower and the work is more labor intensive.

Other Paving Equipment

There are other types of paving equipment that can form and place concrete trails. Many companies have found that homemade or modified paving equipment may be used and is often more functional and economical for specific applications, such as trail paving. Creativity when developing a suitable device is encouraged in order to increase efficiency for future projects. It is important to require test sections or examples of past work to verify that the quality of the work will meet specifications.

An example of equipment ingenuity is the box paver that can be self-propelled or pulled by either a skid loader or a ready-mix truck (see Figure 29). Like a traditional slipform paver, the box paver operates without fixed forms.

Use of a box paver requires the subgrade to be stable and finely trimmed to grade because there is typically no traditional stringline for elevation control. Similar to a traditional slipform paver, a box paver is equipped with a hydraulic vibration system to assure concrete consolidation. The hydraulic manifold block on the paver allows control of the vibration frequency of each vibrating device.



Howrey Construction

Figure 29. Skid-loader-pulled box paver

Concrete is dumped into the box paver behind the skid steer alternately from the left and right sides via a buggy to make sure that concrete is spread evenly since there is no auger for even distribution. The simplicity of the equipment makes it very quick and easy to clean and mobilize. Figure 30 shows a track-driven box paver.

Heavy Equipment Path

The design of trail subgrade may or may not be suitable for fully loaded mixer trucks or other heavy equipment. Where corridor width allows, it may be beneficial to utilize a lane adjacent to the trail to prevent any failure of the subgrade that could impact the integrity of the pavement and create potential maintenance concerns. Within narrow corridors or in heavily treed areas, a path near the trail may be inaccessible. Tree roots near a trail may also be crushed in heavily wooded areas, which may affect the health of the trees and create maintenance issues and the need for tree removal. In these instances, the subgrade should be compacted to withstand the additional loading. In many cases, concrete is delivered to the subgrade and placed in front of the paver. Where possible, it is beneficial to provide truck turnarounds throughout the corridor.

Surface Treatment (Finishing)

Burlap

Wet burlap can be used for finishing and texturing the trail surface. Burlap that covers the trail width is attached to the back of a paving machine or screed and is dragged along to create the textured surface. It can also be dragged manually by two people on either side of the trail. The texturing should be completed once the concrete is sufficiently set and without the presence of bleed water (Figures 31 and 32).

Brooming

A broom can be used for texturing the concrete surface by dragging it in the transverse direction (Figure 33). Brooming helps create a slightly roughened surface with a uniform appearance, thus increasing surface friction. A proper and uniform surface texture helps prevent slick areas during wet weather.



City of Rock Valley, Iowa

Figure 30. Track-driven box paver



Jamie Johnson, ACPA, CO/WY Chapter

Figure 31. Burlap attached to paving machine



Figure 32. Manual burlap drag finish



GBR Paving (<https://www.youtube.com/watch?v=Nr24a2wgdBY>)

Figure 33. Broom finish

Smoothness Requirements

The trail surface should be smooth for the comfort of pedestrians and bicyclists. The smoothness requirements for trails are less stringent than for concrete roadways. However, friction and skid resistance of the trails should not be compromised for the sake of smoothness. Slipform paving and transverse saw cut joints typically result in a smooth trail.

Importance of Curing

With any concrete pavement, it is essential to properly cure fresh concrete to minimize water loss during hydration. If proper steps are not taken to cure the pavement, water will evaporate from the freshly placed mix, causing increased risk of shrinkage and cracking.

Most curing procedures include spraying the fresh concrete surface with a curing agent immediately after the burlap drag or broom finish and as soon as the bleed water is no longer present on the surface (Figure 34). Curing may also be accomplished by placing plastic or wet burlap on the pavement surface and keeping it in place for three to seven days. If wet burlap is used, it is important that the burlap is kept saturated during the entire curing period.

There are various curing agents, including white pigmented agents and clear curing agents. Material type and application rate should follow the jurisdictional requirements for conventional concrete pavement.

Jointing

The three types of joints in concrete paving are contraction, construction, and isolation/expansion joints. The majority of joints are transverse contraction joints.



Jamie Johnson, ACPA, CO/WY Chapter

Figure 34. Cure over fresh concrete

Contraction Joints

Concrete shrinks due to decreases in temperature, drying, and to a lesser extent, volume loss during hydration. This shrinkage, in combination with pavement base restraint, results in the buildup of internal stress in the concrete. When the amount of internal stress is higher than the fresh concrete's strength, a random crack will result. By establishing transverse contraction joints at regular intervals, the pavement is more likely to crack at the weakened plane of the joint (Figure 35).

Longitudinal joints along the center of the pavement are not required on paths that are 12 ft wide or narrower. In trails wider than 12 ft with a longitudinal joint, it is recommended to tie the joint with 36 ft long #4 deformed bars, 36 in. apart. Without a tied connection, the two panels may separate from subgrade movement. If the gap becomes wide enough, a bicycle tire can become lodged, resulting in injury to the bicyclist (Figure 36).

Contraction joints can be established by saw cutting or tooling. Even though tooling is the simpler method, it requires skilled effort. Typically, saw cuts provide a smoother ride. Both saw cuts and tooling should be at a depth of at least $\frac{1}{4}$ of slab thickness to achieve proper joint activation.



Figure 35. Activated transverse joint

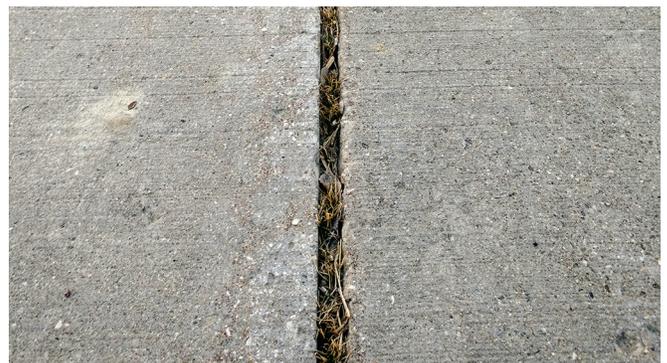


Figure 36. Longitudinal joint without tie bar becomes wide over time

Some contractors tool transverse contraction joints at long intervals prior to sawcutting to reduce the probability of an early random crack. The concern with this method is the extra care needed so that the formed joint does not make a depression in the surface and negatively impact trail smoothness (Figures 37 and 38).

Transverse contraction joints should be spaced at intervals equal to the trail width. Although the width of sawcuts vary between $\frac{1}{4}$ and $\frac{1}{8}$ in., some agencies prefer the narrow $\frac{1}{8}$ in. sawcut. The narrow cut provides less reaction to bicycle tires than a wider joint.

Early-entry saws can be used to increase the speed of construction. These saws are lighter than conventional saws and have unique characteristics to allow for early sawing. New developments in early-entry saws allow for sawblade cuts as narrow as 0.10 in. Early-entry saws can be used once the pavement is strong enough to support human weight without leaving an impression (Figure 39).

Construction Joints

A construction joint is defined as the joint located between two separate concrete placements. Transverse construction joints typically perform well without steel reinforcing. In addition, dowels are not needed due to the overall thickness and lack of vehicle loading.

Isolation/Expansion Joints

Isolation/expansion joints should be used at locations where structures are located. This includes bridges, utility access risers, and roadway crossings. Expansion joints placed at regular intervals throughout a long corridor in the trail are not required.

Joint Sealing

Trail joints have demonstrated good performance without the use of joint sealant. Sealants are typically only used during maintenance activities.



Figure 37. Hand-tooled joints prior to saw operations



Figure 38. Tooled transverse joint in fresh concrete



Iowa DOT

Figure 39. Early-entry concrete saw

Maintenance

Common Repairs

For the success of the trail, the goals of long-term durability and low maintenance are of critical importance. Concrete has the advantage of providing long-term service with minimal maintenance efforts. A well-prepared trail management plan will pay dividends for the life of the pavement as well as protect the overall asset. When distresses are observed, rehabilitation should be carried out at the right time to keep the pavement in good condition.

Common maintenance and rehabilitation techniques for concrete trails include crack filling, full-depth panel repair, grinding with a rotomill or other small equipment, and partial-depth repair. Table 5 lists common concrete distress types along with recommended repair methods. The trigger limits will vary depending on the level of service desired.

When a distress reaches the trigger limit, it is time for rehabilitation. The trigger limits in the table are minimum and are to be considered as guidance for a comfortable ride for cyclists.

Full panel replacement also provides the opportunity to improve subgrade conditions if needed. If a longitudinal crack is not given proper attention, it may separate, causing the same safety hazard as a separated longitudinal joint. Therefore, it is important to regularly inspect the trail pavement and take measures for rehabilitation at the proper time.

Frequently, random cracking and faulting are the result of subgrade conditions or construction traffic. This can include poor support, nonuniform subgrade, as well as soil that has shrinkage and swell potential.

Table 5. Concrete trail distress, causes, and repair

Distress	Example	Cause	Repair
Random cracking		Poor subgrade support, subgrade freeze/thaw, or differential subgrade movement	If crack is not working (no vertical movement or horizontal separation), routing and sealing is recommended If crack is working, remove and replace panel
Transverse joint faulting		Subgrade freeze/thaw or differential subgrade movement	If less than ¼ in., do nothing If from ¼ to ½ in., grind with rotomill or other small equipment If more than ½ in., perform a full-depth repair or slab jacking (raising the settled panel) with pressure grout
Longitudinal crack		Excessive panel width, poor subgrade support, or differential subgrade movement	If tight (less than ¼ in.), do nothing If moderate (¼ to ½ in.), fill with sealant If open (more than ½ in.), replace panel
Divided slabs	 Panel is divided into three or more pieces	Poor subgrade support or deficient pavement thickness	Replace panel

Special Details

Utility Conflicts

Utility Access Castings

Trails may follow utility corridors or roadways where utilities are present. Utility access castings (manhole covers) are often in proximity to trail construction. Ideally, the trail paving would be designed with the casting outside the pavement. If this is unavoidable, then the trail should be designed so the casting is fully within the concrete slab (Figure 40). It is not desirable to locate the casting on the edge of the trail pavement (Figure 41).



Figure 40. Utility access casting—completely within trail pavement slab



Figure 41. Utility access casting—partially within trail pavement slab

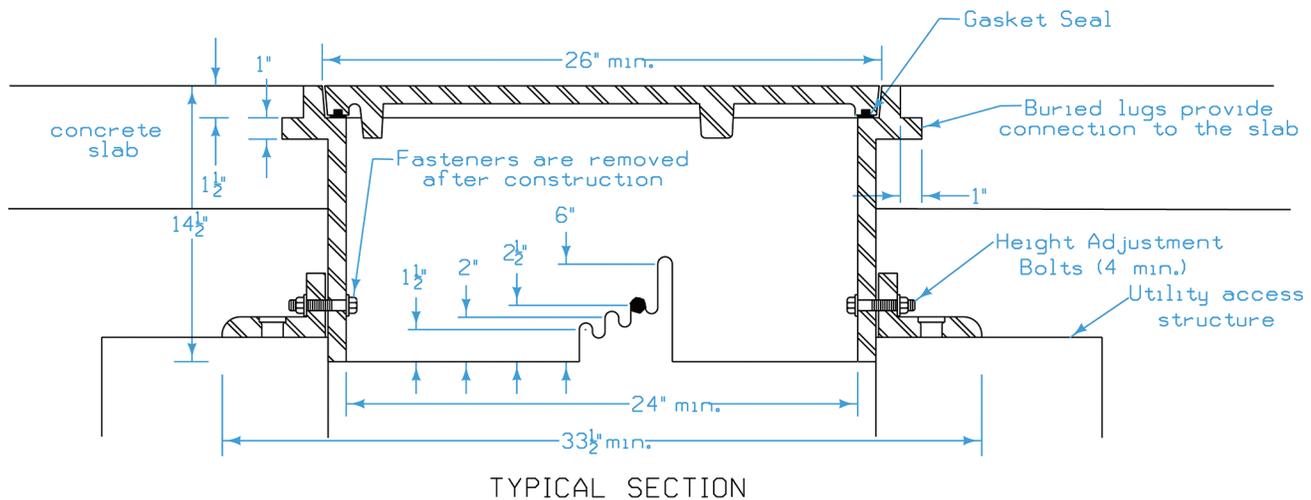
A three-piece floating casting should be considered to allow the trail pavement to move vertically, independent of the fixed utility structure (Figure 42).

Truncated Domes and ADA Ramps

Detectable warnings, truncated domes, and tactile warning strips refer to the same product that provides advance warning to persons who are visually impaired. The detectable warning must provide full coverage across the trail opening, except for the sloped flares (Figures 43 and 44). The location of the detectable warnings shall be where the ramp ends and the street begins. For urban sections, they are located at the back of the curb line. For rural applications, they are located at the edge of the shoulder. Detectable warnings must be installed per the manufacturer's recommendations, which can vary depending on the material type specified in the contract documents. If the material requires a concrete border away from a joint or edge for proper installation, it shall be 2 in. or less per the Public Right-of-Way Accessibility Guidelines (USAB 2011).



Figure 43. ADA ramp in rural section



Iowa SUDAS

Figure 42. Three-piece floating casting

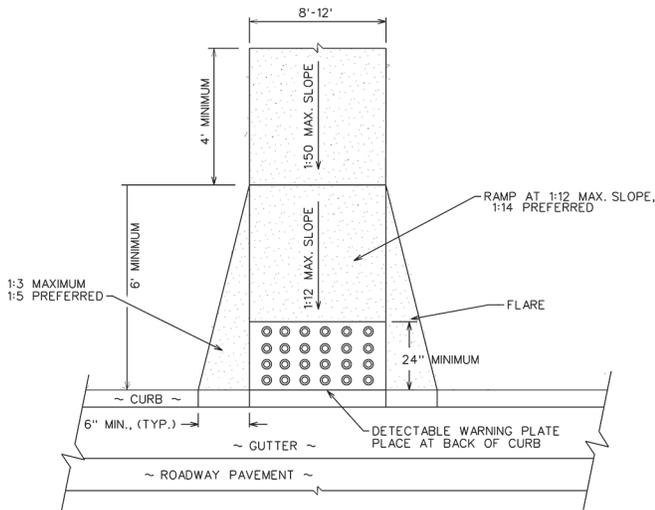


Figure 44. Typical trail ADA ramp detail

Cast iron materials perform better in areas that require snow removal but are more difficult to cut and place if an irregular shape is needed. Composite material panels suffer from domes shearing off; however, they can be installed as replaceable panels with bolt-on connections. Figure 45 shows damage to truncated domes during snow removal.

Pervious Concrete

The use of pervious concrete for trails/paths is a good way to provide a sustainable and environmentally friendly pavement system (Figure 46). Pervious concrete is an open-graded concrete mix with a void content between 15% and 25% and a low water/cement ratio. It has a flexural strength between 150 and 550 psi.

On a trail with an impervious surface, stormwater collects and runs off; however, the void space in pervious concrete allows rainwater to drain through the pavement and into the underlying soil. During design, the underlying soil properties should be investigated to ensure proper drainage characteristics. If the subgrade soil has low permeability, an additional drainage component consisting of a drainable subbase stone along with a subdrain pipe and outlet is required.

In order for pervious concrete to have long-term performance, special maintenance activities are required. A minimum of one time per year, the pavement should be cleaned of debris to allow water infiltration. The best process for cleaning pervious concrete pavement is a combination of high-pressure washing and vacuuming.



New Hampshire DOT

Figure 45. Snow removal can cause damage to plastic domes



Figure 46. Pervious concrete



Figure 47. Colored sidewalk

Colored Concrete

Colored concrete is specified when an owner wants to bring attention to special areas for safety or aesthetic value (Figure 47). It can be used near crossings and transitional locations to focus user attention. It can also be used to blend the trail into the surroundings or create patterns.

Construction techniques for a colored concrete trail are similar to a traditional concrete trail except for curing and water/cementitious materials ratio. Research performed by the Minnesota DOT (Burnham et al. 2014) recommended a lower water/cementitious materials ratio (<0.43) and increasing consolidation of the mix during placement.

Colored concrete costs are slightly higher because of their color pigment and curing wax. Colored dyes and stains can also be applied to the surface of traditional concrete to achieve similar aesthetic and safety considerations. Colored pigments may increase water demand, so the mixture must be designed for the purpose.

Case Study #1: Dam West Subdivision Trail System

Project Information

Construction Year(s)	1991 to 1997
Location	Peoria Street and Yale Avenue, Aurora, Colorado
Trail Type	Neighborhood walking path
Width	4 to 5 ft
Length	10,500 ft
Thickness	4 in.
Subgrade System	Recompacted clay soils after removing old asphalt path
Contractor	Thoutt Bros. Concrete Contractors, Inc., Denver, Colorado
Type of Paver	Hand formed
Special Accomplishments	Systematically replaced entire asphalt path system that runs throughout 20 ac of greenbelt with a concrete trail. A total of 4 projects over an 8-year period to accommodate budget constraints.
Total cost	\$105,000

Discussion

The Dam West is a unique subdivision located in Aurora, Colorado. The subdivision, which includes 327 single-family homes, was the first homeowners association (HOA) in the state of Colorado. Dam West was groundbreaking in that it was the first subdivision to include amenities such as a pool, clubhouse, tennis courts, and over 20 ac of open space. The trail system connects the residents to all of the various amenities (Figure 48).

In 1991, the HOA board of directors faced a decision on what to do with the asphalt trail system built by the subdivision developer. The trails were literally falling apart, shrinking in width, and in some places completely disintegrating. After considering the life-cycle costs of replacing the pavement, the board elected to systematically replace all the trails with concrete pavement over the next 8 years (Figure 49). The final project was completed in 1997. Other than replacing a panel or two due to tree root expansion, the HOA has not spent any money on maintaining the concrete trail system over the last 25 years, freeing up resources to spend in other areas.



Don Clem, National Ready Mixed Concrete Association

Figure 48. Concrete path around a subdivision in Aurora, Colorado



Don Clem, National Ready Mixed Concrete Association

Figure 49. Asphalt path was replaced by concrete 20 years ago

Case Study #2: Sauk Rail Trail Reconstruction Project

Project Information

Construction Year(s)	2015
Location	Swan Lake State Park, Carroll, Iowa
Trail Type	PCC trail
Width	8 ft
Length	18,653 ft (3.5 mi)
Thickness	5 in.
Subgrade System	Scarified and recompactd existing asphalt trail
Contractor	Howrey Construction, Rockwell City, Iowa
Type of Paver	Custom slipform paver
Special Accomplishments	Existing asphalt trail was scarified in place and incorporated into the project as a subbase.
Total Cost	\$516,000

Discussion

Howrey Construction completed reconstruction of the 3.5 mi of trail around Swan Lake State Park in Carroll, Iowa. Scarification of the existing asphalt trail saved the Carroll County Conservation Board money in many ways. The existing pavement did not need to be removed and disposed of, saving time and money. It also served as a base once compacted, and no additional base material was needed. Western Engineering Company reclaimed the asphalt in 6 working days, and the entire project was paved over 14 working days during the fall of 2015 (Figures 50 and 51).

Some construction challenges existed, including a crowded right of way with vegetation and steep grade changes. Construction access was also limited on the project. Some ready-mix concrete trucks had to park as far away as half a mile from the slipform paver. Concrete buggies and dumpers were utilized for long-haul distances.



Brian Madsen, Howrey Construction

Figure 50. Western Engineering Company reclaiming the existing asphalt trail



Brian Madsen, Howrey Construction

Figure 51. Howrey Construction paving in October 2015

Case Study #3: Legacy Trail

Project Information

Construction Year(s)	2010
Location	Lexington, Kentucky
Trail Type	Conventional—shared path Pervious—shared path
Width	9 to 12 ft
Length	Conventional—approximately 8 mi Pervious—approximately 4 mi
Thickness	Conventional—6 in. for 3 mi and 4.5 in. for 5 mi Pervious—6 in.
Subgrade System	Native ground
Contractor	Conventional—FOX Enterprises, Richmond, Kentucky Pervious—Bluegrass Contracting Corporation, Lexington, Kentucky
Type of Paver	Conventional—four-track Power Curber Pervious—triple-roller screed
Special Accomplishments	—
Total cost	Average price—\$36 yd ²

Discussion

The Legacy Trail is a 12 mi multiuse path stretching from downtown Lexington, Kentucky, to the Kentucky Horse Park. It runs north to south through green spaces, neighborhoods, and parks. About 8 mi of the trail is off-road, and it is all paved. A section of the trail was placed with a slipform paver (Figure 52). Limestone pillars mark each end of the trail. An 8 mi section of the trail is conventional concrete (Figure 53), and a 4 mi section is pervious concrete.

The trail enters the Kentucky Horse Park just north of I-64. The pervious section is just south of the Kentucky Horse Park (Figure 54). The Kentucky Horse Park is a 1,200 ac working farm with museums and horse shows.

The park itself has many concrete paths and trails. About 3 mi of conventional path was 6 in. thick 4,000 psi concrete, and 5 mi of the path was 4.5 in. thick concrete on a 4 in. thick dense-graded aggregate base. No fibers were used. The pervious path was 6 in. thick and done with a riding triple-roller screed.

The owner’s maintenance staff is pleased with the trails, and new projects are planned (Figure 55).



Greg Smith, Kentucky Concrete Pavement Association

Figure 52. Slipform paving was used for part of Legacy Trail



Greg Smith, Kentucky Concrete Pavement Association

Figure 53. 8 mi of the trail were built with conventional concrete



Greg Smith, Kentucky Concrete Pavement Association

Figure 54. Pervious concrete trail south of Kentucky Horse Park



Greg Smith, Kentucky Concrete Pavement Association

Figure 55. Completed trail

Case Study #4: Parklands of Floyds Fork Trails

Project Information

Construction Year(s)	2015 to 2016
Location	Jefferson County, Kentucky
Trail Type	Shared path
Width	9 to 12 ft
Length	Approximately 8 mi
Thickness	6 in., turndown edges (8 in.)
Subgrade System	Native ground with spot lime stabilization
Contractor	Filcon Construction, LLC, Coxs Creek, Kentucky Hall Contracting of Kentucky, Inc., Louisville, Kentucky
Type of Paver	Fixed form
Special Accomplishments	Fiber-reinforced concrete
Total Cost	Average price—\$33 yd ²

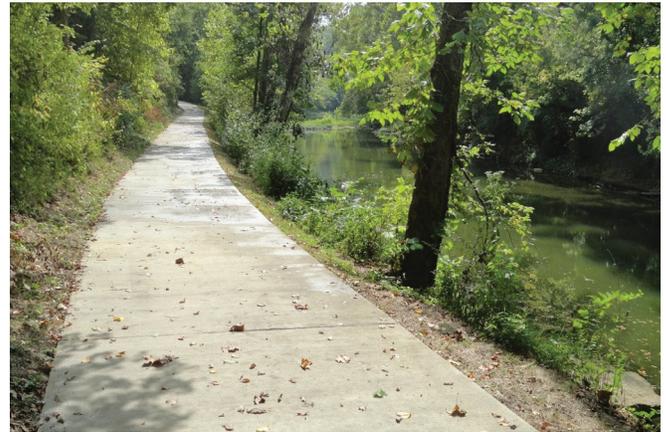
Discussion

The Parklands of Floyds Fork project was one of the largest park initiatives in the United States in 2015 (see www.theparklands.org). The project team chose concrete for approximately 8 mi of the new multipurpose trail. These 8 mi are largely in a flood plain and weave through woods, by streams, and through grass fields (Figure 56).

There are hot-mix asphalt (HMA) trails on some slopes above the flood plain. One rationale to use HMA was cost, though the concrete and HMA paths are not structurally equivalent. Another rationale was constructability on slopes. The HMA trails are showing edge cracking already.

The design of 6 in. thick concrete with turndown edges (8 in. depth) was used to address flooding concerns and to accommodate lightweight maintenance trucks. The mix was 4,000 psi, was fiber reinforced, and had a high-range water reducer (Figure 57).

Bikers, strollers, rollerbladers, and walkers love the trails. Since construction, the maintenance staff at the parks speak highly of the concrete trail. There have been lots of positive comments on the reflectivity and visibility. The client is pleased with the concrete trails and more are to be let soon.



Greg Smith, Kentucky Concrete Pavement Association

Figure 56. Trail is in flood plain, passing along water bodies, woodland, and grass



Greg Smith, Kentucky Concrete Pavement Association

Figure 57. Fiber-reinforced concrete was used for the trail

Case Study #5: Wingate South Park Trail

Project Information

Construction Year(s)	2019
Location	Littleton, Colorado
Trail Type	PCC trail
Width	6 ft
Length	3,900 ft
Thickness	4 in. concrete overlay with 4 lb/ yd ³ macrofibers
Subgrade System	3 in. of existing asphalt on 3 in. aggregate base
Contractor	SLV Quality Concrete, Inc., Monte Vista, Colorado
Type of Paver	Hand placed
Special Accomplishments	Unbonded concrete overlay, early-entry saw
Total Cost	\$127,000

Discussion

The Foothills Park & Recreation District is a special district formed in 1959 to focus on parks and recreational facilities in Jefferson County, Colorado. The district maintains several recreation centers, trails, and golf courses throughout Jefferson County. The asphalt trail at Wingate South Park in Littleton, Colorado, had reached the end of its service life, and the district was considering removing and replacing the trail with asphalt (Figure 58). This approach would have required removal of a large amount of material in an area with few access points.

Solution

The district decided to instead overlay the existing asphalt trail with concrete pavement. This approach saved the district the cost and associated environmental impact of removing the existing asphalt from the park. Once the new concrete overlay was in place, the district added shoulder material to ensure the safety of trail users. There were several areas that required new construction to improve drainage and/or safety.

Results

Trail users at the Wingate South Park are now greeted by a beautiful, bright, and safe concrete trail running through the scenic open space (Figure 59). In addition, the district not only saved time and money over the asphalt reconstruction alternative, but they will also enjoy years of low maintenance, freeing up money to spend on other important recreation projects.



Don Clem, National Ready Mixed Concrete Association

Figure 58. Wingate South Park trail before construction



Don Clem, National Ready Mixed Concrete Association

Figure 59. Wingate South Park trail after construction

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Appendix A: Concrete Overlay on Hot-Mix Asphalt Trails

A cost-effective rehabilitation option for existing asphalt trails is a concrete overlay. In many cases, the asphalt can serve as a uniform support base for the concrete pavement. The main benefits of a concrete overlay are the speed of construction and long-term performance. In addition, the existing asphalt trail can provide a stable platform for concrete delivery. The increase in profile elevation will require material to backfill the edges and bring the shoulders back up to grade.

If considering a concrete overlay of an asphalt trail, the existing pavement should be evaluated (Figure 60). A similar process is outlined in the *Guide to Concrete Overlays of Asphalt Parking Lots* (Harrington et al. 2012). The evaluation steps include the following:

1. Pavement history and performance goals
2. Visual examination
3. Core analysis
4. Optional analysis

Pavement History and Performance Goals

It is important to know the history of the existing surfacing. The age, thickness, and any construction records provide the designer with the background information necessary for thickness design.

Visual Examination

The visual evaluation allows for the collection of data and determination of distress types within the existing pavement. Common asphalt distress on asphalt trails includes thermal cracking, raveling, random cracking, and block cracking.



Figure 60. Pavement evaluation for concrete overlay

Severity of Distress and Repair

Normally, low-severity distresses do not require repairs prior to the placement of an overlay. High-severity distresses, however, must be repaired or removed prior to the placement of an overlay. Care must be exercised to make sure the distress is not the result of a poor support layer. If the subgrade is poor in areas, it should be removed and replaced prior to the concrete overlay.

The support layer and asphalt pavement must be stable and uniform to support the new pavement. If the existing pavement has a large amount of high-severity distresses that require preoverlay repairs, it is likely not a good candidate for a concrete overlay. Table 6 illustrates typical asphalt trail distress and severity.

Table 6. Asphalt distress causes and repair prior to concrete overlay

Distress	Definition/causes	Preoverlay repair	Low severity	High severity
Thermal cracking	Temperature drop causes thermal cracking in asphalt pavement as asphalt binder contracts and shrinks faster than the aggregate. It usually occurs in transverse direction.	Cracks between 1/2 and 3/4 in. wide should be sealed. When cracks are between 3/4 and 1 1/2 in., fly ash slurry, concrete grout, or other nonasphalt material can be used to fill. If subgrade or drainage is causing vertical movements in the cracks that are 1 1/2 in. wide, then the asphalt pavement should be stabilized and drained before filling the cracks.		
Random cracking	Random cracking consists of diagonal, transverse, and longitudinal cracks. It could be caused by any of the reasons: poorly constructed lane joint, hardening of asphalt, subgrade failure, etc.	Cracks between 1/2 and 3/4 in. wide should be sealed. When cracks are between 3/4 and 1 1/2 in., fill them with fly ash slurry, concrete grout, or other nonasphalt material. If the subgrade or drainage is causing vertical movements in the cracks that are more than 1 1/2 in. wide, then the asphalt pavement should be stabilized and drained before filling the cracks.		
Block cracking	Block cracking is interconnected cracks that divide the pavement up into rectangular pieces. It is typically caused by the inability of asphalt binder to expand and contract with temperature cycles because of asphalt binder aging or poor choice of asphalt binder in the mix design.	If the cracks are less than 1/2 in. wide and there are no loose pieces, no repair is required. If severe cracks (more than 1/2 in. wide) are present in isolated areas, then remove and replace those locations with a concrete patch covering and nonwoven fabric interlayer. If severe block cracking is present throughout the trail, then consideration should be given to constructing new pavement, including repairs to the support layer where necessary.		
Raveling	Raveling is the wearing away of the pavement surface caused by the dislodging of aggregate particles. The cause can be the hardening of the asphalt binder, poor quality mix, or poor compaction. The progressive disintegration from raveling occurs from the surface downward as a result of the dislodgement of aggregate particles.	If the binder/aggregate is worn with loss of fine aggregate and some loss of coarse aggregate, but the surface is not too rough, remove all loose material by power cleaning the asphalt surface, followed by cleaning with compressed air. If the binder/aggregate is worn away, and surface texture is very rough and pitted with loss of coarse aggregate, then additional milling can be completed for a uniform profile and support. The minimum remaining thickness of the asphalt is 3 in.		

Source: *Guide to Concrete Overlays of Asphalt Parking Lots* (Harrington et al. 2012)

Images: Thermal cracking and Random cracking images were provided by Snyder & Associates, Inc. Block cracking and Raveling images were provided by J. Dewayne Allen, Allen Engineering Corporation; Bryan Birdwell, Structural Services, Inc.; Jon Hansen, National Ready Mixed Concrete Association; and Randy Riley, formerly Illinois Chapter, Inc. – American Concrete Pavement Association originally for the 2012 *Guide to Concrete Overlays of Asphalt Parking Lots* from the National CP Tech Center

Core Analysis

Subsurface investigation is the third step in the pavement evaluation process. This step involves taking cores from the existing asphalt and support layer. A 1 in. hammer drill can also be used as a simple solution to determine the depth of existing pavement (Figure 61).

The data from the core sample or hammer drilling can determine layer thickness.

A uniform support system for the concrete pavement is critical to the long-term performance of the trail. Therefore, it is important to have a good understanding of the existing trail pavement structure prior to considering a concrete overlay.



David White, Iowa State University

Figure 61. Hammer drill being used to check pavement thickness

Optional Analysis

The fourth step is an optional, in-depth analysis of the existing trail pavement. Many times, a visual examination and cores can provide enough information to determine if the existing asphalt is a good candidate for an overlay. However, there are situations that arise where further analysis is required to make an informed decision, particularly in borderline situations. One such analysis is the determination of the support condition under the asphalt. This is referred to as the California Bearing Ratio (CBR). The CBR can be converted into the k value in accordance with the *Guide for the Design and Construction of Concrete Parking Lots* (ACI 2008).

Appendix B: Fiber Reinforcement

Steel and synthetic fibers are the most common types of fiber used in paving. Synthetic fibers are polymeric and may be monofilament or multifilament (Figure 62). Steel fibers can have circular, semicircular, or rectangular cross sections, and the individual fibers can be straight, hooked-end (crimped), enlarged-end, or deformed. Synthetic fibers are easier to handle, are less prone to balling and clumping, and have no rust issues like steel fibers. Steel fibers can also settle at the bottom of pavement if not properly mixed because of their higher density than synthetic fibers. Steel fibers are also typically more costly than synthetic fibers.

If fibers are incorporated into the mix, fiber manufacturers should be consulted to determine the appropriate dosage rates for concrete trial applications.

Fibers can be dispersed by hand or by an automated system in the plant or truck (Roesler et al. 2019). Fiber balling (clumping) can occur if the fibers are not dispersed properly. For this reason, a method of mixing to produce well-distributed fibers is required. Some agencies specify this requirement, and the contractor can determine the means and methods to meet the specification.

There are many factors that can affect fiber balling, including the following:

- Type
- Volume
- Sequence of adding fibers
- Type and speed of mixer
- Condition of mixing blades

To minimize the potential for balling and to increase workability, a well-graded aggregate gradation is encouraged. Other options to increase workability include increasing paste content (cementitious material and water) to coat the aggregate and fiber while maintaining the desired water/cementitious materials ratio and adding a quality water-reducing admixture.

The images in Figures 63 and 64 are of the same concrete pavement. Figure 63 shows a section of the pavement without fibers where a noticeable crack has formed. Figure 64 shows a test area with 4 lb/yd³ of synthetic fibers incorporated into the mix, and only a hairline crack has formed in this area.



Figure 62. Synthetic macrofibers



Figure 63. Concrete pavement without fibers and with noticeable longitudinal crack



Figure 64. Concrete pavement with fibers and hairline crack

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