Concrete pavements: Key technical resources directory

March 2024 | v2.0

Cement Association of Canada

Using This Guide

This guide contains the best technical resources and references available to support the designing, planning and installation of concrete pavements and roads.

It has been produced by the Cement Association of Canada for the sole purpose of ensuring that concrete roads and pavement continue to deliver best in class performance for those who build them, use them and pay for them.

The guide will be updated annually. For suggestions on how we can make this guide more useful to you, or to report any links that no longer direct you to the correct resource, please contact info@cement.ca

Disclaimer: The technical resources provided in this Guide are for reference and educational purposes only, and are not intended to provide legal or other professional advice for any specific project or application. The examples used in this should not be construed as engineering advice or guidance and project proponents must seek out and rely on duly qualified consultants and professionals for their projects. Companies and products which may appear in this Guide are provided with consent of those parties and in no way constitutes and endorsement or representation or warranty of said companies and products. CAC shall not be liable for any loss whether direct, indirect, incidental or consequential, arising from access to, use of or reliance upon any of the content of this Guide.

Using This Guide

Sustainability 5
- Concrete Zero. 5
- Portland-Limestone Cement. 6
- Environmental Product Declarations. 7
- Carbon Calculators. 8
- Athena Pavement Life Cycle Assessment Software. 8
- MIT Concrete Sustainability Hub 9
- Concrete Pavement's Role in a Sustainable and Resilient Future 10

An Excellent Choice for Roads, Taxpayers, and the Environment . . 12

Conventional Concrete Pavements 13
- Jointed Plain Concrete Pavement (JPCP). 13
- Continually Reinforced Concrete Pavement (JPCP). 14
- Jointed Reinforced Concrete Pavement (JRCP). 14

Roller Compacted Concrete 16

Interlocking Concrete Pavement 17

Concrete Overlays 18

Pervious Concrete Pavement 20

Precast Concrete Pavement 21

Engineered Soils 22
- Cement Modified Soils 23
- Cement Treated Base 23
- Cement Stabilized Subgrade 23
- Full Depth Reclamation (of Ashphalt Pavements) 23

Economics 25
- Competition. 25
- Life Cycle Cost Analysis (LCCA) 26

Design Methods and Software 27

Construction 28

Preservation and Maintenance 30

Additional Resources 31

Concrete building for life.

Application Mapping

Click on the boxes below to navigate to the relevant section.

Sustainability

Types of Concrete Pavements		Typical Applications
Conventional Concrete Pavements	Jointed Plain Concrete Pavement	New construction, municipal streets, highways, parking lots, airports, turning lanes, intersections, bus pads and transit lanes.
	Continuously Reinforced Concrete Pavement	
	Jointed Reinforced Concrete Pavement	
Roller Compacted Concrete		Industrial and commercial applications, heavy duty traffic and parking areas, intersections, sub-divisions, pavement shoulders, intermodal yards, port facilities and some roadways.
Interlocking Concrete Pavement		Crosswalks, aesthetic applications, parking lots, stormwater infiltration sites. May also be used in streets and port applications under heavy duty loading.
Concrete Overlays	Bonded	Repair method for concrete and asphalt pavements, turning lanes, intersections, municipal streets and roads, parking areas.
	Unbonded	
Pervious Concrete Pavement		Parking lots, stormwater infiltration sites.
Precast Concrete Pavement		Highways, streets and roads where fast-track construction or repair is required.
Engineered Soils	Cement Modified Soils (CMS)	CMS: Used to modify characteristics of existing soils that are not suitable for pavement structures.
	Cement Treated Base (CTB)	CTB: Used to decrease subbase or asphalt thickness. Also used to support heavy duty pavement applications like airports.
	Cement Stabilized Sub-grade (CSS)	CSS: This material has structural engineering properties similar to or better than those of natural granular material.
	Full Depth Reclamation (FDR) of Ashphalt Pavements	FDR with cement is used to rejuvenate deteriorated asphalt pavement and provide improved pavement structure strength.

Sustainability

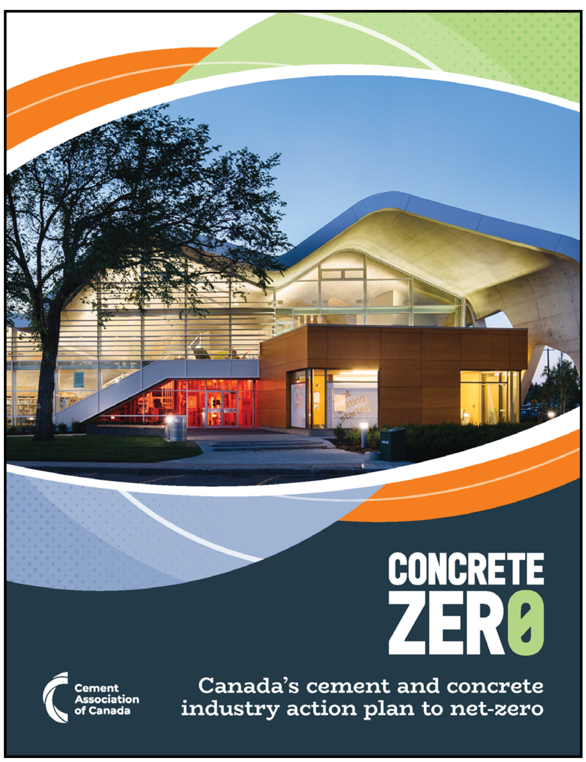
Concrete Zero

In Concrete Zero, Canada's cement and concrete industry action plan to net-zero, we lay out the steps that we—together with our members and partners in the concrete sector—will take to help Canada achieve its net-zero carbon goals as we continue to make concrete a versatile, durable, cost-effective, resilient, and essential construction material.

Concrete Zero shares the journey we have been on as an industry. We have already begun our transition to lower-carbon fuel sources, carbon-reduced cements, and clean technologies. Cement-based materials—including ready mixed, precast and masonry concrete—have also been implementing carbon reductions in their product composition and manufacturing processes. Our industry has been on the leading edge of transparently disclosing and verifying carbon reductions. Our Action Plan lays the foundation for what we will do next and our role in delivering solutions to climate change.

Resources:

ConcreteZero.ca



Sustainability

Portland-Limestone Cement

Portland-limestone cement is a more sustainable, lower carbon cement that reduces CO_2 emissions by up to 10% while still producing concrete of comparable performance, including comparable strength and durability, to concrete produced with portland cement. Portland-limestone cement's 10% reduction in CO_2 emissions occurs during the cement manufacturing process. While portland cement may contain up to 5% ground limestone, portland-limestone cement is made by intergrinding up to 15% limestone, reducing the amount of clinker required. By reducing the amount of clinker used in the manufacturing process, the associated energy demand and process emissions per tonne of PLC are reduced. As a result, the CO_2 emissions associated with PLC are less than those of traditional PC, while equivalent performance is maintained. Overall, the transition to PLC has the potential to save Canada approximately one megatonne of CO_2 emissions annually.

The Canadian cement industry is fully poised to transition from the manufacturing of traditional portland cement (PC) to portland limestone cement (PLC), including PLC-based blended hydraulic cement.

The Cement Association of Canada released the updated Technical Introduction to Portland-Limestone Cement in August 2023.

Resources:

[Technical Introduction to Portland-Limestone Cement]

[Greenercement.com]

[FHWA Portland Limestone Cement Technote]

Sustainability

Environmental Product Declarations

An Environmental Product Declaration (EPD) is an independently verified and registered document that communicates transparent and comparable information about the life cycle environmental impact of a product.

Both the cement and concrete sectors have fully embraced regionally-specific industry-wide average Environmental Product Declarations (EPDs) as a way of quantifying and confirming industry improvements in carbon reduction. All cement facilities in Canada have also published facility-specific EPDs and an increasing number of concrete producers have as well.

List of EPDs:

- ASTM Environmental Product Declaration
- General Use and Portland-Limestone Cements
- British Columbia
- Alberta
- Saskatchewan
- Manitoba
- Ontario
- Quebec
- Atlantic
- Structural Precast
- Insulated Concrete Panel Precast
- Below Grade Precast
- Manholes and Catch Basins
- Concrete Pipe
- Precast Box Structures
- Concrete Block Masonry Units

Cement Association of Canada | Association Canadienne du Ciment

AN ENVIRONMENTAL PRODUCT DECLARATION

FOR GENERAL USE (GU) & PORTLAND-LIMESTONE (GUL) CEMENTS

The Cement Association of Canada (CAC) is pleased to present this Canadian and CAC member regionalized industry average environmental product declaration (EPD) for general use (GU) and portland-limestone (GUL) cements. This EPD was developed in compliance with CAN/CSA-ISO 14025 and is verified by ASTM International.

The EPD includes life cycle assessment (LCA) results for the production stage or cradle-to-gate manufacture of GU and GUL cements as produced in three regions of Canada by CAC members in 2020. It is intended for business-to-business communication.

For more information about [Cement Association of Canada], please go to [www.cement.ca].

Sustainability

Carbon Calculators

There are several tool and software programs available or under development for calculating facility specific concrete EPDs.

List of Carbon Calculators

GCCA Environmental Product Declaration

Climate Earth –All Digital EPDs for Low Carbon Construction

National Research Council of Canada: Low-carbon assets through life cycle assessment initiative

Carbon Star Rating System

Athena Pavement Life Cycle Assessment Software

A free, web-enabled software application that provides environmental life cycle assessment (LCA) results for materials manufacturing, roadway construction and maintenance life cycle stages, allowing for quick and easy comparison of multiple design options over a range of expected roadways lifespans. The tool allows custom roadway design but also comes pre-populated with a library of editable roadway designs. It includes a large equipment and materials database and the flexibility to specify unique pavement systems and a host of user-specified concrete mix designs. Users can also input use-phase operating energy and apply built-in pavement vehicle interaction algorithms to be included in the final LCA results. A life cost analysis analysis (LCCA) modeling capability was also integrated into the software allowing users to consider both cost and environmental burden together.

Read more and access the software.

Sustainability

MIT Concrete Sustainability Hub

The MIT Concrete Sustainability Hub (CSHub) is a dedicated interdisciplinary team of researchers from several departments across MIT working on concrete and infrastructure science, engineering, and economics since 2009. The MIT CSHub brings together leaders from academia, industry, and government to develop breakthroughs using a holistic approach that works to achieve durable and sustainable homes, buildings, and infrastructure in ever more demanding environments.

MIT CSHub Infrastructure Webpage

MIT CSHub investigates how low carbon infrastructure may be built with very finite resources.

Application areas include:

- Albedo and Cool Pavements
- Conductive Concrete
- Crowdsourced Pavement Data: The Carbin App
- Pavement Life Cycle Assessment
- Pavement Life Cycle Cost Analysis
- Pavement Network Asset Management
- Pavement Vehicle Interaction

MIT CSHub Resilience Webpage

MIT CSHub studies how cities can be made more resilient to hazards through investment in stronger, cooler construction.

Application areas include:

- Albedo and Cool Pavements
- Alkali-Silica Reaction (ASR)
- Conductive Concrete - Creep
- Flood Modeling
- Hazard-Aware Building Life Cycle Cost Analysis
- Pavement Life Cycle Assessment (LCA)
- Pavement Life Cycle Cost Analysis (LCCA)

Concrete Pavement's Role in a Sustainable and Resilient Future

Overview

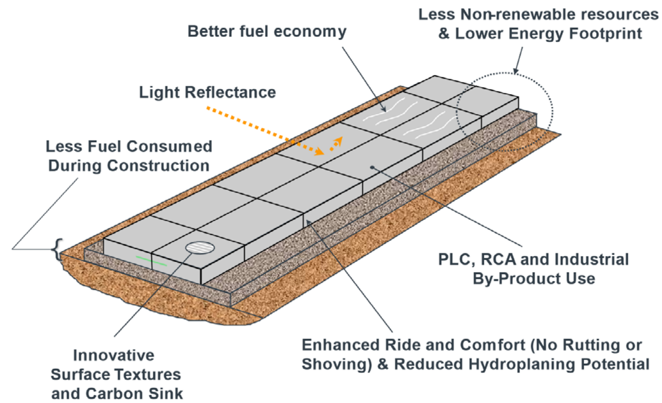
"Across the globe, millions of miles of pavements are placed or rehabilitated every year. As the worldwide challenge to address climate change persists, decision-makers are called on to make pavement type and treatment selections that must meet ever increasing levels for improving sustainability. Additionally, these selections must be resilient to withstand increasing threats of natural and man-made disasters."

The ACPA released a white paper which provides an overview of the research supporting concrete pavement's role in meeting the standards of sustainability and resilience, including life span, use-phase, net zero and life cycle. Download here.

As noted in the publication and depicted in the Figure on page 11, there are many sustainable benefits of concrete pavement. Listed below are a number of the advantages mentioned in the above document and in some of the additional documents noted in the resource list below:

1. Truck fuel savings when operating on concrete pavement due decreased rolling resistance of the rigid pavement structure,
2. Concrete's pavement lighter coloured surface provides superior light reflectance to enhance night time vision,
3. Concrete's higher albedo decreases the ambient air temperature due to urban heat island effect.
4. Concrete's increased albedo radiates more energy out from the Earth and has a cooling effect.
5. Less fuel is consumed during construction of a concrete pavement due to thinner pavement structure,
6. Less non-renewable resources required in a concrete pavement structure,
7. Lower energy footprint of concrete compared to asphalt pavement,
8. Ability to use recycled concrete in concrete mix design,
9. Ability to use industrial by-products such as fly ash and slag safely storing the material in the concrete matrix and preventing it having to go to a landfill with the added benefit of improving the concrete properties (i.e. strength and permeability)
10. Ability to utilize PLC in the concrete pavement mix design which provides a more sustainable lower carbon concrete.
11. Innovative surface texture such as longitudinal tining and grooving improve tire pavement interface in wet weather reducing the potential for hydroplaning.
12. Longitudinally tined or grooved concrete surfaces also decrease pavement noise equal to or better than many asphalt surface types.
13. Enhanced ride and comfort due to a rigid surface that does not rut or shove and has minimal potential for pothole development.
14. Concrete pavements also have a slower roughness progression than asphalt pavement meaning a smoother ride for a longer period of time.
15. Exposed concrete surface acts like a carbon sink absorbing CO2 form the atmosphere. When the pavement needs enhanced skid resistance after several years of operation diamond grinding exposes fresh concrete that will absorb additional CO2.

Concrete Pavement's Role in a Sustainable and Resilient Future



Resources

Additional Analysis of the Effect of Pavement Structure on Fuel Truck Consumption

Concrete Pavement: A Sustainable Choice

Concrete Pavement: A Truly Sustainable Choice

CP Tech Center Concrete Recycling Site

Effects of Pavement Structure on Vehicle Fuel Consumption

Effects of Pavement Surface Type on Fuel Consumption – Phase 2: Seasonal Tests

Effects of Pavement Structure on Vehicle Fuel Consumption – Phase III

Federal Highway Administration - LCA Pave Tool

Fuel Savings and Emissions Reduction When Operating Heavy Trucks on Concrete Pavement

Helping Build a Sustainable Future by Constructing Roadways with Portland Cement Concrete Pavement

Impact of Flooding and Inundation on Concrete Pavement Performance

Life Cycle Assessment of Pavements: A Critical Review of Existing Literature and Research

Life Cycle Cost (2006 Update)

Life Cycle Embodied Energy and Global Warming Emissions for Concrete and Asphalt Roadways

Life Cycle Perspective on Concrete and Asphalt Roadways: Embodied Primary Energy and Global Warming Potential

Pavement Roughness Progression: A Case Study

Pavement Flooding Risk Assessment and Management in the Changing Climate

Solar Reflectance of Concretes for LEED Sustainable Sites Credit: Heat Island Effect

Sustainable Concrete Pavements: A Manual of Practice

The Sustainable Benefits of Concrete Pavement

Transportation Association of Canada - Canadian Guide for Greener Roads

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An Excellent Choice for Roads, Taxpayers, and the Environment

Concrete roads can deliver superior value and performance over their lifetime. According to independent research, concrete roads can save money, reduce harmful emissions, improve safety, and spare users the aggravation of roads under constant repair.

Here are some important advantages of putting concrete roads to work:

1. More reliable and less expensive
- Cities and their taxpayers can save about 15% on every kilometer paved with concrete and save an extra 51% on road maintenance over a 50- year lifespan, as seen in Ontario for example.

2.Lower energy costs
- Require significantly less embodied energy to build than asphalt pavements
- Reduce roadway night-lighting needs by as much as 24% while improving visibility.

3.Lower emissions
- Improved fuel efficiency for drivers of up to 7% saves money and cut GHG emissions by up to 12,000 tonnes per lane kilometer – the equivalent of avoiding the consumption of over 5 million liters of gas over the lifespan of the pavement. Commercial trucks consume less fuel on concrete pavement.

4. Superior environmental benefits
- Its cooler temperature prolongs tire life and reduces GHG emissions.
- Concrete naturally absorbs GHGs from the atmosphere. Studies show that up to 20% of cement emissions are re-absorbed into a concrete product.

5. Improved Comfort, Safety and Reliability
- Better braking and handling performance, with reduced potential for hydroplaning due to improved tire pavement interface.
- Its cooler temperature means less flash freezing and “black ice” in the winter.
- Its brighter qualities improves night-time visibility for drivers and pedestrians.
- Strong resilience to extreme weather means virtually zero potholes or ruts.

6. Improved construction timeliness
- Innovative construction techniques such as fast track concrete or precast concrete panels allow opening roadways on the same day.
- Proper concrete pavement mix designs and installation allow for late season placement of concrete pavement and provide durable salt resistance.

7. Life cycle approaches reduce long-term costs and environmental impacts
- Life cycle cost-analyses consistently rank concrete as “best in class” when comparing alternative materials. Longer life means taxpayers pay once, not twice.
- Concrete is 100% recyclable and re-usable.

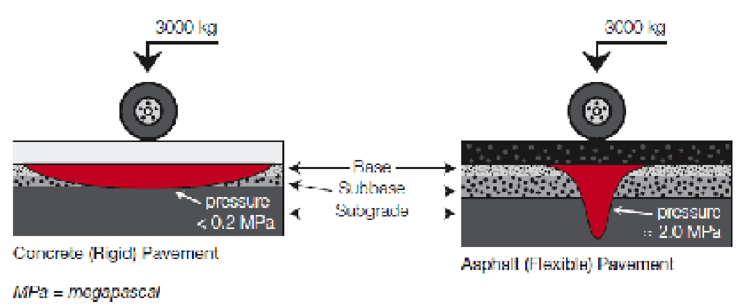
Conventional Concrete Pavements

Overview

Concrete is hard, rigid and durable—it is the traditional material of choice for constructing buildings, bridges and other types of infrastructure. For the same reasons, concrete is also an excellent choice for roads.

There are essentially two types of pavements – rigid and flexible. A rigid concrete pavement distributes heavy loads over a relatively wide area, with minimal pressure on the subgrade (the natural soil under the roadway). On the other hand, flexible asphalt material concentrates weight into more of a point loading and transmits it deeper into the roadbed. As a result, asphalt pavements require a thicker gravel base and subbase (material between the subgrade and the gravel base) for equivalent highway designs, as illustrated in Figure 1.

FIGURE 1: TYPICAL LOAD DISTRIBUTION FOR RIGID AND FLEXIBLE PAVEMENT LAYERS



Concrete pavement acts as a bridge over the subgrade.

Types of Conventional Concrete Pavements

Where conventional concrete pavements are concerned, there are three subtypes of pavement, which vary in terms of steel reinforcement requirements:

Jointed Plain Concrete Pavement (JPCP)

Jointed Plain Concrete Pavements are the most common conventional concrete pavement. For JPCP, concrete slabs are constructed directly over a prepared aggregate base structure. Transverse joints separate the concrete into panel sections, and are located where the concrete would be expected to crack naturally (typical panels are 4 – 6 meters wide, with a maximum width to length ratio of 1.5:1). The industry standard is to use a maximum joint spacing of 18 to 24 times the thickness of the concrete with no more than 4.5 metres for roadway pavements. Proper jointing of the concrete pavement is required to ensure good performance of the pavement. Transverse joints are installed perpendicular to traffic, and allow load transfer between the panels according to two different methods, as determined by pavement thickness:

Undoweled: Typically, for pavements 175 mm thick or less, joints do not require dowel bars, and load transfer is achieved through aggregate interlock.

Doweled: For pavements 200 mm thick or greater, smooth steel dowel bars are placed at the midpoint of the pavement thickness parallel to the direction of traffic. Tie bars (deformed rebar) hold the pavement lanes together, placed perpendicular to traffic direction along the longitudinal joint.

Conventional Concrete Pavements

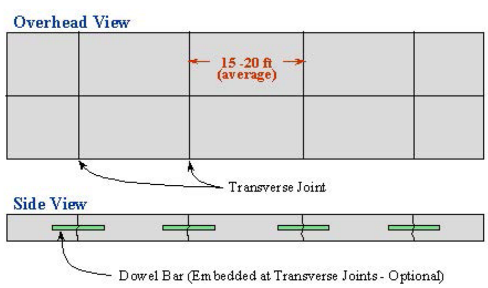
Types of Concrete Pavements (Continued)

Continuously Reinforced Concrete Pavement (CRCP)

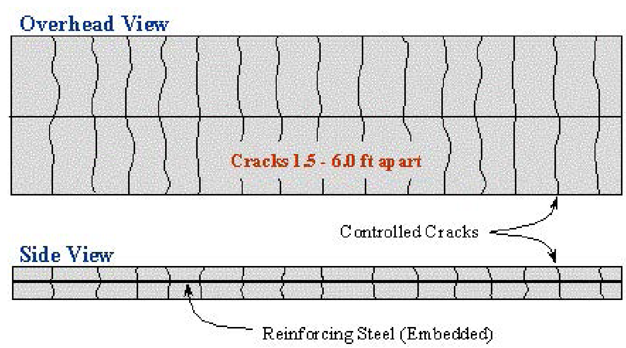
Typically used for heavy duty applications, such as bus lanes and bus stops. CRCP does not require construction joints, and instead utilizes reinforcement steel (approximately 0.6-0.7% by cross sectional area) to hold the expected transverse cracks together tightly. Quebec utilizes CRCP in the Montreal area due to the congested highway system and the need to have a pavement that has very minimal rehabilitation requirements.

Jointed Reinforced Concrete Pavement (JRCP)

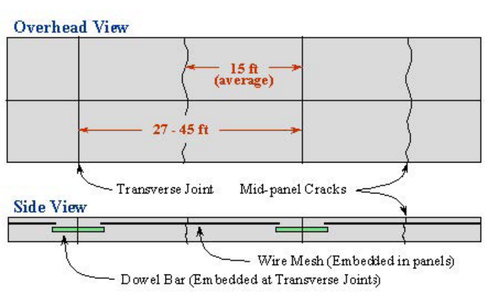
Older JRCP concrete pavement designs utilized a layer of thick wire mesh located in the top third of the concrete panels, in addition to the dowel bars located along the transverse joints. **NOTE: This type of concrete pavement design is no longer recommended for new construction.**



Jointed Plain Concrete Pavement (JPCP)



Continuously Reinforced Concrete Pavement (CRCP)



Jointed Reinforced Concrete Pavement (JRCP)

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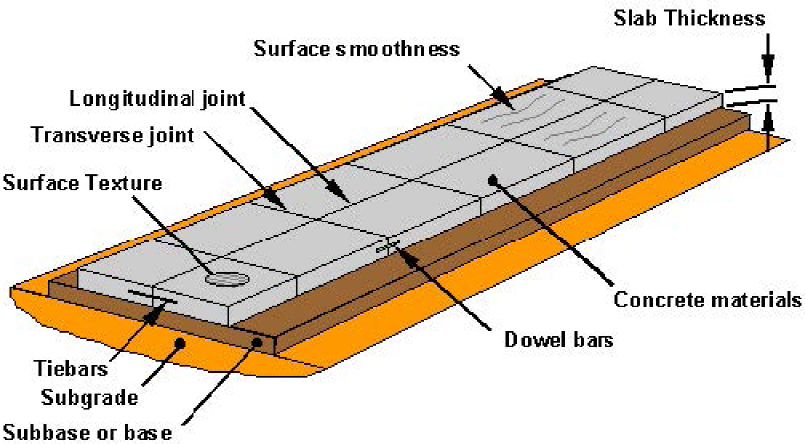
Conventional Concrete Pavements

Concrete Pavement Components



Jointed Plain Concrete Pavement

Resources

[Design Methods and Software](#)
[Construction](#)
[Preservation and Maintenance](#)
[Joint Layout for Concrete Pavements](#)

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Roller Compacted Concrete

Overview

Roller Compacted Concrete (RCC) is a durable, economical and sustainable pavement solution, which gets its name from the heavy vibratory and rubber-tired rollers used to compact its final form. RCC is a heavy-duty pavement, used when large paved areas must stand up to heavy vehicle loads, abrasive environments and sharp turning movements, as well as, spills and specialized equipment.

RCC is placed at the same speed as asphalt, using much of the same equipment, but the pavement has similar strength and durability properties as conventional concrete. The key difference between conventional concrete and RCC is the way the materials are proportioned. For an equivalent strength mix between RCC and conventional concrete, the RCC mix has more fine aggregates passing the 200-micron sieve and a lower air, cement and water content than conventional concrete. Due to the additional amount of fine aggregates, the unit weight of RCC is higher than conventional concrete.

RCC is comprised of a zero-slump concrete. This stiff consistency due to a low water cementitious ratio allows it to be placed without any forms and does not require dowels or reinforcement steel. For finishing, RCC can be left as an exposed wearing surface with a texture similar to asphalt, or diamond grinding can be used to achieve a smoother surface. Additives can also be used in the RCC mix to allow a texturing of the RCC surface. Curing is performed the same as with conventional concrete.

Typical applications for RCC include industrial pavements and heavy-duty parking lots, in addition to several specialized uses in ports, intermodal yards, snow melt sites, scrap metal facilities, and dams. Several key resources with respect to the design, construction, and maintenance of RCC are available through the external links below.

Resources

RCC Pavement Council

Guide to Roller Compacted Concrete Pavements

ACPA RCC Project Explorer

PCA Roller Compacted Concrete Overview

FHWA Tech Brief on Roller-Compacted Concrete Pavement

ACI 330.2R-17: Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities

ACI 327R-14 Guide to Roller-Compacted Concrete Pavements

RCC Pave (now a part of pavementdesigner.org)

ACI PRC-309.5-22: Compaction of Roller-Compacted Concrete – Report

ACI PRC-327.1-21: In-Place Density Testing of Freshly Placed Roller-Compacted Concrete by Nuclear Gauge Testing – TechNote

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Interlocking Concrete Pavements

Overview

Interlocking concrete pavement (ICP) pavers are a versatile, multi-purpose pavement alternative that are becoming a popular solution across many areas in Canada. They can be utilized in both architectural and structurally functional applications, including streetscaping, delineation of crosswalks, or heavy-duty applications like ports or airports.

Increasingly, ICP are being used as an infiltration solution to restore the natural ability of an urban site to absorb stormwater. They can play an important role in flood mitigation in urban environments.

Resources

Concrete Masonry and Hardscapes Association

ICPI Design Manuals

Education for Professional Designers

FHWA Tech Brief on Permeable Interlocking Concrete Pavement

Permeable Interlocking Concrete Pavement (68-18) by American Society of Civil Engineers

Concrete Overlays

Overview

The overlaying of concrete on asphalt, composite or old concrete pavements provides an environmentally friendly, long-lasting and cost-effective rehabilitation pavement solution.

There are two types of concrete overlays:

- Bonded — Relatively thin concrete placed directly on existing pavements that are in good to fair structural condition.
- Unbonded — Usually thicker than bonded overlays, unbonded overlays restore structural capacity to existing pavements that are moderately to significantly deteriorated.

This pavement solution is a cost-effective approach that can bring new life to streets and roads. Rather than removing and reconstructing the original pavement, the owner maintains and builds equity in it, realizing a return on its original investment as long as the original pavement remains part of the system. Overlays can be used for surfaces and rehabilitation of mainline highways; high volume streets and local roads; residential streets; heavy industrial/intermodal/military facilities; airport runways, taxiways and aprons; and parking lots.

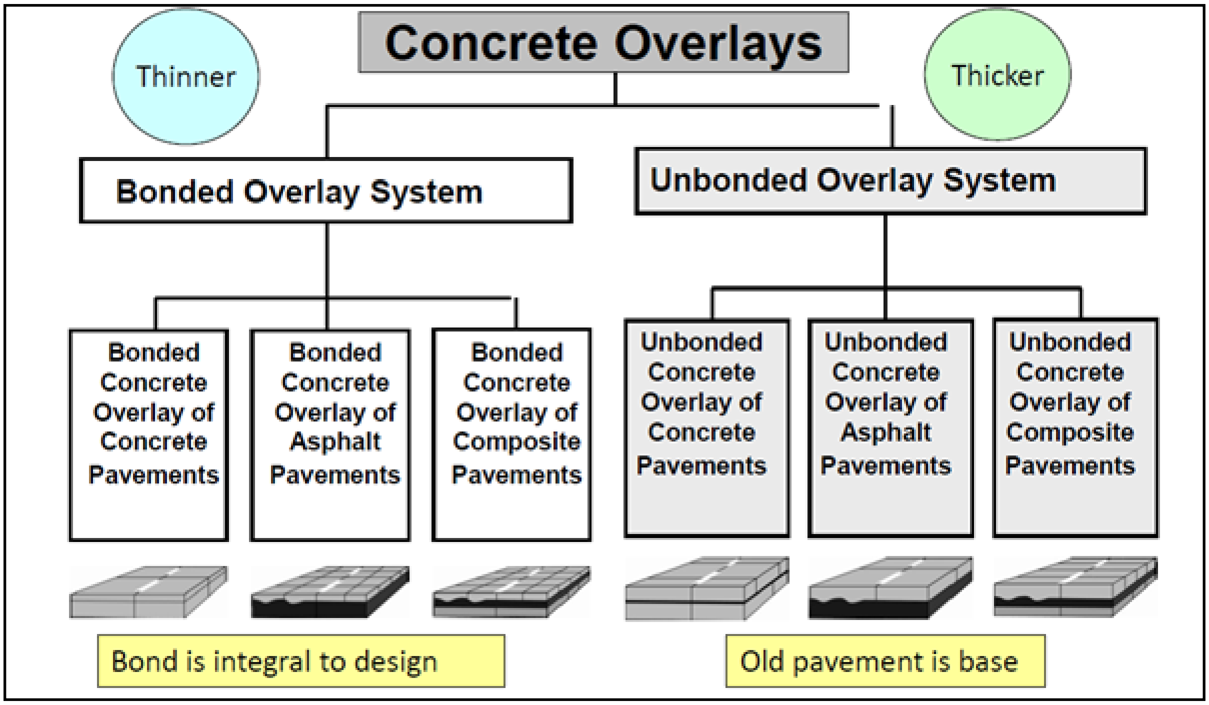
Bonded Concrete Overlay

- Process — A thin layer of concrete (50 to 125 mm) is bonded directly to the pavement surface. Bonding is essential so thorough surface preparation is necessary before restoration.
- The new pavement — Bonded together, the overlay and the existing pavement perform as one monolithic pavement with the existing pavement continuing to carry a significant portion of the load.
- When to use it — For use on pavements in good to fair structural condition. Use on roads and intersections that need added structure to handle the increased traffic loads and volumes
- Notable — Adds structural capacity and eliminates distress such as rutting and shoving of the asphalt.

Unbonded Concrete Overlay

- Process — Prior to overlay, a separation medium or stress relief layer is placed on the old concrete pavement to isolate the existing deterioration, prevent reflective cracking and to act as cushioning layer. A layer of concrete (normally 100 to 275 mm) is then placed over the thin separation layer. Existing asphalt or composite pavements do not require the separation layer. Note: If the asphalt pavement is in a severely deteriorate state the asphalt has to be milled and replaced so the distortion(s) do not reflect up through the concrete pavement during its strength development stage.
- The new pavement — The overlay performs as a new pavement, and the existing pavement provides a strong and stable base.
- When to use it — For use on existing pavements that are moderately to significantly deteriorated.
- Notable — Does not have reflective cracking or rutting problems. The unbonded concrete overlay of an asphalt pavement was previously called whitetopping.

Concrete Overlays



Resources

[CP Tech Centre Concrete Overlays]
[Guide to Concrete Overlays 4th Edition]
[ACI 325.13R-06: Concrete Overlays for Pavement Rehabilitation (Reapproved 2020)]
[Guide for the Development of Concrete Overlay Construction Documents]
[Pave Ahead Resources]
[FHWA LTBP Summary - Current Information on the Use of Overlays and Sealers]

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Pervious Concrete Pavements

Overview

Pervious concrete is a porous medium that allows storm water to drain from the surface to the underlying base and soil structures. It is comprised of a gap graded aggregate with little to no sand, creating a concrete with a void structure that maximizes stormwater infiltration and provides a low impact development alternative to overland drainage designs. Increasingly, porous pavements are being recognized by local regulations as a best management practice for stormwater control. When properly maintained, pervious concrete pavements present a long lasting alternative for applications like parking lots, alley ways, and low volume roads.

Resources

Pervious Concrete Pavement Website

ACI Specification for Pervious Concrete Pavement

Maintenance and Operations Guide

Green Building Alliance - Permeable Pavements

ACI SPEC-522.1-20: Specification for Construction of Pervious Concrete Pavement

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Precast Concrete Pavements

Overview

Precast concrete pavements are a relatively new type of pavement system slowly gaining popularity in North America because of its prefabricated, modular nature, which allows for expedited construction schedules over asphalt and cast-in-place concrete. Precast pavement slabs are particularly useful for rehabilitation of highly traveled concrete roadways because of the difficulty in re-routing traffic. The precast pavement repair technique may also be useful for highways of much lower ADT at certain locations such as approaches to bridges where shoulders for accommodating traffic detours are minimal or non-existent (i.e. main thoroughfares, ramps, intersections, bridge approaches, roundabouts, as well as airfield runways and taxiways).

Additionally, precast concrete pavements provide innovative maintenance solutions, and panels can be standardized to address common roadwork like utility cuts, or re-used for temporary repair activities.

Resources

Canadian Precast Prestressed Concrete Institute

Precast/Prestressed Concrete Institute

Jointed Precast Concrete Pavement Web Explorer

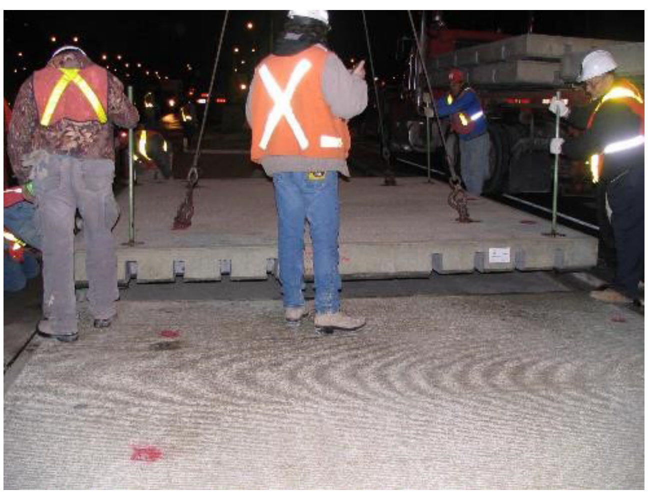
PCI Journal: Precast Concrete Pavements Technology Overview and Technical Considerations

FHWA Research and Technology Evaluation on Precast Concrete Pavement

Manual for Jointed Precast Concrete Pavement 3rd Edition

FHWA: Precast Concrete Pavement Implementation by US Highway Agencies

Additional FHWA Resources



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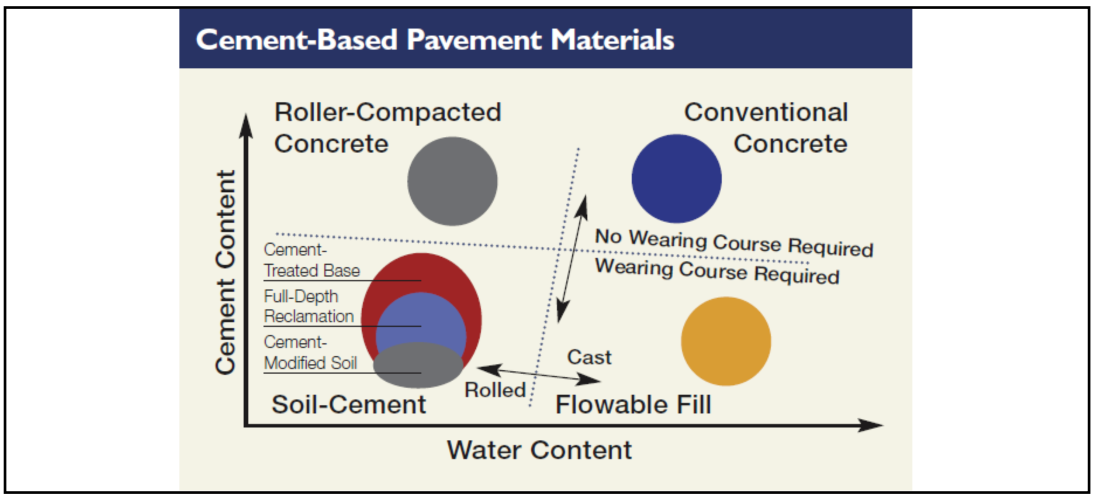
Engineered Soils

Overview

Cement based soil-cement, also know as Engineered Soils, was first used in 1935 to improve the roadbed for State Highway 41 near Johnsonville, South Carolina. Since that time, portland cement has been used to stabilize soils and aggregates for pavement applications on thousands of kilometres of roadway all over the world. After more than 85 years, collective experience has demonstrated that different kinds of engineered soil mixtures can be tailored to specific pavement applications. The basics, however, always remains the same: soil-cement is simply a hydraulic binder (portland cement or portland cement blended with supplementary cementing materials) blended with soil and/or aggregate, and water and compacted for use in a pavement structure. There is no secret ingredient or proprietary formula that makes soil-cement work. Although sharing a similar chemical process, engineered soil differs from conventional portland cement concrete in the consistency of the material, quantity of hydraulic binder required, overall construction procedures, function and strength requirements. The figure below illustrates how soil-cement compares to other cement-based pavement materials.



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Engineered Soils

Types of Engineered Soils

Engineered soils can be divided into four main categories:

Cement Modified Soils (CMS) - a material treated with a relatively small proportion of portland cement in order to amend its undesirable properties so they are suitable for use in subgrade or foundation construction (i.e. drying, reducing plasticity and providing stability). Also eliminates the need for undercutting and provides solid working platform.
Cement Treated Base (CTB) - a material treated with predetermined amount of portland cement to provide strong, durable bases and subgrades.
Cement Stabilized Subgrade (CSS) - is used to improve the engineering properties of the native in-situ subgrade soil so that it behaves similarly to or better than an enhanced, untreated aggregate base with uniform support. This type of stabilization provides all the benefits of CMS in addition to reducing moisture susceptibility, permeability, volume change potential, and plasticity, as well as, improving bearing strength of the subgrade.
Full Depth Reclamation (FDR) of asphalt pavements with portland Cement - The FDR-PC process pulverizes the existing bituminous surfacing and blends it with underlying base, subbase, and/or subgrade materials, which are mixed with portland cement to create a new stabilized base. A new surface is then applied, providing a new roadway structure using recycled materials from the failed pavement.

Table 1 below provides a summary of the types of engineered soils noting the purpose, types of soil stabilizing and comments on construction practices.

Table 1.1. Key features of soil-cement products

Soil-Cement Type	Cement-Modified Soil (CMS)	Cement-Stabilized Subgrade (CSS)	Cement-Treated Base (CTB)	Full-Depth Reclamation (FDR)
Purpose	• Promotes soil drying • Provides a significant improvement to the working platform • Provides a permanent soil modification (does not leach)	• Provides all the benefits of CMS plus the following: - Potentially allows for a reduction in pavement thickness or increased pavement life - Increases the bearing capacity for building slabs, footings, and other structural elements	• Provides a strong, frost-resistant base layer for asphalt or concrete pavements	• Provides a strong, frost-resistant base layer for asphalt or concrete pavements
Materials	• Primarily fine-grained soils • 2%–4% cement	• Primarily fine-grained soils • 3%–6% cement	• Primarily coarse-grained manufactured materials • 3%–6% cement	• Pulverized asphalt blended with existing pavement base, subbase, and/or subgrade • 3%–6% cement
Material Properties	• Reduced moisture susceptibility	• 100–300 psi (0.7–2.1 MPa) seven-day compressive strength	• 300–600 psi (2.1–4.1 MPa) seven-day compressive strength	• 300–600 psi (2.1–4.1 MPa) seven-day compressive strength
Construction Practices	• Minimum 95% of maximum density • Mixed in place	• Minimum 95% of maximum density • Mixed in place	• Minimum 95%–98% of maximum density • Mixed in place or at a plant	• Minimum 95%–98% of maximum density • Typically mixed in place

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Engineered Soils

Full Depth Reclamation Resources

Recommended Construction Guidelines For Full Depth Reclamation (FDR) Using Cementitious Stabilization

Recommended Mix Design Guidelines For Full Depth Reclamation (FDR) Using Cement or Cement Kiln Dust (CKD) Stabilizing Agent

Recommended Quality Control Sampling and Testing Guidelines For Full Depth Reclamation Using Cementitious Stabilizing Agents

Guide to Full-Depth Reclamation (FDR) with Cement

Cement Modified and Cement Treated Resources

Guide to Cement-Stabilized Subgrade Soils (CP Tech Centre)

ACI 230.1R-09 Report on Soil Cement

Guide to Evaluating Soil and Material Stabilization Products by the Transportation Association of Canada

Lightweight Cellular Concrete Resources

Lightweight Cellular Concrete

General Resources

Engineered Soils – CAC Presentation for Chatham – Kent

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Economics

Overview

Construction costs are regionally variable and fluctuate over time according to a variety of economic factors (cost of raw materials, equipment, labour, etc.). Though every project should be evaluated on a case by case basis, concrete highways have an excellent track record as a cost effective investment. Rigid concrete pavement outperforms flexible asphalt pavement with economic and safety benefits and has less impact on the environment. Nearly 30% of U.S. interstate highways are built with concrete.

In Canada, however, governments typically award highway pavement construction contracts based only on initial costs. Asphalt pavements are often selected because they are perceived to be less expensive than concrete. But planners are now beginning to recognize that tenders for road infrastructure projects should include a life cycle cost analysis (LCCA) component, based on the estimated costs of a project over its entire service life. When this concept is applied to maintenance, rehabilitation, reconstruction and salvage value of pavements, life cycle costs are evaluated, as well as initial costs, revealing the full expense of the selected material.

Owners and government agencies across Canada are increasingly recognizing the need to innovate and modernize procurement practices to achieve best value for money and for taxpayers, aligning economic and climate objectives for investments. Such practices will see a move away from "low bid" tenders towards other procurement methods like public-private partnerships, or implementation of a three-screen decision-making approach that considers (i) life cycle cost, (ii) lowest carbon, and (iii) "best available solutions" when choosing different construction materials.

As Canada's transportation infrastructure comes under growing stress from escalating traffic, informed decision-makers who base their pavement selection on life cycle cost analysis, safety, environmental and social benefits will increasingly secure the future in concrete.

Competition

Experience shows that a competitive environment will allow you to pave more kilometers for the same amount of money. Competition in market economies can also be directly linked to achieving higher quality of services or products, leading to the development of new products/technologies which would give greater selection and better products.

The greater selection typically causes lower prices, compared to what the price would be if there was no competition. Studies have shown that competition between paving industries represents the most significant opportunity for agencies looking to extend the purchasing power of their infrastructure dollars.

Resources

MIT Concrete Sustainability Hub – Competition Landing Page

Alliance for Concrete Pavement Competition

Concrete Canada – Building Better, More Sustainable Intersections

Concrete Canada – Paving with Concrete Infographic

Concrete Canada – Concrete Intersections Fact Sheet

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Economics

Life Cycle Cost Analysis (LCCA)

Life cycle cost analysis (LCCA) is a tool to determine the most cost-effective option among different competing alternatives to purchase, own, operate, maintain and, finally, dispose of an object or process, when each is equally appropriate to be implemented on technical grounds. For a pavement, in addition to the initial construction cost, LCCA takes into account all agency costs related to future activities, including future maintenance and rehabilitation. On occassion, user costs are also considered (e.g., reduced capacity at work zones). All the costs are usually discounted and total to a present day value known as net present value (NPV).

LCCA Standard Practice Guideline
This project reviewed the LCCA practices in place across transportation agencies in Canada as well as in select international agencies. The guideline provides a reference guide on LCCA for alternate pavement type bidding. The project also included the development of user-friendly EXCEL spreadsheet (based on the guideline) to aid in the analysis of life cycle costs of alternate pavement designs.

Equivalent Pavement Designs and LCCA for Municipal Roadways
The Equivalent Pavement Design Matrix for Municipal Roadways reports provide municipal engineers and consulting engineers with the reference information they need to effectively compare the costs of concrete and asphalt pavements of equivalent design over their respective life cycles. They present a comprehensive matrix of equivalent 25-year concrete and asphalt pavement designs for various traffic volumes, roadway classifications and subgrade strengths. They also identify the anticipated maintenance required on the pavement structures over a 50-year period and the corresponding life cycle cost.

Alberta

BC

Manitoba

Ontario

Québec

Nova Scotia

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Design Methods and Software

Overview

Concrete pavement thickness design methods have and continue to evolve across North America, as new innovations in cement manufacturing, concrete mix design, and the incorporation of additives and fibres are constantly under development, providing improved performance and durability in thinner road sections.

The modern concrete pavement thickness design tools that are commonly used are:

- ACPA StreetPave™ 12 design software
- Pavementdesigner.org, a modified, free online version of ACPA StreetPave™ 12
- WinPAS 12 (AASHTO 1993 pavement design procedure based)
- Pavement ME™ (aka Darwin-ME, AASHTOWare ME, or MEPDG)
- OptiPave™ by the TCPavment group.
- ACPA AIRPave 11 design software
- FAA FAARFIELD 2.0 airport pavement design software

Because of the development of the modern thickness design software tools, AASHTO 93 is now considered outdated and is not a recommended design for concrete pavements. As can be seen by the graphic below, advancements in design and concrete technologies have resulted in thinner pavement structures than seen with AASHTO design methods.

The design tools available for concrete pavements vary in complexity, as well as price, and while each produces a similar result, it is important to understand the differences in their output and how they might be compared. A brief description of the design programs and their respective inputs are highlighted below:

- StreetPave 12 design tool accounts for the concrete properties and the stress under load but does not consider the warping and curling in pavement panels - It has about 12 inputs and only predicts pavement fatigue cracking and faulting. While the software has its limitations, it provides a conservative and reasonably accurate answer.
- OptiPave has around 50 input and predicts pavement cracking, faulting and IRI using many of the same equations and approaches as the Pavement ME. Note: I believe this also takes into account curling and warping of the concrete slabs.
- Pavement ME software has about 1000 inputs and predicts cracking, faulting and IRI using the world's most advanced and comprehensive performance models.
- WinPAS 12 software is based on the AASHTO 1993 design procedure and has 10 inputs. It estimates either the pavement thickness or amount of ESALs the pavement structure can handle based on the input values provided.
- AIRPave 11 is a design tool is used for concrete pavement design for aircraft and off-road vehicles such as container handlers, fork lift, and mining vehicles. Inputs include aircraft loading or vehicle loading, modulus of elasticity, modulus of subgrade reaction and modulus of rupture.
- FAARFIELD 2.0 is the standard thickness design software accompanying AC 150/5320-6G, Airport Pavement Design and Evaluation, and pavement strength reporting using the ACR/PCR Method accompanying AC 150/5335-5D, Standard Method for Reporting Airport Pavement Strength – PCR.
- PCASE 7.0 (Pavement Transportation Computer Assisted Structural Engineering) software implements Department of Defense Unified Facility Criteria for the design and evaluation of airfields and roadways.

Design Methods and Software

As noted above, there are several concrete pavement thickness design softwares which can be used to analyze the required thickness to handle the anticipated traffic loads. Listed below are the various softwares available with links to provide more detailed information on each software:

Design Softwares

AASTHOWare Pavement ME Design

Bonded Concrete Overlay of Asphalt Mechanistic-Empirical Design Procedure (BCOA-ME)

WinPAS 12

StreetPave 12

PavementDesigner.org

Video Tutorial for Jointed Plain Concrete Pavement Design

OptiPave

AIRPave 11

FAARFIELD 2.0

PCASE 7.0

Construction

Overview

As with any built infrastructure, good construction is key to ensuring a concrete pavement structure performs to expectations. Construction activities for concrete pavements can range from simple, handplacement practices, to highly sophisticated operations with fully automated equipment.

Uniformity of the subgrade and base structures are the most critical aspect of concrete pavement construction, as it ensures the concrete distributes the traffic load uniformly and no dynamic loading is present due to varied supporting strengths throughout the length of pavement project. An equally important consideration is ensuring proper drainage is in place within and surrounding the base structure. Without proper drainage, the concrete pavement can experience severe effects such as: erosion of the base structure, non-uniform support causing dynamic loading of the concrete and potential slab cracking, increased warping stresses due to high moisture differential from the top and bottom of the slab, and potential decreased freeze-thaw performance causing premature joint failure.

Resources

FHWA Concrete Clips Web Series

Concrete Ontario Municipal Concrete Pavement Guide

ACI 325.9R-15 Guide for Construction of Concrete Pavements

ACI 325.14R-17: Guide for Design and Proportioning of Concrete Mixtures for Pavements

ACI 330.2R-17: Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities

ACI 325.12R-02: Guide for Design of Jointed Concrete Pavements for Streets and Local Roads (Reapproved 2019)

California Concrete Pavement Guide

ACPA Video Webinars

Integrated Materials and Construction Practices for Concrete Pavement: A State-of the Practice Manual

Preservation and Maintenance

Overview

Determining the timing of preservation or rehabilitation activities over the service life of a pavement is critical to ensuring a pavement meets or exceeds its expected performance according to its design. With transportation agencies facing rising traffic volumes and reduced budgets, it is therefore also critical to ensure the scheduling of routine and major maintenance activities throughout the life of the pavement to maintain an acceptable serviceability index at the lowest cost to the stakeholders.

Rehabilitation activities for concrete pavements include: resealing of joints, replacing/restoring malfunctioning joints (i.e. dowel bar retro-fits or cross-stitching), grinding of pavements to restore smoothness, partial or full-depth repairs, removing deteriorated materials, strengthening of bases or subbases, concrete overlay installations over existing concrete or asphalt structures, and adding drains.

Resources

CP Tech Center Preservation and Maintenance Landing Site

CP Tech Center Concrete Pavement Preservation Guide

Ontario Good Roads Association Manual - Best Management Practices for Municipal Concrete Infrastructure

MIT Concrete Sustainability Hub: Pavement Network Asset Management

How to Construct Durable Full-Depth Repairs in Concrete Pavements (FHWA-NHI-134207A)

How to Construct Durable Partial-Depth Repairs in Concrete Pavements (FHWA-NHI-134207B)

Proper Diamond Grinding Techniques for Pavement Preservation (FHWA-NHI-134207C)

Proper Construction Techniques for Dowel Bar Retrofit (DBR) and Cross-Stitching (FHWA-NHI-134207D)

Proper Joint Sealing Techniques for Pavement Preservation (FHWA-NHI-134207E)

Additional Resources

For a more detailed look at key websites with information on concrete pavements please visit the flowing websites noted below:

Cement Association of Canada Expertise Centre

Concrete Ontario Website

Concrete Alberta Website

National Concrete Pavement Technology Centre

American Concrete Pavement Association

MIT Concrete Sustainability Hub

PAVE AHEAD

RCC Pavement Council

International Society for Concrete Pavements

EUPAVE (European Concrete Paving Association)

Australian Society for Concrete Pavements

International Grooving & Grinding Association

Federal Highway Administration Resource Center Office of Innovation Implementation -Pavements and Material

Federal Aviation Administration – Tools and Resources for Airports

Canadian Airfield Pavement Technical Group

MTO Technical Publication Concrete Related OPSS And MTOD Documents

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