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An Introduction to Concrete Pavement Construction

by

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Recent changes in the construction industry have made concrete paving a more desirable choice of many owners for their projects. However, concrete paving is a specialized construction operation that relatively few contractors in the U.S. can perform on a large-scale basis. Exposure for “hands-on” experience has been limited. This course is designed to give an overview of the construction practices and procedures for this type of pavement structure and to describe the changes in the industry that have moved more owners to make concrete the paving material of choice.

Traditionally, the original cost to provide concrete pavement on a project could cost as much as 50% more than an equivalent asphalt section, based on design loading. The true savings an owner could realize was in the significantly reduced maintenance costs and the much longer usable life span of the product. Interstate highways of asphalt pavement typically need to be replaced every 10 to 12 years. Equivalent concrete roadways will provide a satisfactory riding surface with minimal maintenance for 20 years, and many have performed for double that number. These numbers are highly variable and depend on many factors like freeze/thaw cycles, average daily traffic



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volumes, and traffic loading types but, assuming similar quality of construction, they are historically correct.

Improved methods of construction have lowered the cost of providing concrete paving and have improved the final product offered. The volatility of the petroleum-based asphalt cement used in asphalt paving has negatively impacted the material cost and availability of this pavement type. Lastly, environmental concerns and LEED (Leadership in Energy and Environmental Design) approaches have all narrowed the upfront cost differential and added to the long-term benefits of choosing concrete paving over asphalt.

Concrete Pavement Types and Uses





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Concrete pavement is usually defined by dimensional properties, such as layer thickness; by physical properties such as concrete strength (either compressive or usually flexural); and by joint and reinforcing type. The specified type will depend on use, loading, maintenance, and budget. Typically layer thickness will vary from six to nineteen inches. Concrete strengths vary from owner to owner, from aircraft rated to pedestrian use. Lastly reinforcing can be light, heavy, or none at all.

Concrete Physical Properties – These properties, more than any other, will dictate the paving method used. Properties can include layer thickness, lane widths and lengths, and regularity of shape. Pavement methods will be broken down later in the course, but in summary, more regular-shaped lanes and mass-quantity pavement types lead towards the slip form paving method, while irregular-shaped panels, varying thicknesses, and limited quantity are usually hand-formed.

Concrete Strength – Most concrete strength requirements for concrete pavement are specified in flexural strength. The anticipated use for the pavement will determine the minimum flexural strength needed. The designers will use the design vehicle footprints to determine the bending forces placed on the concrete by the wheel loads. The testing of the concrete for flexural strength requires the breaking of concrete beams. The casting, curing, and testing of these beams are extremely sensitive. If special care is not taken, the test results can be highly variable. Testing concrete's compressive strength using cylinders is a much more reliable method of confirming a produced concrete strength but there has not been an established method of equating a concrete's tested compressive strength to a flexural performance. Many owners recognize the limits of the flexural test and specify a compressive strength they determine to be equivalent to their flexural needs, while others allow for simultaneous testing of beams and cylinders for the same mix and use the more consistent cylinder tests to "weed out" obviously errant flexural results.



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Reinforced Concrete Pavement – This refers to pavement of any depth or type having some sort of tensile reinforcement, reinforcing bars, mesh, or fibers in the pavement. The reinforcing can be continuous through the transverse and longitudinal joints or non-continuous with interruptions at the joint locations. Load transfer devices across joints in themselves don't classify the pavement as reinforced. Continuous reinforcing typically would have stock lengths of the designed bars (#4,5, or 6s) lap spliced in each direction with no transverse joint requirements except at starting and stopping points for the day's production (construction joint). The mats of steel are held in place with either steel or plastic chairs at a designed depth below finished grade. Concrete or other masonry blocks can be used as chairs for light pavement thicknesses.

Unreinforced Concrete Pavement – This pavement type refers to pavement of any depth with no reinforcement.



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Jointed Concrete Pavement – This pavement type refers to unreinforced pavement or non-continuous reinforced concrete pavement with designed locations of longitudinal and transverse joints to control concrete cracking. Typical joints are located 20 to 60 feet apart, load transfer devices are specified as needed, and joint sealing items are required, depending on use and exposure designs.

Roller Compacted Pavement – This is a concrete pavement typically found in lock and dam construction and airports. This type is gaining popularity for roadway shoulders and odd shaped paving areas.



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Ingredients

Raw Materials for concrete:

Fine Aggregate – Sand (natural or man-made)

Coarse Aggregate – Depending on use and depth may be a mixture of two or more gradations)

Cement and other cementitious materials (flyash, slag)

Admixtures (air entraining, water reducer, etc.)

Mix Designs for the concrete are obviously dependent on the intended use, constructability, availability of materials, and owner's specifications. Thin lift, light weight pavements may use pea gravel; while heavy duty airport pavements may include 1-1/2" stone or larger. Slipform pavement methods require very stiff mixes with slumps preferably less than 1" while reinforced panels with side forms can have much higher slumps as long as the water cement ratio allows. Winter mixes may require heated water, while summer months need ice, etc.

Once the mix is identified, trial mixes of varying proportions are made and tested for suitability and application. Ingredients will be modified to find the most cost effective mix that will meet the owner's needs and the contractor's construction.

Portland Cement:

Type I General Purpose – used when specific properties of other types are not specified

Type II General Purpose exposed to moderate sulfate action, or when a moderate heat of hydration is required

Type III Used for high early strength

Type IV Used for low heat of hydration

Type V High sulfate resistance



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CONCRETE PAVING TYPES

CONCRETE ROADWAY PAVEMENT



Concrete roadway pavement will vary from state to state depending on the DOT's preferences and input from the federal highway department. Interstate Highways and State Routes are the typical projects for concrete pavement, but some inner city streets and minor roads will choose this pavement based on loading, exposure, and service life. Typically travel lane widths will be 12 feet, shoulders 10 feet, and ramps 16 feet. Depending on cross slope consistency slipform crews can place multiple lane widths with a single pull 24 to 36 feet wide. If load transfer devices are designed at the joints, they may be inserted mechanically by the paving machine with a dowel bar or tie bar inserter, or they may be placed ahead of the paving operation in baskets set to the line and embedment depth of the joint.



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Rideability specifications are becoming very common with all pavement. Pavement smoothness will increase the service life of the concrete and reduce the impact loads at the joints. Many states have gone to a “100% grind spec” where the surface of the pavement is diamond ground to a profile grade. This method is also being used to refurbish older concrete pavements resulting in extending the useful life many years past traditional expectations for failure.





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AIRPORT CONCRETE PAVEMENT

New pavement construction at airports, commercial or military, for taxiways, runways, or parking aprons will likely be concrete pavement. The large wheel and impact loads from the aircraft and the operations make concrete pavement the best value. The investment made by the various tenants (airlines) and the safety to the passengers and protection of equipment and cargo make the long-term durability of concrete the preferred choice of materials. Also the chemical de-icers, fueling operations, and other physical and chemical exposures add to the harsh environment the pavement must withstand.

Runways may run 9,000 to 16,000 feet in length and 150ft to 200ft wide. Paving lanes run from 18.5ft to 37.5ft in width making runways the most suitable airport pavement for slipforming. Taxiways and Aprons have much shorter paving lanes and have irregular boundaries which will produce a mixture of both handform placements and slipform placements. Each of these paving areas run much deeper than normal roadway pavement. Airport pavements are usually deeper than 12" and may run in excess of 21" deep. **Keeping a consistent mix and a constant supply is critical for slipforming at these depths because the pavement sides tend to "slough" down and cause the edges to round.** This condition will be unacceptable to the owner due to consolidation issues in the pavement and drainage issues at the pavement joints.

Airport pavements also have many embedded items that will affect the construction methods. Conduit and metal bases for lighting and signaling, fuel pits, and drainage structures may need to be "blocked out" with forms while slipforming production lanes, then hand placed at a later date after the utility is installed and set to grade.



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Airports usually have many large open areas for staging and storing paving equipment. This makes the ideal for mobilizing a portable concrete batch plant. These plants can effectively be set up on less than three acres, but this will restrict aggregate storage, truck routes, truck washing, and may cause environmental issues. Central batch plants, single or double drum depending on production, are preferable. 10 CY batches can be produced in about a 90-second mix time. The mix will be loaded and hauled by dump trucks or agitory dump trucks; a positive method of locking the dump beds is needed due to the liquid head of the concrete on the tailgate. The site should be as close to the placement as possible. A haul time under 15 minutes should be the goal.



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Typical Airport Concrete Paving Machine List:

Plant

Johnson Ross Central Mix Plant, Cat 966 Loader, Cat Mod. 3412 Gen Set

Paving Prep

Cat 16 Grader w/ 8 gang-drill, JD 595 Excavator w/ 4 gang-drill, Water Truck

Paving

CMI SF6004 SLIPFORM PAVER, CMI Placer MTP400AS PLACER, Cure Machine
GOMACO MOD. TC-600

Haul

Tandem, Tri-Axel, Quad-Axle, Quint-Axle Dumps



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Apron Paving:

The main portion of the new pavement shown is on a 20' x 20' grid of 16" and 17" concrete. The concrete placement was therefore slipped at 20' lane widths. Due to the amount of obstructions (i.e., fuel pits, trench drain, and thickened edges) there are very few productive slip lanes. Instead, there were a lot of small chopped up lanes that required multiple moves with the slip form paver in a single day's pour. These obstructions also created a lot of hand pours.



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ROLLER COMPACTED CONCRETE PAVEMENT



Another paving type that is gaining popularity is RCC paving, which stands for roller compacted concrete. This type of paving was specialized a few years ago; uses were limited to roller compacted concrete dams and levees, or small parking lots in urban areas. The method is more mainstream today. DOTs are experimenting with the product mostly with roadway shoulders and areas of low traffic but the results for cost, durability, and service support expansion, therefore, RCC Paving will probably expand further in both private and public markets.



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A stiff concrete mix is delivered to an asphalt or ABG type paver and either dumped directly into the paver hopper, run through a concrete placing machine or both. Similar to asphalt paving, the compacting tamps of the paver will set the initial density of the concrete. Subgrade, Mix Design, and Moisture are critical but the mix usually gets 92% compaction at the paver with a 6.5% moisture. A steel drum roller follows the paver to achieve the final density. For placements of around 400 to 600 cubic yards per day, a single roller is sufficient, but for productions around 1000 cubic yards a second steel drum or rubber-tired roller will be necessary. Different weather conditions and production rates will determine the second roller type. Over rolling is a concern, and the crew must be aware of the established roller pattern to maintain consistency.

For rideability, the skis from the asphalt paver provide a physical means of controlling the pavement surface. Many asphalt crews use electronic sensors for that type of mix but currently the concrete product is substantially better using the skis. Also maintaining a constant head of mix in the paver hopper will limit starts and stops which will minimize transverse ruts cut by the screed.



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RCC PAVING RE-CAP



- 1) Subgrade is critical.
- 2) Mix design & moisture is also critical.
- 3) Over rolling is possible.
- 4) For rideability 1. start with a wire on the outside & run cross-slope, then use a ski & cross-slope as you add lanes. 2. If possible start in the middle with ski's & work to the outside using a ski & cross-slope.
- 5) Production will vary with every project. Whenever possible use a placer and back trucks to the paver. The paver has to move at 3% speed minimum. Over 100 yards per hour is possible.
- 6) **Pave crew size** – Paver operator, placer operator, grader/hoe operator, 2 screed men, 2 shovel men, a dump man, wheel barrow man, truck organizer, mechanic, 2 roller operators and a Foreman.
- 7) **Plant crew size** – Plant operator, loader operator, laborer and mechanic.(Higher production would require a second laborer)
- 8) Other equipment & personal to consider: QC person, Water truck, Core truck, Cure buggy/truck, Survey and Sub to green cut.



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CONCRETE PAVING METHODS

SLIPFORM CONCRETE PAVEMENT



Slipform Paving is a paving method that uses very stiff concrete mixes (1/2" to 1-1/2" slumps) and extrudes the concrete through a paving machine. The machine sets the pavement to alignment and grade. The stiffness of the mix allows it to maintain its shape with minor handwork. Maintaining a constant speed and constant mix are critical to providing a quality pavement.

If the project meets the requirements to justify Slipform Paving, it is the most cost-effective method of mass concrete paving. It usually will include:

1. Long, uninterrupted lanes of pavement.
2. A large quantity of pavement to distribute mobilization and set-up costs.
3. Uniform pavement widths and depths and typical sections. Varying widths and varying finished surfaces can be accommodated by some pavers.



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Finished grade elevations are set by surveyors on string lines that the paving machine can read. These string lines control the pavement alignment and elevation. Fully automated machines that utilize GPS and laser survey control are currently in limited use. The technology is improving, but the risk of costly concrete repairs due to an errant satellite reading has kept the industry from adopting this method as readily as other grading activities in construction.

HAND FORMED or SIDE FORMED PAVEMENT



When concrete pavement can't be slipformed, we must use forms to support the sides of the wet concrete until it has set and initially cured. Odd-shaped blocks, reinforcement, joint types, access, and quantity are all reasons that contribute to the decision for hand forming concrete placements.

Even though quantities of placement may not be sufficient for slipforming, they may still be significant and require machinery for placement and finishing. Transit mix trucks can be used to deliver hand formed concrete placements utilizing the shoots to spread and distribute the mix uniformly into the forms. Concrete belt placers can also distribute the



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concrete uniformly across the pavement sections, so dump trucks can still be used for hauling while minimizing hand work for spreading the load. Allen screeds or Clary screeds finish the surface of the concrete while riding the tops of the forms. Afterwards, a textured finish like a burlap drag may be applied. Forms can be made from varying materials but are usually 10 foot long steel of the required height. Steel is used for durability and strength. The forms are set to grade and pinned in place with steel rods. Alignment and grade of the forms are critical for a quality pavement surface for rideability and drainage, and quality joints.



Above an air screed rides the forms while below a clary roller screed is used to provide the initial surface finish and set the pavement to final grade elevations.





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CONCRETE PAVING EQUIPMENT

CONCRETE DISTRIBUTER



Concrete is usually delivered to the concrete placement in dump trucks rather than transit mix trucks normally associated with concrete placements. The trucks will dump the loads into the hopper end of the distributor, which will then be conveyed out the arm of the distributor to the point of placement. This spreads the load evenly across the paving lane in front of the placement, consolidation, and finishing operations. Distributors can be track mounted or rubber tired as shown.



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CONCRETE PAVERS



Concrete Pavers are very variable in shape and application. All contain equipment to vibrate, consolidate, shape, and finish the concrete. Most slipform pavers extrude the concrete and are track mounted as shown above and below.





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Others ride on the rails of steel forms.



CONCRETE FINISH/CURE MACHINES





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Usually the last piece of equipment in the “paving train,” the machine applies the final surface finish to the pavement like a burlap drag or rake tined grooves. Then the machine sprays the concrete with a curing compound to seal the concrete moisture in order to prevent surface drying and promote hydration.

PORTABLE CONCRETE BATCH PLANTS



The quantity of concrete involved in most concrete pavement projects will require a concrete plant dedicated to the paving operations. Most local suppliers will not be able to meet the demands of the concrete paving crews because their plants are not the right type or they have other customers to satisfy. Slipform paving projects will need a central drum plant set up onsite. Transit mix plants and off-site suppliers typically won't be capable of producing the cubic yards per hour to make the required production for a slipform paving project.



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Correct planning for setting up a concrete plant onsite is needed. Finding the right location will involve access to the site and suppliers, adequate storage and operational area, cost for purchase or rental, and environmental considerations. First obtain the site, get the permits for construction and operation, deliver and erect the plant, verify trial mixes, then start producing a consistent quality mix.

Most plants will be equipped with additional storage “pigs” for cement, electronic batching technology, admixture dispensers, and a control trailer for the plant operator.



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Central Drum Concrete Plant with extra cement storage next to a cement treated aggregate Pugmill Plant at an airport apron concrete paving site. Cement treated aggregate was used for base course material under 16" of concrete pavement.





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CHANGES IN CONCRETE PAVING

Changes in technology have changed the views of concrete pavement. Improvements in slipform paving are yielding longer lasting, better riding, and more cost-effective pavements for owners. Dowel bar inserters are providing a reliable labor-saving method to install load transfer devices. 100% diamond grinding has provided rideability measurements that surpass other pavement types and eliminates the impact loads at joints extending the pavement life (the characteristic “thump-thump” associated with driving over concrete joints). Similarly older pavements are given new life by grinding the surface to produce a new ride. Thinner concrete pavements in bonded and unbonded overlays (white topping) can be provided for rehabbing older pavements. Full depth reclamation with infused concrete is an in place alternative for pavement rehab that can be performed with very tight schedules, minimal impacts, and produces a long lasting cost effective repair. Stamped concrete, colored concrete, and textures allow architectural considerations (Excellent examples of both texturing and coloring of concrete are the simulated mud roads of the Disney Animal Kingdom’s safari ride. The concrete was colored to mimic mud and after initial concrete pavement finishing, bus tires were rolled over, fake animal tracks were pressed into, and twigs/leaves were embedded to resemble the poorly kept mud roads of the African Savannah).



Concrete paving dowel bar inserter



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unbonded concrete “white topping” overlay

Lastly, concrete pavement can be used for LEED construction. Permeable concrete helps control pavement run-off, provides root space and irrigation for trees and plantings, and controls surface transported pollutants. All concrete pavement aids the heat sink in controlling high temperatures unlike other pavement types. Light-colored pavements (concrete vs. asphalt) reflect sunlight rather than absorbing solar heat. Communities can lower average temperatures by replacing pavement types as a temperature controlling device. An additional benefit of the light reflection is better night-time lumination. Business developments and communities can reduce energy costs from reduced air conditioning needs and reduced lighting for similar visibility. Also concrete has been shown to help clean the air by bonding chemically to automobile exhausts and rendering the emissions inert. TX Active “pollution eating” concrete is also self-cleaning and returns to a white finish even after staining with organic and inorganic pollutants.



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Concrete Paving fun facts from various internet sources

Romans constructed nearly 5300 miles of concrete paved roads from 300 BC to 476 AD using pozzolana cement.

The first US Highway of concrete pavement was 24 miles long, 9 foot wide lane of 5" thick concrete constructed in 1913 near Pine Bluff, AK

The invention of the slip-form paver was in 1949.