Concrete

Components

- Portland Cement (ASTM C150)
  - Type I (normal) general purpose
  - Type II (modified) resistance to alkali attack
  - Type III (high early strength) high heat
  - Type IV (low heat) used for massive structures
  - Type V (sulfate-resistant) max. alkali resistance
Concrete

Components

• Aggregates
  – Coarse, fine, and lightweight
  – 60 to 80% volume of mix
  – Strong and durable
  – Resistant to freezing and thawing
  – Chemically stable (ASR)
  – Saturated surface-dry (SSD) optimum condition

• Water
  – Potable, balanced pH, no organics or salts
Concrete

Components

- Admixtures
  - Air-entraining agent:
    - Greater resistance to freezing and thawing
    - Greater chemical resistance
    - Reduces permeability
    - Improved workability
Concrete

Components

- Admixtures
  - Water-reducing admixtures
  - Decrease water requirements without reducing workability
Concrete

**Components**

- **Admixtures**
  - **Retarders**
    - Slows the rate of hardening to increase working time
  - **Accelerators**
    - Increase the rate of hardening
  - **Pozzolans**
    - Used to replace some of PC with var. benefits
  - **Plasticizers**
    - Increases workability of the mix
Concrete

Water-Reducing, Set-Controlling Admixtures

ASTM C 494

Type A  Water-reducing admixtures
Type B  Retarding admixtures
Type C  Accelerating admixtures
Type D  Water-reducing & retarding admixtures
Type E  Water-reducing & accelerating admixtures
Concrete Mix Design

• Water/cement ratio directly affects:
  – Compressive strength
    • High W/C ratio = lower strength
    • Low W/C ratio = higher strength
  – Durability
  – Workability or plasticity
  – Watertightness

• Slump affects:
  – Workability or plasticity
  – Shrinkage
Concrete

Mix Design

• Cement, aggregates, and admixtures are produced according to ASTM specs
• American Concrete Institute (ACI) provides guidelines for mix designs
• Specifications refer to and incorporate ASTM Specs and ACI guidelines
Concrete

Mix Design
Concrete specifications are generally based on one or more of the following:
1. Mixture proportions designed and controlled by the owner
2. Minimum cement content, max. water/cement ratio, and range of slump are specified
3. Concrete strength specified @ 28 days
Paving and Surface Treatments

- Paved surfaces include:
  - highways and local roads
  - airfield runways, taxiways, and aprons
  - parking lots and driveways
  - bridges
  - race tracks & recreational facilities
  - slope paving

- Paved surfaces are generally rigid (PCC) or flexible (bituminous HMA)
Paving and Surface Treatments

- Surface treatments provide
  - sealing or waterproofing existing pavements
  - bond new pavement to existing (tack coat)
  - wearing course for rural roads i.e.: tar and chip
Paving and Surface Treatments

- Hotmix asphalt paving is generally placed in layers or lifts (base, binder, and wearing course)
- Thickness of lift is in proportion to the aggregate size
- HMA is placed with temperatures ranging 250° - 330° F
- HMA must be placed on a firm, stable, well-draining base
Hotmix Paving

Placing HMA

- Confirm that base (GABC, recycled crushed concrete, or gravel mix) has been compacted to required density and is stable
- Existing surfaces must be swept clean
- Tack coat applied to existing surfaces at the rate specified (DelDOT = CSS-1-h at 0.2 gal/SY)
- Tack is also applied to curb, gutters, manhole frames and other surfaces where bonding is required
Hotmix Paving

Paving Equipment

- Paver/Finisher spreads and provides initial compaction of hotmix
- Must be able to compensate for minor grade irregularities, while forming crowns and superelevations
- Must be able to travel on various types of surfaces and push dump trucks
Hotmix Paving

Paver/Finisher

- Paver/Finisher consists of a tractor unit and floating screed unit
- Tractors are either wheel or track mounted
- Tractor unit includes receiving hopper, feeders, distributing augers or spreader screws, power plant, transmission, dual controls, and operators seat
Hotmix Paving

Paver/Finisher

• The screed unit is attached to and towed by the tractor unit
• The screed unit is attached to the tractor by long, pivoting screed arms
• The screed forms and rides on the finished surface
• Screed unit consists of a tamping bar or vibratory unit, thickness controls, crown controls, screed heater, and screed plate
Hotmix Paving
Hotmix Paving

Paver/Finisher Operation

1. Material is dumped into the hopper from a truck or conveyor unit
   - Rollers mounted on front of paver contact rear tires of truck
   - Paver pushes truck while it is dumping into the hopper
   - Truck drivers must be experienced in delivering hotmix
Hotmix Paving

Paver/Finisher Operation

2. Two independently controlled bar feeders carry mix through control gates to spreader screws
   - Each spreading screw is synchronized to its feeder
   - Operator can control distribution of mix in front of the screed unit
Hotmix Paving

**Paver/Finisher Operation**

3. Screed unit is pulled by the tractor across the material and adjusted to produce the desired thickness
   - The screed is equipped with a heater to prevent the material from sticking to the screed plate
   - The tamper bar or vibrating screed strikes-off and provides the initial compaction
   - Screed units can be set for precise thickness, crown, and superelevation
Hotmix Paving

Paver/Finisher Operation

- Paver/finishers are capable of self-leveling
  - Minor base irregularities are eliminated
  - Screed bottom rides parallel with the direction of pull
- Mat thickness is set by the thickness controls on the screed
  - Irregularity in the base causes machine to automatically increase/decrease thickness to compensate
  - Thickness changes at the screed board are not abrupt, but slowly inclining or declining until the new thickness has been reached
Hotmix Paving

Paver/Finisher Operation

• Screed width can be increased or decreased by hydraulic telescoping extensions
• Automatic feeder controls are moved outward with the extensions
• Control of screed level can be manual, semiautomatic, or fully automatic
• Automatic screed controls include joint-matching shoe, string line to grade, and long ski
Hotmix Paving

Paver/Finisher Operation

- Joint-matching shoe senses surface grade and sends information to the electronic control system
  - Used to match adjacent pavement or gutter grade or maintain thickness over a previous course
- String line to grade system – not used often
Hotmix Paving

Paver/Finisher Operation

- Long ski automatic grade control system
  - Semi-rigid boom or floating beam
  - Serves as a floating grade reference connected to the electronic sensing and control system
  - Averages out longitudinal errors and irregularities of the surface being paved
  - Used generally for surface course or near-surface binder course
Hotmix Paving

*Paver/Finisher Operation*

- Pavers are also equipped with automatic transverse slope control
Crew Requirements

- Paving crew size and composition can vary depending upon:
  - desired production rates
  - lift thickness
  - amount of handwork
  - job conditions
  - Union labor contract or agreements
Crew Requirements

Basic crew composition and function include:

- Foreman
  - Estimates and orders required material and tack
  - Determines labor, equipment, fuel, and maintenance requirements
  - Plans actual paving operation i.e.: number of trucks, paving sequence, direction of pulls, etc
- Front-line supervisor responsible for quality, production, and safety
Hotmix Paving

Crew Requirements

• Paver Operator
  – Controls paver direction and speed
  – Controls hopper and feeders
  – Checks and controls overall machine operation

• Screedman
  – Controls thickness, width, and cross slope of mat
  – Must understand grades and machine operation and behavior
Hotmix Paving

Crew Requirements

• Dump man
  – Coordinates and directs truck driver movements and dumping
  – Aids truck drivers in obstructed view situations or aerial hazards
  – Collects material delivery tickets

• Shovel man
  – Manual distribution of material as needed
Hotmix Paving

Crew Requirements

• Rake or “Lute” man
  – Rakes edges or joints to assure tight, smooth seams
  – Finishes areas not accessible to the paver or screed (handwork)
  – Skill position that requires experience and finesse
Hotmix Paving

Crew Requirements

• Roller Operator(s)
  – Multiple operators are usually required for breakdown, intermediate, and finish roller operations
• Lab technician
  – Owner’s inspector or contractor’s QA/QC technician (on performance spec contracts) verifying density
Hotmix Paving

- The paving machine is preheated prior to paving and the grade controls are checked and set
- The screed board is set to a height that upon compaction will yield the desired lift thickness
- Compaction is performed by steel drum water-cooled rollers
- Roller(s) completes initial breakdown passes
- Intermediate rolling essentially completes compaction
- Finish or cold rolling removes creases and final sealing
Hotmix Paving

• Rolling patterns (number of passes) is obtained by control strip that determines the target density
• Base courses are compacted to 90% lab density
• Wearing courses (top) are compacted to 95%.
• Rolling should initiate at the curb line in the longitudinal direction overlapping the previous pass by at least half of the roller width
• Alternate length of passes to avoid changing direction at the same location
• Longitudinal joints or seams should be “pinched” by rolling directly behind the paving operation
Hotmix Paving

- Roller speed should be slow and uniform, avoiding sudden stops
- Idle rollers should stay only where the mat has cooled sufficiently
- Superpave mixes have much narrower temperature ranges for compaction
- “Tender zone”
- Various other polymer, SMA, and open-graded mixes have special rolling requirements, and behave differently than conventional mixes
Hotmix Paving

• Minimum ambient temperature requirements:
  – 32°F for base courses > 2”
  – 40°F for base, binder, or wearing course ≤ 2”
  – 50°F for wearing or surface courses ≤ 1”
  – 60° to 65°F for open-graded and certain polymer surface courses

• Succeeding course should not be placed until the previous course has cooled to < 140°F

• Traffic should not be allowed on pavement until the surface temperature has cooled to < 140°F
Hotmix Paving

- Tack must be applied to new pavement surfaces immediately prior to the next lift when:
  - 10 days have elapsed
  - it has rained since placing the last lift
  - the surface has become dirty
- Tie-ins to adjoining (existing) pavements must be saw cut (transversely) to provide a clean vertical joint
- Tie-in smoothness is enhanced by cutting transverse “butt joints”
- Hotmix used to overlay concrete can be saw cut & sealed over the concrete joints to prevent reflective cracking
Hotmix Paving

Pavement Rehabilitation

• Periodic pavement rehab can be a cost effective means of extending the service life
• Existing surface course is removed by rotomilling (a.k.a. milling or planing)
• The base is patched as necessary
• Manhole and inlet frames are adjusted to new grades as required
• New butt joints are cut
• Surface is cleaned, tacked, and overlaid with a new wearing course (top)
Hotmix Paving

Pavers working in Echelon (tandem)

- Elimination of cold joint
- High capacity and production operation
Hotmix Paving

Mobile conveyor
- Material handler receives material from trucks and conveys to paver resulting in:
  1. Increased paver production
  2. Nonstop paving operation
  3. In-line or offset paving
  4. Reduced hauling cost and time wasted at the paver
Keys to Successful Hotmix Paving

- Employ well-trained, experienced personnel i.e. foreman, operators, laborers (especially lute man!)
- Good grade control (survey function)
- Thorough understanding of the paving equipment and electronic control systems
- Good mix design and production
- Quality control in the plant and field
- Desire to produce a high quality, smooth, and durable pavement
Concrete Pavement

- Rigid pavement placed on a stone (GABC), soil cement, or permeable treated base (asphalt or PCC)
- Placed using fixed forms or slipform
- Crew requirements depend on method of placement
- Modern practice is to place un-reinforced concrete with close control joint spacing @ 15’
- Smooth dowel bars usually spaced 12” o.c. are used at joints to transfer the load across the joint and provide shear strength
- Bars or hook bolts are used to connect slabs longitudinally
Concrete Pavement

• Fixed-form placement can employ any number of mechanical form riding equipment
• Equipment is used to spread, strike off (screed), consolidate, and finish concrete
• Concrete is usually delivered and placed by mixer trucks
Concrete Pavement

Placement can be by conveying equipment
Some finishing is usually completed by hand
  - floats and trowels along the edges
  - straight edge “bump cutters” and bull floats transversely across the slab
Concrete Pavement

Slipform Paving

- No forms used to contain the sides of the slab
- Grade and alignment control is by string line followed by electronic sensors mounted on the machine
- Paving train operation employees single or multiple machines for placement and distribution, forming, consolidation, and finishing
- State-of-the-art equipment has self-contained dowel bar and longitudinal bar inserters
- Concrete is usually hauled in dump trucks at a very low slump, typically 1”±
Concrete Pavement

- Concrete is placed directly on the grade in front of the paving train or into a belt placer (conveying machine)
- Slipform strikes off and consolidates the concrete
- Minimal hand finishing is generally required (bump cutter and bull float)
Concrete Pavement

• Automated or manual texturing using steel tines to form groves transversely across the pavement
• Tines are 1/8” to 3/16” wide x 3/16” deep
• Transverse grooving by saw cutting can be performed after concrete has cured
Concrete Pavement

- Pavement is then sprayed with curing compound to prevent rapid evaporation.
- Saw cutting at transverse joints must be done as soon as the concrete can be cut without excessive damage to the slab i.e. spalling, tearing, rutting, or washing away mortar.
- Saw cutting depth is typically $T/4$ to $T/3$.
- Upon completion of the paving and curing period, these joints are widened and sealed.
Concrete Pavement

Pavement Smoothness

• Performance spec regarding pavement smoothness

• Devices for measuring smoothness include:
  – 10’ straight edge
  – rolling straight edge
  – computerized California type Profilograph

• Profilograph measures the cumulative bumps per tenth of a mile (528’) and provides a Profile Ride Index (PRI) in bumps per mile
Concrete Pavement

- Profilograph locates and records bumps or dips > 0.3” in height
- Specs stipulate acceptable PRI ranges
- Bonus/penalties can be assessed for the various ranges
- Diamond grinding is done to correct roughness
Keys to Successful Concrete Paving

• Good grade control
• Proper selection and maintenance of equipment
• Consistent mix i.e. slump, air%, delivery rate
• Qualified supervision, operators, and finishers
• Steady, continuous paving operation
• Stable base grade (wet prior to paving)
• Desire to produce a high quality, smooth, and durable pavement
Bridge Construction
Bridge Construction

Classification of bridge by:

- Function
- Span Length
- Span Type
- Structure Materials
- Cross Section
- Degree of Redundancy
- Floor System
- New or Rehab
Bridge Components

Superstructure

a. Floor Beams
b. Girders
c. Stringers
d. Diaphragms
   1) Intermediate
   2) End
   3) Continuity (concrete)
Bridge Components

Superstructure

e. Deck
   1) Roadway & shoulder
   2) Sidewalk/overhang

f. Parapet and railings

g. Expansion dams
Bridge Components

h. Truss members
   1) Chords (top & bottom)
   2) Vertical & diagonal web members
   3) Lateral bracing
   4) Portal
   5) End post

i. Struts & wind bracing system

j. Cable system

k. Hangers – fixed and expansion
Bridge Construction

Superstructure Erection Techniques

a. On falsework
b. By cantilevering
c. Hoisting into position
d. Rolling or sliding into position
e. Floating into position
f. Suspension erection
g. Segmental construction
h. Combination of two or more techniques
Bridge Construction

Factors involved in determining method of superstructure erection

a. Condition of the river or stream bed
b. Amount of interference to/from navigation
c. Interference from railroad and vehicular traffic
d. Water depth
e. Stream current
f. Presence of driftwood, ice, etc.
Factors involved in determining method of superstructure erection

g. Bridge height
h. Utility conflicts
i. Physical constraints imposed by adjacent structures, facilities, wetlands, parklands, etc.
j. Locally available equipment
k. Contractor’s resources and preferences
Bridge Components

Substructure

a. Abutments

1) Breastwall
2) Wingwalls
3) Bridge seat
4) Backwall
5) Footing or pile cap
Bridge Components

**Substructure**

b. Piers

1) Stem wall
2) Column or pier shaft
3) Web wall
4) Pier cap
5) Footing or pile cap
Bridge Components

Substructure

c. Pile bent
   1) Piles (steel, concrete, or timber)
   2) Bent cap
d. Caisson
e. Piling
f. Dolphins and fenders
g. Cofferdams
Bridge Construction

Substructure construction details

a. Modular formwork using “gang forms” placed by crane
b. Forms include outriggers for scaffolding
c. Vinyl form liners used to provide texture, brick/stone patterns, fins/ribs, etc
d. Chamfer should be used at all corners and edges, and at construction joints
e. Concrete surface treatments include silicon-based waterproofing and epoxy protective coating
Bridge Construction

Substructure construction techniques

a. Concrete placed by crane and bucket or pumped
b. Pumping affects the air% and slump
c. Superplasticizers used in concrete to maximize flow around tight rebar configurations i.e.: spiral wrapped columns and heavily reinforced caps (form design must consider full liquid head)
Bridge Components

**Bearings**

- Fixed or expansion
- Referred to as “shoes”
- Steel, bronze, neoprene
- Rocker, roller, spherical, and elastomeric
- New or retrofit
- Masonry plate, sole plate
Bridge Components

Substructure Alternatives

• Mechanically Stabilized Earth Walls
  – Used in place of conventional CIP concrete
  – Used with pile supported stub abutments eliminates need for breast wall
• Piles are driven prior to placing embankment and isolated with sleeves
• MSE walls and soil reinforcement are installed after sleeves are installed
• Pile cap serves as bridge seat and MSE wall coping
Bridge Components

**MSE Walls** – two major systems

1. *Reinforced Earth* Walls by RECO
2. *Retained Earth* Walls by Foster Geotechnical (formerly VSL)
Bridge Rehabilitation

*Typical Work Elements*

- Deck patching or replacement
- Latex modified concrete or micro-silica overlay
- Bearing retrofit/replacement, cleaning, lubricating
- Expansion dam and seal replacement
- Parapet/barrier modification
- Substructure repair by patching spalls, pressure injection of cracks, and waterproofing
- Painting (including removal of old paint systems)
Bridge Construction

**Safety**

- OSHA has adopted strict new regulations regarding fall protection
- Fall arrest protection including harness -- safety belts are no longer permitted
- PPE includes life jackets when working over or adjacent to water
Submittals

• Submittal requirements generally include shop drawings for:
  – all formwork, falsework, containment systems, shoring
  – erection plans/procedures, dewatering, staging
  – fabricated and precast items, embedded items, and rebar
  – Material certification for everything incorporated into the final structure

• Submittals must include design calculations when applicable
Bridge Construction
Current and Future Trends

• Bridge Management programs include periodic condition inspection and rating of existing structures
• Many existing bridges are structurally deficient or functionally obsolete, and require replacement or rehabilitation.
  - More rehab/retrofit/replacement
  - Fewer new structures on new alignment
• Increase use of high strength steel in hybrid girders greatly reducing dead load
Bridge Construction
Current and Future Trends

• Expanding use and improvement of PS/PC concrete
• Growing use of segmental construction
• More sophisticated design software will enable designers to push the envelop
• Use of moisture-cured painting systems
• Use of composite construction techniques
• Use of composite materials
• Installation of noise barriers
Bridge Construction
Current and Future Trends

• Greater emphasis on aesthetics to include:
  – Context sensitive design
  – More public input in T.S. & L., materials, timing, and final appearance
  – Architectural input

• Addition of lighting for safety and appearance
• Demand for increased deck smoothness
• More stringent OSHA requirements
Bridge Construction