Why Concrete Pavements?

- Concrete pavements are the pavement of choice in many parts of the US and in many European countries because concrete pavements:
  - Are longer-lasting/durable under heavy truck traffic
  - Can provide low maintenance service
  - Can provide desired surface characteristic - smoother riding surface and lower wet weather accidents
  - Are cost-competitive initially and over the life cycle
  - Can be very sustainable by incorporating recycled and locally available materials during use phase (40+ years of user benefits)

**CONCRETE PAVEMENTS ➔ DURABLE, ECONOMICAL, SMOOTHER, SAFER & SUSTAINABLE**

Concrete Pavements Technology

- A Mature Technology

Resulting from improvements in design, construction & material technologies (over 100+ years)

- But still evolving to improve reliability of design, efficiency of construction, and cost competitiveness; and better meeting road user needs

**Presentation Outline**

- Long-Life Concrete Pavement Practices
- Emerging Concrete Pavement Types
- Sustainability Considerations
- Concrete Pavements – Current Developments
**US Definition of Long-Life & Sustainable Concrete Pavements**

- Original PCC surface service life – 40+ years
  - The next frontier – 60+ years service life
- At some point in future, India will need to strive for such expectations for its concrete pavements – to make concrete pavements in India risk-free, more cost-effective and more sustainable!
- Pavement will not exhibit premature failures and materials related distress
- Pavement failure should be a result of traffic loading
- Pavement will have reduced potential for cracking, faulting & spalling, and pavement will maintain desirable ride and surface texture characteristics with minimal intervention activities to correct for ride & texture, for joint resealing, and minor repairs

**Long-Life Concrete Pavements A Global View**

- European generic:
  - Concrete pavements → long life pavements
  - Typical design life: 30 year design, but expect more
  - Good surface texture for safety & low noise
  - Sustainable
- South America generic:
  - Concrete pavements → long life pavements
  - But, many countries still design for 20 years, even though life cycle cost analysis typically show concrete pavements to be a better long-term solution
  - Good surface texture for safety (noise not an issue yet)
  - Sustainable

**Concrete Pavements in Latin America**

- Brazil

**US Focus: Attaining Long Life**

- Long-life concrete pavements have been attainable for a long time
  - Many pavements are still in place after 40+ years of service under heavy traffic
- The main concern is achieving long-life consistently thru:
  - Reliable structural designs
  - Durable materials
  - Quality construction, and
  - Timely maintenance & repair

**Sustainable Concrete Pavements - Making the Construction Phase More efficient**

- US efforts to combine SMART engineering and SOUND materials technology with GOOD construction practices to minimize energy and resources use, cost, & GHG (CO2) emission
  - By optimizing key pavement design features
  - By working with limited material resources to achieve design objectives
  - By balancing competing, and often contradictory, objectives during the construction phase

**US Expectations of Concrete Pavements**

- At end of service life
  - 40+ years for primary system
  - 20 to 40+ years for secondary system (?)

<table>
<thead>
<tr>
<th>Distress</th>
<th>Failure Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cracked Slabs, % (plain jointed)</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Faulting, mm</td>
<td>6 or less</td>
</tr>
<tr>
<td>(Consider grinding before threshold is reached)</td>
<td></td>
</tr>
<tr>
<td>Smoothness (IRI), m/km</td>
<td>2.5 to 3.0</td>
</tr>
<tr>
<td>Joint Spalling</td>
<td>Minimal</td>
</tr>
<tr>
<td>Materials Related Distress</td>
<td>None (thru good specs &amp; construction practices)</td>
</tr>
</tbody>
</table>
### Concrete Pavement Types

- **Jointed concrete pavement (most popular)**
  - 100+ years of experience/innovations
- **Continuously reinforced concrete pavement**
  - No joints; but a bit more expensive first cost
  - 50+ years of experience
- **Roller compacted concrete pavement (30 years)**
  - For lower speed roads, shoulders and parking lots
  - And, heavy duty port & truck freight areas
- **Thin concrete overlays (20 years)**
  - Typically, for resurfacing of distressed asphalt pavement

- **Pervious concrete (10 years)**
  - In urban areas – low speed streets & parking lots; helps with storm water management
- **Precast concrete pavement (10 years)**
  - Conventionally jointed and posttensioned (joints at 70 to 100 m)
  - Used in urban areas for rapid overnight repair and rehabilitation
- **Cast in place prestressed concrete pavements** (experimental only – 1980’s)
  - Thinner and joints at 70 to 100 m

### Current US Practice

- **Jointed concrete pavements**
  - 4.6 m joint spacing (default)
  - Steel: 15 to 20 cm (streets); 20 to 25 cm (secondary roads); 25 to 35 mm (primary roads)
  - Dowels & stabilized base for medium/heavy volume of trucks
- **Continuously reinforced concrete pavement (CRCP)**
  - Steel: 0.70 to 0.80%
  - Cracking at 1 to 2 m, tight cracks
  - No joints; terminal joints only at structures

### Roller-Compacted Concrete (RCC) Pavements

- RCC is a **cheaper** no-slump concrete that is placed using an asphalt paver and compacted by vibratory rollers.
- Consistency of damp gravel
- No forms and no reinforcing steel/dowel bars
- No finishing
- Compactled using vibratory rollers and finished with rubber-tired rollers

### Common Applications of RCCP

- Ports/Heavy Industry
- Light Industry
- Airports
- Local & Arterial Streets
- Intersections
- Retrofit Concrete Shoulders
- Military Use (Tank Hardstands)
**Thin Bonded Concrete Overlays of AC (Whitetopping)**

- PCC overlay of existing distressed AC pavement
  - Thickness – 125 to 175 mm.
  - Jointing – 1.8 by 1.8 m
- Use increasing in the US & Latin America

**Thin Unbonded Concrete Overlays (of asphalt & concrete pavements)**

- Thin unbonded overlay (placed over AC or concrete pavement)
  - Thickness – 125 to 175 mm
  - Jointing – 1.8 by 1.8 m
- Use of geo-fabric interface of unbonded overlays over existing concrete pavements, based on German practice for new construction

**Unbonded Overlay over Existing Concrete Pavement with Geo-Fabric Interlayer**

**Guatemala Variation**

(Short joint spacing for new pavements based on good experience with bonded overlays of AC pavements)

- New Toll highway – Guatemala City
- Thickness – 225 mm or as needed
- Jointing – 1.8 by 1.8 m
- Cement treated base; 5 mm thick fabric interlayer
- No dowel bars; only tie-bars

**Pervious Concrete Pavements**

(A no fines concrete surface to reduce surface runoff)

- Being used in the US for low level traffic applications – parking lots and city streets where flooding potential is high after a rainfall
- Also, being tested for low volume highway applications
**Precast Concrete Pavement Technologies**

- Introduced in 2001, use of precast concrete pavement for full-depth repairs & rehabilitation is on the increase in the US
  - Production use by many US agencies
  - Cost effective & longer-lasting repairs & rehabilitation
  - Minimize lane closures (~8 pm to 5 am)

**Jointed Precast Concrete Pavements**

- Repair Panels
- Conventional Jointed PCP System

**Precast Prestressed Concrete Pavements**

- Post-tensioned Systems
- 75 to 100 m post-tensioned sections

**Repair Applications**

- NJ I-295
- 15 to 20 repairs/night

**California I-680 Precast Prestressed**

- Up to 11 m long panels over new rapid setting lean concrete base, 2011
- Post-tensioned lengths up to 66 m (6 panels) – Night-time placement
- Up to 125 m of panels have been placed per night closures

**Current Efforts to Continue to Improve Concrete Pavement Practices**

- **Design**
  - Mechanistic design (MEPDG) implementation by most US agencies
  - Optimizing design features & improve design reliability
  - Composite pavement (Top lift PCC+/Bottom lift PCC-)
    - New pavement types
      - Thin concrete overlays of existing asphalt pavements
      - Precast pavement (for rapid rehab/reconstruction)
- **Materials** (major focus: durability & sustainability)
  - Dense (well) graded aggregates (3+ sizes)
  - Less cement use, more SCM (flyash & slag)
  - Two-lift paving concrete mixtures (PCC+/PCC-)
  - Internally cured concrete
Current Efforts to Continue to Improve Concrete Pavement Practices

- Construction
  - Two-lift paving (Two plants & two sets of paving equipment)
  - Stringless paving (controlled using GPS)
  - End product and performance-related specification (PRS)
  - Pro-active contractor process control
    - Reject poor materials & construction practices
  - Green construction

- Repair/Rehabilitation
  - Rapid/Accelerated (typically at night)
  - Thin concrete overlays to extend life of exist. pavements
  - Precast pavement use (mainline, ramps, bus lanes, intersections) in high volume corridors

Summary

Smart Engineering = Big Gains
Many Small Steps = Big Gains

- We have the engineering know-how to design & construct concrete pavements that are long-lasting & sustainable, but we need to apply this knowledge consistently
  - Pavements that are not long-lasting ARE NOT sustainable

- We are beginning to recognize the sustainability related impacts & are making more use of recycled & locally available marginal materials in concrete & using green cements

Comprehensive Long-Life Concrete Pavement Design

- New Mechanistic-Empirical Pavement Design Guide (MEPDG) allows optimization of many key design features to develop LLCP designs
  - Joint spacing
  - Base type (& drainage)
  - Edge support
  - Load transfer at joints
  - Concrete thickness/strength

- End result
  - More cost-effective & reliable designs
  - More sustainable designs

- Most US agencies have adopted the new procedure
  - Agencies are at various stages of implementation

Thank You!
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Some Examples of Recent Developments & On-Going Efforts to Improve Concrete Pavement Practices

Current Efforts to Continue to Improve Concrete Pavement Practices

- Surface characteristics/user benefits
  - Improve ride (longer lasting smoother surface)
  - Improve surface texture
    - Reduce wet weather accidents
    - Reduce pavement/tire noise

- Construction management (Every Day Counts)
  - Minimize extended lane closures in urban areas
  - Reduce congestion
  - Reduce work zone accidents
New Delhi Workshop – Concrete Pavements: Current Developments
Shiraz Tayabji, World Bank, February 2015

**ME Design Process**

- Foundation Analysis
- Climate
- Materials Properties
- Traffic Analysis
- Performance criteria & reliability

**Analysis**

- Trial Design
- Pavement Response Model
- Damage Accumulation Over time
- Calibrated Damage-Distress/IRI Models

**Seasonal Analysis of Pavement Damage over Service Life**

- Each load application
- CTB Modulus
- PCC Modulus
- Traffic
- AC Modulus
- Granular Base Modulus
- Subgrade Modulus

**Example Results**

- Percent slab cracked
- Slab crack at specified reliability
- Limit percent slab cracked

- Similar outputs for joint faulting and roughness

**Joint Load Transfer**

- Dowels for truck-loaded highways
  - Slab > 20 cm or Trucks > 5 million
  - Minimum 32 mm diameter
- Round dowels meet needs & are economical
- Need to maintain LTE at joints - > 70%
- No need for middle 2 to 4 bars in each lane

**US Long Term Pavement Performance (LTPP) Program**

- 2,009 Original Sections, 750 Remaining
- Performance monitoring of in-service pavements & other data collection started 1989 & continuing

- New pavement design guide (concrete & asphalt pavement) would not have been possible without LTPP data

**US Efforts to Reduce Cement Use for Paving Concrete**

- Some simple changes to reduce cement use
  - Reduce paste content (most problematic component)
    - Use of optimized gradation & use larger maximum aggregate size
    - Reconsider minimum cementitious materials requirement; consider end product specification
  - Increase use of flyash & slag
    - Results in more durable concrete
    - Efficient use of waste products/by-products
  - UseGreener cements
    - Blended cements (ASTM C595)
    - Performance-based cements (ASTM C1157), including portland limestone cement
    - Non-portland cements – under development
Use of Sustainable Concrete
Reduction of Portland Cement Use
By Using Pozzolans and Slag & Greener Cements

- Class F fly ash: 15% - 25%
- Class C fly ash: 15% - 35% (limited use)
- Slag: 25% - 50%
- Silica fume: Not used in US for paving
- Natural pozzolan: Not used in US for paving

Blended cement use is allowed & common
Green cements under development

Surface Texture Development
(for safety & now for low noise)

Concrete Texturing – New for US
(enhanced safety & low noise surface)

- Addresses noise concerns in urban areas
- Conventional grinding for new
- Under development
  - Next generation surface texture (grinding)
  - Exposed aggregate (not in US yet)

Next Generation Concrete Surface
(Shallow grinding & grooving)

US Efforts to Develop Better Construction Processes

- The future is end product specifications/PRS
  - US moving away from prescriptive specs
- End product specs enable clear definition of
  Good Specs lead to Good Construction!
  A quality pavement performs well!
  - Processes are objectively defined, are constructible, are not arbitrary & can be measured
  - Contractor responsible & accountable for end product
  - Contractor process control prevents placement of marginal concrete and use of marginal construction processes
  - Penalties are set by estimating impact on performance

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