U.S. Strategies for Concrete Highway Bridge Durability and Management

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Sustainable and Resilient Concrete Structures
-Codes and Practices-
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Agenda

- Overview of U.S. Highway Bridge Inventory
- Life Cycle of a Bridge
- Recent Trends toward Enhanced Durability
  - Design
  - Materials and Construction
  - Inspection
  - Preservation and Management Practices
U.S. Highway Bridge Inventory

OVERVIEW
Based on FHWA NBIS data:

The U.S. has 616,087 highway bridges (over 20 ft) and many more bridges and culverts < 20 ft

About 47% of bridges are owned by state governments and 50% are owned by local governments

Large/complex bridge types include:
- 782 long-span bridges (> 400 ft)
- 828 movable bridges
- 400 segmental bridges

Average U.S. bridge is about 45 years old
Over 1 in 6 bridges is over 65 years old

Condition of Highway Bridges Nationwide

47,052 bridges (7.6%) in poor condition, 1,900 on Interstate Highway System

- By deck area, 6.3% are deficient
- $20.5 Billion needed over 16 years to repair and replace
- Poor bridges dropped by 565 in 2018

Per ARTBA February 2019 Condition Report:


Bridge Performance Issues

Interviews of State DOTs for the Long Term Bridge Performance Program showed the most common performance issues with highway bridges.

- **Decks:**
  - Cracking
  - Delamination and Spalling (Concrete)
  - Pot Holes
  - Fatigue Cracks (Steel)
  - Weathering and Rot (Timber)
  - Leaking or Failed Joints

- **Superstructures:**
  - Cracking
  - Corrosion
  - Deterioration of Paint Systems
  - Girder End Deterioration
  - Steel Fatigue
  - Box Girder Hinges
  - Joint Deterioration
  - Impact of Girders and Railings
  - Concrete Pop-outs due to Freezing

- **Substructures:**
  - Scour
  - Cracking
  - Corrosion, Spalling and Delamination,
  - Alkali-Aggregate Reaction
  - Seismic
  - Bearing Pedestals Deterioration
  - Frozen, Misaligned or Failed Bearings

- **Functionality:**
  - Serviceability Issues
  - High Traffic Loads and Volumes
  - Low Load Ratings
  - Bridge Width not Matching Road Width
  - Inadequate Vertical Clearance
  - Drainage, Impact Damage
Life Cycle of a Bridge
Bridge Life Cycle Activity Profile

Condition Resulting from Deterioration and Intervention

Life Cycle Activity profile – Cost-flow diagram related to bridge activities

Note: resource flows are generally represented as occurring at beginning or end of period
Service Life Engineering

Consider service goals and exposure for New or Existing Structures

— Concrete Service Life Modeling
  • Chloride diffusion/corrosion
  • Carbonation
  • Sulfate, ASR, F/T and others

— Materials Selection and Design
  • High-Strength/Stainless steels
  • Carbon and Glass FRP
  • Coatings and Sealers
  • Galvanic protective systems

— Structural Fatigue Analysis
  • Structural redundancy

— Rehabilitation Strategies
  • Overlays, strengthening & patching
  • Corrosion Mitigation Strategies

— Life Cycle Cost Analysis
Enhancing Durability: DESIGN
AASHTO Committee on Bridges & Structures considering draft of *Guide Specification for Service Life Design of Highway Bridges*

- In current structural design codes, durability-focused limit states are not identified; addressed through “deemed-to-satisfy” requirements.
- Establishes target service life categories and exposure classes.
- Considers probabilistic chloride-induced corrosion limit state for reinforced concrete, referencing:
- Protection index for foundations and retaining walls.
- Provides consideration for renewable elements.
## Service Life Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Bridge Component Type</th>
<th>Bridge Description</th>
<th>Level of Qualitative Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable</td>
<td>Bearings, joints, strip seals, guardrails, barriers, sign structures, coating systems, approach slabs, sleeper slabs, deck overlays</td>
<td>All</td>
<td>Replaceable</td>
</tr>
<tr>
<td>Normal</td>
<td>All other components</td>
<td>Typical bridges</td>
<td>Good</td>
</tr>
<tr>
<td>Enhanced</td>
<td>All other components</td>
<td>Bridges with high cost, high ADT, social context, etc.</td>
<td>Better</td>
</tr>
<tr>
<td>Maximum</td>
<td>Bridges with higher cost, higher ADT, social context, etc.</td>
<td></td>
<td>Best</td>
</tr>
</tbody>
</table>
Macro-Environment Exposure Zones
- Rural/Mild/Nonaggressive
- Industrial/Moderate
- Marine
- Deicing

Concrete Exposure Classes
- Chloride-induced corrosion
- Carbonation-induced corrosion
- Freeze-thaw attack
- Alkali aggregate reaction
- Sulfate attack
- Abrasion
- Pre-service Cracking

Steel Exposure Classes
- Corrosion
- Fatigue

Micro-Environment Exposure Zones
- Atmospheric Zone
- Buried Zone
- Submerged Zone
- Indirect Deicing Salts Zone, Splash Zone, Spray Zone
- Tidal Zone or Water-level Zone
- Direct deicing salts zone
DESIGN: Chloride-induced Corrosion Limit State

- Corrosion initiation of reinforcement defines the end of service life (EFSL)
- Good predictive models do not exist for propagation period
- Propagation period is typically much shorter than initiation period
- EFSL assumed to occur when critical chloride threshold is reached at reinforcement
DESIGN: Chloride Initiation Phase

![Graph showing the relationship between depth of rebar, chloride concentration, and critical chloride levels. The graph includes a line representing the diffusion coefficient, a point indicating the surface chloride concentration, and shaded area representing a range of chloride levels over a duration of 50 years.](image-url)
DESIGN: Why do we use a Probabilistic Approach?

- Input parameter values are not a single value but a range of values
- Using lower (or upper) bound values will result in uneconomical designs

Probabilistic variables:
- $x =$ cover depth
- $C_s =$ surface Cl$^-$ concentration
- $D_c =$ concrete diffusion coefficient
- $T =$ Temperature (annual)
- $C_{crit} =$ critical chloride concentration
DESIGN: Chloride Diffusion Model Input Parameters

\[ C(x,t) = C_0 + (C_s - C_0) \times \left[ 1 - \text{erf} \left( \frac{x - \Delta x}{2 \sqrt{D_c t}} \right) \right] \leq C_{\text{crit}} \]

Input values depend on:

- **Exposure condition**
  - Geographical location and climate
  - Local data from nearby structures, or
  - Similar projects in the past
- **Materials**
  - Concrete mixture design
  - Type of reinforcement
- **Design Details**
  - Cover depth

### Example variable inputs:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Distribution</th>
<th>Mean (m)</th>
<th>Standard Deviation (s)</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Chloride (Chloride Threshold)</td>
<td>%</td>
<td>Beta</td>
<td>0.6</td>
<td>0.15</td>
<td>0.2</td>
<td>2</td>
</tr>
<tr>
<td>Aging Factor</td>
<td>n</td>
<td>Beta</td>
<td>0.6</td>
<td>0.15</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Depth of convection Zone</td>
<td>( \Delta x )</td>
<td>Normal</td>
<td>10</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression Variables</td>
<td>( b_e )</td>
<td>Normal</td>
<td>4800</td>
<td>700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete Cover</td>
<td>x</td>
<td>Normal</td>
<td>50</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>T</td>
<td>°k</td>
<td>283.6</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Chloride</td>
<td>( C_s )</td>
<td>Normal</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Chloride</td>
<td>( C_0 )</td>
<td>Constant</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRCM,0</td>
<td>( D_c )</td>
<td>Normal</td>
<td>3.00E^{-12}</td>
<td>6.00E^{-13}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DESIGN: Concrete Service Life Design Steps

1. Define exposure zones and degradation mechanisms
2. Select limit state
3. Quantify and Evaluate Design Parameters
   - Materials
   - Concrete Quality
   - Concrete Cover
   - Reinforcement Type
4. Incorporate into Project Specifications
5. Implement during Construction Qualifications testing (pre-testing and production testing)
6. Monitor/verify during the service life
DESIGN: Post-tensioned Concrete

PT System Selection based on exposure (examples):
- PL1 - grouted tendons in steel duct (benign environments)
- PL2 - grouted tendons encapsulated in polymer duct, or
  - unbonded replaceable tendons with flexible filler in polymer duct
- PL3 - electrically isolated grouted tendons encapsulated in polymer duct

Specific attention to:
- Adequate concrete quality and cover
- Segment joint seals (epoxy or wet cast c.i.p.)
- Watertight duct couplers
- Proper grout/filler materials and procedure
- Quality anchorage protection cap or pour-back
DESIGN: Shear-key Design and Retrofits

Standard Key

Standard with Kevlar

Bar Splice Detail

Kevlar strip

Cast-in block-out with short lap-splice

Retrofit “dog-bone” non-contact bar splice

27”

48”

continuous typical keyway filled with UHPC

blockouts for drop-in splice bar (spaced at ~ 2 ft centers) filled with UHPC
Enhancing Durability: MATERIALS
Materials for longitudinal shear keys, and closures, link slabs, etc. require higher tensile strength, low shrinkage, good bond and crack resistance.

- High to very high cementitious content
- Reactive silica filler (UHPC)
- Small or No coarse aggregate
- Distributed thin fibers
  - **FRC** uses straight or hooked steel, PP or PVA
  - **UHPC** fine brass-coated steel
- Compressive Strength
  - **FRC**, $f_c = 8 - 15$ ksi
  - **UHPC**, $f_c = 17 - 30$ ksi

Small distributed fibers provide post-crack tensile strength

UHPC putty-like consistency
Requires high-shear mixer

PVA (left) and Steel (right) fibers for FRC
MATERIALS - Fiber-Reinforced Concrete

Conventional shear keys fail, causing poor load distribution and premature corrosion.

Fiber-reinforced concrete developed to reduce lap splice length of reinforcing steel in connections.
MATERIALS - Concrete for Decks

Low-shrinkage Concretes

- Normal weight concrete with:
  - low paste content
    (≤600 lb/yd³ cementitious materials)
  - Shrinkage Reducing Admixture
    (28-day shrinkage < 0.035%)

- Lightweight concrete
  (≤650 lb/yd³ cementitious materials)

- Shrinkage-compensating concrete
  (Type-K cement)

Mixes incorporate pozzolans for HPC to maintain low permeability
MATERIALS: Reinforcing Bars for Corrosion Durability

- Carbon Steel (ASTM A615)
- Epoxy-coated steel (ASTM A775)
- Galvanized steel (ASTM A767)
- MMFX2 (ASTM A1035)
- Z-Bar (carbon steel + Zinc + Epoxy)
- LDX 2101
- 2304 Duplex Stainless (ASTM A955)
- Stainless Steel Clad
- 316 LN Stainless Steel (ASTM A955)
- FRP (E-Glass)

Design criteria also include yield and ultimate strength, hardness, elongation, development length and cost.
MATERIALS: Corrosion-Resistant Prestressing Strand

Materials:
- Stainless Steel Strand
- Carbon-Fiber Composite Cable

Applications:
- Marine Piles
- Bulb-T Girders
Enhancing Durability: INSPECTIONS
INSPECTION: Inspection Standards

- All U.S. National Highway System bridges must be inspected per the NBIS
- In 2013, FHWA introduced 23 metrics by which inspection programs are assessed
- In general, bridges are inspected at least once per 24 months
- NBI General Condition Ratings (1-9) are assigned to deck, superstructure, substructure or culverts
- Many states also assign element-level condition states (1-4) according to AASHTO national bridge elements (NBE) and bridge management elements

<table>
<thead>
<tr>
<th>Metric</th>
<th>Category</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Qualifications of personnel</td>
<td>Bridge inspection organization</td>
</tr>
<tr>
<td>#2</td>
<td>Program Manager</td>
<td>Qualifications of personnel</td>
</tr>
<tr>
<td>#3</td>
<td>Team Leader(s)</td>
<td>Program Manager</td>
</tr>
<tr>
<td>#4</td>
<td>Load Rating Engineer</td>
<td>Team Leader(s)</td>
</tr>
<tr>
<td>#5</td>
<td>UW Bridge Inspection Diver</td>
<td>Load Rating Engineer</td>
</tr>
<tr>
<td>#6</td>
<td>Inspection frequency</td>
<td>UW Bridge Inspection Diver</td>
</tr>
<tr>
<td>#7</td>
<td>Routine - Lower risk bridges</td>
<td>Inspection frequency</td>
</tr>
<tr>
<td>#8</td>
<td>Routine - Higher risk bridges</td>
<td>Inspection frequency</td>
</tr>
<tr>
<td>#9</td>
<td>Underwater - Lower risk bridges</td>
<td>Inspection frequency</td>
</tr>
<tr>
<td>#10</td>
<td>Underwater - Higher risk bridges</td>
<td>Inspection frequency</td>
</tr>
<tr>
<td>#11</td>
<td>Fracture Critical Member</td>
<td>Inspection frequency</td>
</tr>
<tr>
<td>#12</td>
<td>Frequency criteria</td>
<td>Inspection frequency</td>
</tr>
<tr>
<td>#13</td>
<td>Quality Inspections</td>
<td>Fracture Critical Member</td>
</tr>
<tr>
<td>#14</td>
<td>Load Rating</td>
<td>Frequency criteria</td>
</tr>
<tr>
<td>#15</td>
<td>Post or Restrict</td>
<td>Load Rating</td>
</tr>
<tr>
<td>#16</td>
<td>Bridge Files</td>
<td>Post or Restrict</td>
</tr>
<tr>
<td>#17</td>
<td>Fracture Critical Members</td>
<td>Bridge Files</td>
</tr>
<tr>
<td>#18</td>
<td>Underwater</td>
<td>Fracture Critical Members</td>
</tr>
<tr>
<td>#19</td>
<td>Scour Critical Bridges</td>
<td>Underwater</td>
</tr>
<tr>
<td>#20</td>
<td>Complex Bridges</td>
<td>Scour Critical Bridges</td>
</tr>
<tr>
<td>#21</td>
<td>QC/QA</td>
<td>Complex Bridges</td>
</tr>
<tr>
<td>#22</td>
<td>Critical Findings</td>
<td>QC/QA</td>
</tr>
<tr>
<td>#23</td>
<td>Inventory</td>
<td>Critical Findings</td>
</tr>
<tr>
<td></td>
<td>Prepare and Maintain</td>
<td>Inventory</td>
</tr>
<tr>
<td></td>
<td>Timely Updating of Data</td>
<td>Timely Updating of Data</td>
</tr>
</tbody>
</table>
INSPECTION: Reliability-based Inspection

A 2014 NCHRP study proposed a Guideline for reliability-based bridge inspection practices; the goal is to improve safety and reliability of bridges by focusing inspection effort where most needed.

Risk = Probability of Occurrence \times Consequence

Probability of Occurrence

<table>
<thead>
<tr>
<th>Level</th>
<th>Category</th>
<th>Description</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Remote</td>
<td>Remote probability of occurrence, unreasonable to expect failure to occur</td>
<td>≤1/10,000</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>Low likelihood of occurrence</td>
<td>1/10,000 - 1/10,000</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Moderate likelihood of occurrence</td>
<td>1/100 - 1/1,000</td>
</tr>
<tr>
<td>4</td>
<td>High</td>
<td>High likelihood of occurrence</td>
<td>&gt;1/100</td>
</tr>
</tbody>
</table>

Consequence of Occurrence

<table>
<thead>
<tr>
<th>Level</th>
<th>Category</th>
<th>Consequence on Safety</th>
<th>Consequence on Serviceability</th>
<th>Summary Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>None</td>
<td>Minor effect on serviceability, no effect on safety</td>
<td>Minor effect on serviceability, no effect on safety</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Minor</td>
<td>Moderate effect on serviceability, minor effect on safety</td>
<td>Moderate effect on serviceability, minor effect on safety</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>Moderate</td>
<td>Major effect on serviceability, moderate effect on safety</td>
<td>Major effect on serviceability, moderate effect on safety</td>
</tr>
<tr>
<td>4</td>
<td>Severe</td>
<td>Major</td>
<td>Major effect on serviceability, major effect on safety</td>
<td>Structural collapse/loss of life</td>
</tr>
</tbody>
</table>

Element Damage Modes

Steel Girder
- Corrosion damage/section loss
- Fatigue cracking
- Fracture
- Impact damage

Prestressed Girder
- Corrosion damage (spalling/cracking)
- Strand fracture
- Shear cracking
- Flexural cracking
- Impact damage

Piers and Abutments
- Corrosion damage (spalling/cracking)
- Damage to bearing areas
- Unexpected settlement/rotation

*Washer, G. et al, 2014
INSPECTION: NDE Methods for Inspection

Common NDE methods for concrete

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>TRL</th>
<th>Cost</th>
<th>Material</th>
<th>Primary Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR</td>
<td>Infrared thermography</td>
<td>4</td>
<td>◆</td>
<td>Concrete</td>
<td>Subsurface delaminations in concrete</td>
</tr>
<tr>
<td>GPR</td>
<td>Ground penetrating radar</td>
<td>4</td>
<td>◇</td>
<td>Concrete</td>
<td>Detecting damage in concrete associated with corrosion, rebar depth, locating embedded metal objects</td>
</tr>
<tr>
<td>UPV</td>
<td>Ultrasonic pulse velocity</td>
<td>5</td>
<td>◇</td>
<td>Concrete</td>
<td>Deterioration of concrete, concrete modulus/strength, subsurface voids, cracks</td>
</tr>
<tr>
<td>IE</td>
<td>Impact echo</td>
<td>4/5</td>
<td>◇</td>
<td>Concrete</td>
<td>Delaminations in concrete, deterioration of concrete, subsurface voids</td>
</tr>
<tr>
<td>CD</td>
<td>Chain drag</td>
<td>5</td>
<td>◇</td>
<td>Concrete</td>
<td>Delaminations in concrete</td>
</tr>
<tr>
<td>HC</td>
<td>Half-cell potential</td>
<td>5</td>
<td>◇</td>
<td>Concrete</td>
<td>Corrosion potential</td>
</tr>
<tr>
<td>RT</td>
<td>Radiographic testing</td>
<td>4</td>
<td>◇</td>
<td>Concrete</td>
<td>Internal voids, loss of section/fracture in embedded steel</td>
</tr>
<tr>
<td>S</td>
<td>Sounding</td>
<td>5</td>
<td>◇</td>
<td>Concrete</td>
<td>Delaminations, deterioration of concrete</td>
</tr>
<tr>
<td>SAW</td>
<td>Surface acoustic wave</td>
<td>4</td>
<td>◇</td>
<td>Concrete</td>
<td>Cracking and deterioration in concrete, delaminations</td>
</tr>
<tr>
<td>MFL</td>
<td>Magnetic flux leakage</td>
<td>3</td>
<td>◇</td>
<td>Concrete</td>
<td>Loss of section for embedded steel element ( prestressing strand, rebar)</td>
</tr>
</tbody>
</table>

Technical Readiness Level (TRL)
1 = research … 5 = broadly implemented

○ Low cost; $100s
◇ Moderate cost; $1,000s-$10,000s
● High cost; $100,000s

*Washer, G. et al, 2014
INSPECTION: Rapid NDE-based Bridge Deck Inspection

Chain Drag
Coring
Sounding
High Speed IR and HRV
High Speed GPR
Deck Acoustic Response
INSPECTION: Rapid NDE-based Deck Evaluation

<table>
<thead>
<tr>
<th>Spans</th>
<th>2010</th>
<th>Deterioration (CRF - %)</th>
<th>Delamination (IR - %)</th>
<th>Delamination (DAR - %)</th>
<th>Patching (HRV - %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Girder</td>
<td>8.8%</td>
<td>9.0%</td>
<td>6.6%</td>
<td>5.6%</td>
<td>8.0%</td>
</tr>
<tr>
<td>West Truss</td>
<td>8.2%</td>
<td>10.3%</td>
<td>4.5%</td>
<td>3.9%</td>
<td>4.7%</td>
</tr>
<tr>
<td>Suspended</td>
<td>4.5%</td>
<td>14.0%</td>
<td>2.9%</td>
<td>4.0%</td>
<td>5.5%</td>
</tr>
<tr>
<td>East Truss</td>
<td>1.6%</td>
<td>17.9%</td>
<td>4.0%</td>
<td>3.7%</td>
<td>6.1%</td>
</tr>
<tr>
<td>East Girder</td>
<td>3.5%</td>
<td>13.3%</td>
<td>4.4%</td>
<td>4.6%</td>
<td>1.8%</td>
</tr>
<tr>
<td><strong>ALL SPANS</strong></td>
<td><strong>5.5%</strong></td>
<td><strong>13.0%</strong></td>
<td><strong>4.2%</strong></td>
<td><strong>4.3%</strong></td>
<td><strong>5.5%</strong></td>
</tr>
</tbody>
</table>

Rebar-level deterioration detected by GPR
Increasing severity →

Concrete Patching
Delamination Detected by IR

DAR sounding
POOR FAIR GOOD INTACT

Top Mile reinforcement projected to corrode
INSPECTION: UAS (drone) Inspection

Unmanned Aircraft Systems (UAS) have seen increased use in U.S. for various applications

UAS may not replace hands-on inspection in the near term

AASHTO-sponsored study found successful UAS programs:
— Increase safety and efficiency, reduce liability and cost
— Require top-down support, resources and coordination
— Have proper personnel, risk management and safety culture
— Provide adequate training and manage expectations
— Communicate with internal and external stakeholders
— Start small and grow, working across disciplines
— Have workflows for data collection and post-processing

Final Domestic SCAN report:
Enhancing Durability:
PRESERVATION & MANAGEMENT
PRESERVATION: Bridge Preservation Initiatives

FHWA - Bridge Preservation Expert Task Group
- Bridge Preservation Guide
- Preservation Pocket Guides (overlays, coatings, bridge cleaning)

AASHTO - TSP·2 Bridge Preservation Partnerships
- 4 regional meetings annually

TRB - Bridge Preservation committee
AASHTO Committee on Maintenance
- Bridge Technical Working Group
NCHRP-funded research
PRESERVATION: Preventive Maintenance

Cyclic activities
Cleaning and flushing
- Remove debris
- Clear scuppers/troughs
- Flush salts / abrasives
- Remove vegetation
- Clean joints
Sealing
- Decks
- Parapets
- Abutments and pier caps
Scour countermeasures
PRESERVATION: Maintenance

Condition-based activities

Concrete Repairs
Coating Repair/Replacement
Overlays
  – Thin Polymer Overlays (PM)
  – Rigid Concrete Overlays (RM)
    – *LMC & VE-LMC*
    – *UHPC*
Joint Repairs
Bearing Replacement
Cathodic Protection
Electrochemical chloride extraction
PRESERVATION: Deck Joint Maintenance/Elimination

- Flexible plug joint systems
- Joint Elimination
Consider condition, contamination and age to select:

- Sealing and crack repair
- Patching
- Shallow or deep mill/hydrodemolition
- Thin or rigid overlay options
  - Thin polymer (epoxy) overlays
  - Polyester Concrete
  - LMC and VE-LMC
  - UHPC
- Deck replacement
  - in-kind cast-in-place (staged)
  - Precast (ABC) decks
  - Slide-in superstructure replacement
MANAGEMENT: Transportation Asset Management Plans

- MAP-21 and FAST Acts promote performance-based decision-making for managing highway infrastructure
- Require DOTs to develop and implement risk-based Transportation Asset Management Plans (TAMPs)
- Use network-level life cycle planning and risk management analysis to set 10-year investment strategies
- Focus efforts on achieving and maintaining State of Good Repair
  - Set targets for % Good & Fair by system
- Prioritize according to risk
  - High priority routes (interstate, urban arterials, major river crossings, etc.)
  - Vulnerable structures (scour, seismic, etc.)

Thank you!

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