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Impact and Repairs for End Region Cracking in Prestressed Girders

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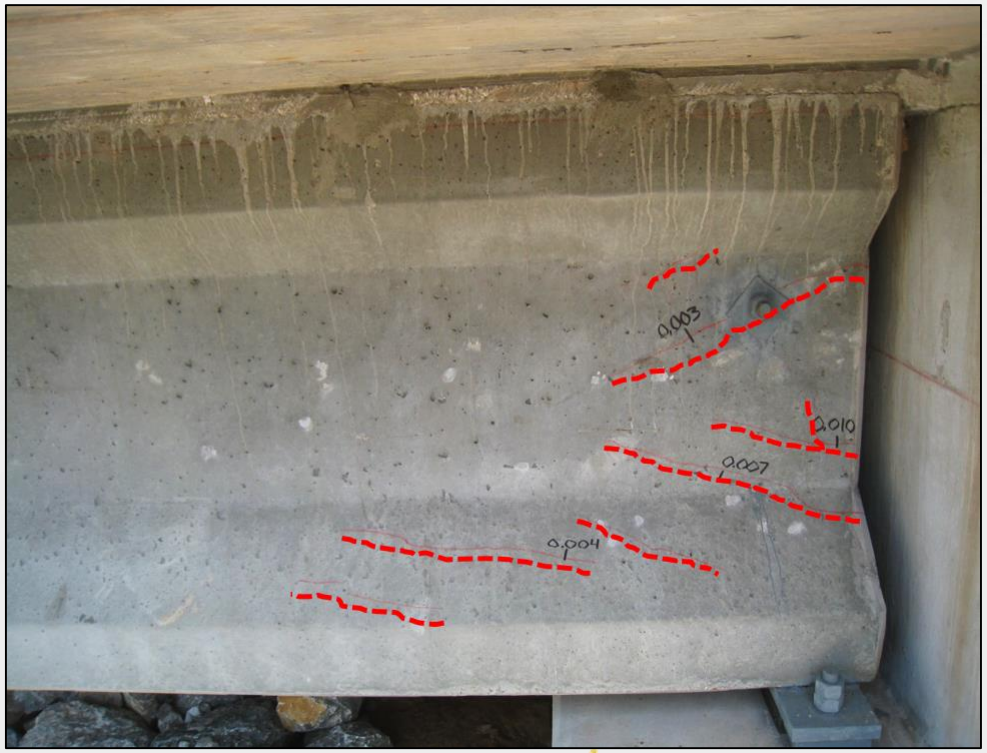
Problem

- Oklahoma DOT (ODOT) prestressed girders: frequent anchorage zone cracking



Approx. 1-2 weeks after casting

Investigation for ODOT

- ✓Phase I: Review Existing Conditions
- ✓Phase 2: Analyze Service Life & Repairs
- ✓Phase 3: Design Crack Control Strategies
- ✓Phase 4: Full-Scale Trial Implementation

Field Investigation

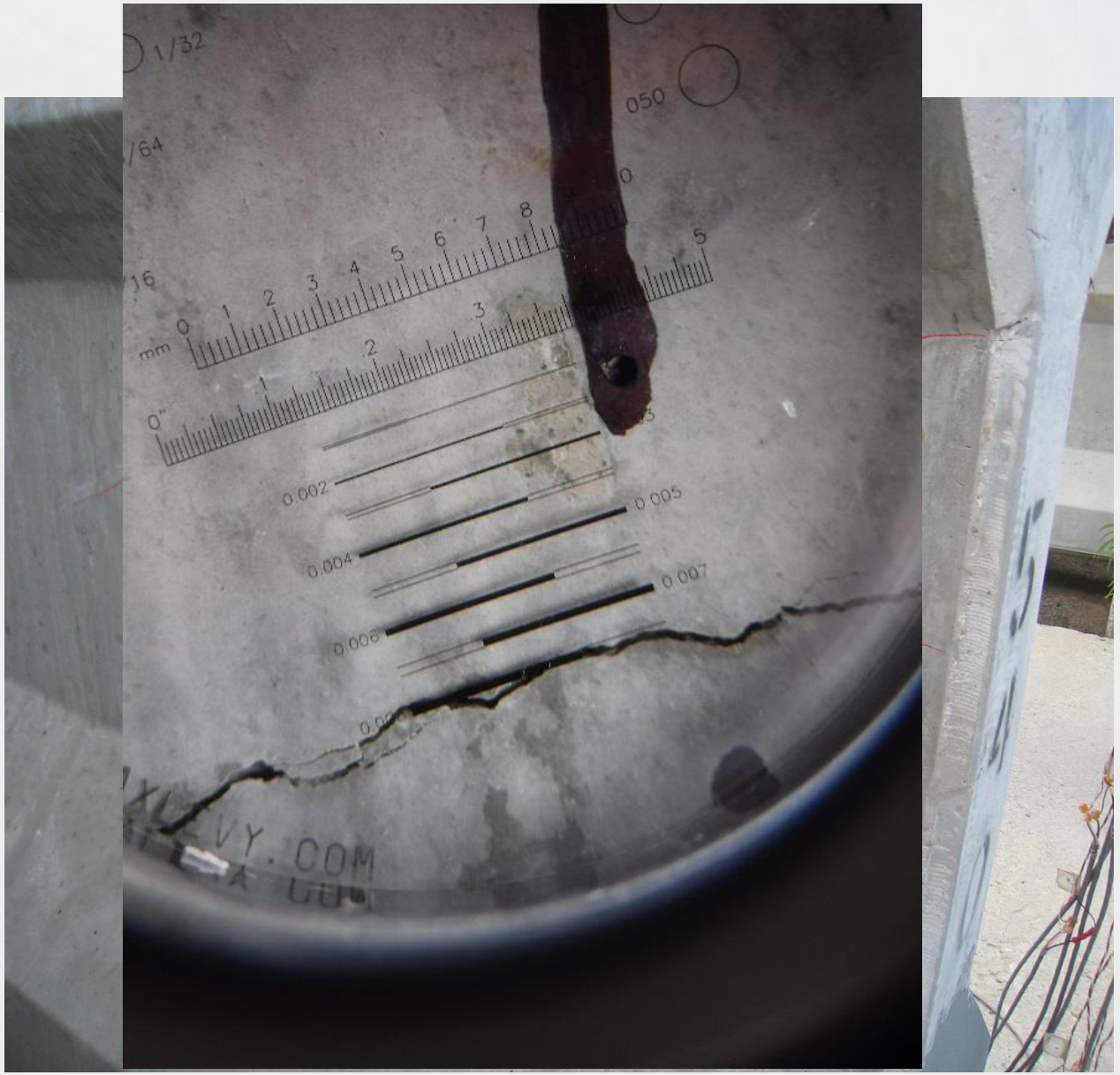
- Girder cracking tracked from casting through deck addition at two bridges (2015 and 2017)

Crack Distribution

- Crack density within first 40 inches:
  - 20 to 30 in. of crack per ft² of web area
  - Crack grew up to 10%-20% in first several weeks (3 to 6 in.)
- Cracks did not close when girders were erected or when deck was cast

Crack Widths

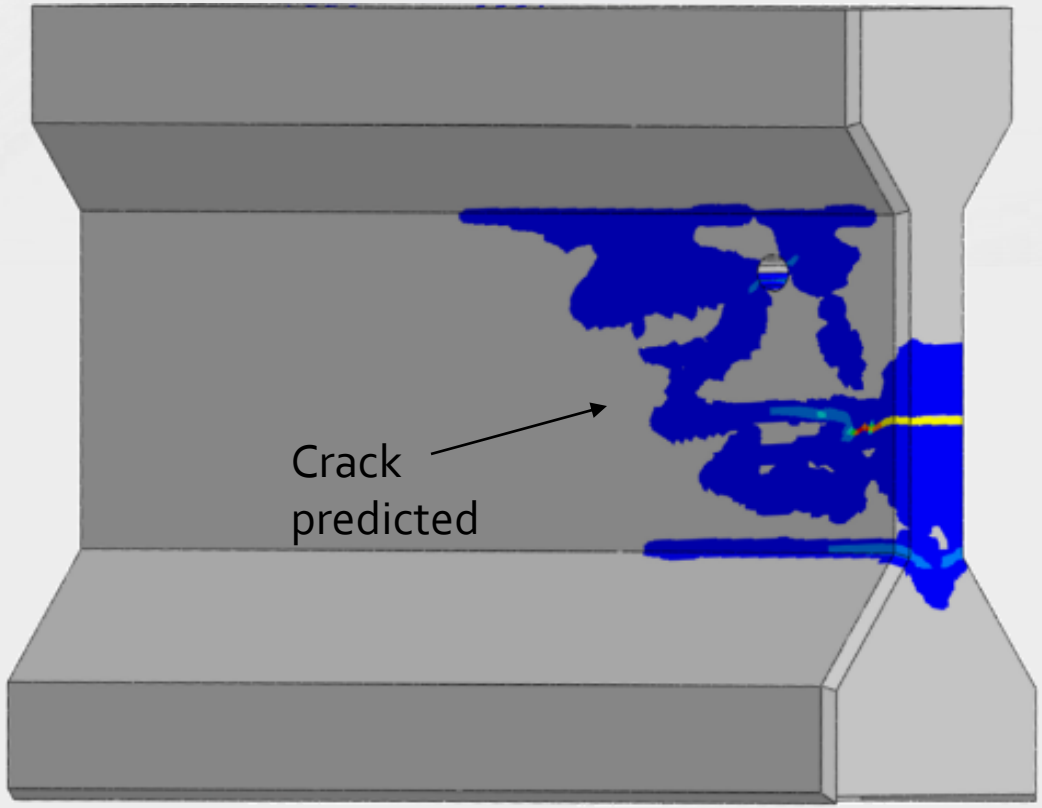
- Marked in field; measured using crack card and loupe
- Crack widths:
  - **8 to 10 mils**
  - Narrowing away from end



Nature of Cracking

- High prestressing forces
  - Start at release or first lift; slight growth due to drying shrinkage
- Not structurally significant
  - Not aligned with strands; perpendicular to typical shear cracks

➡ Impact on Durability?

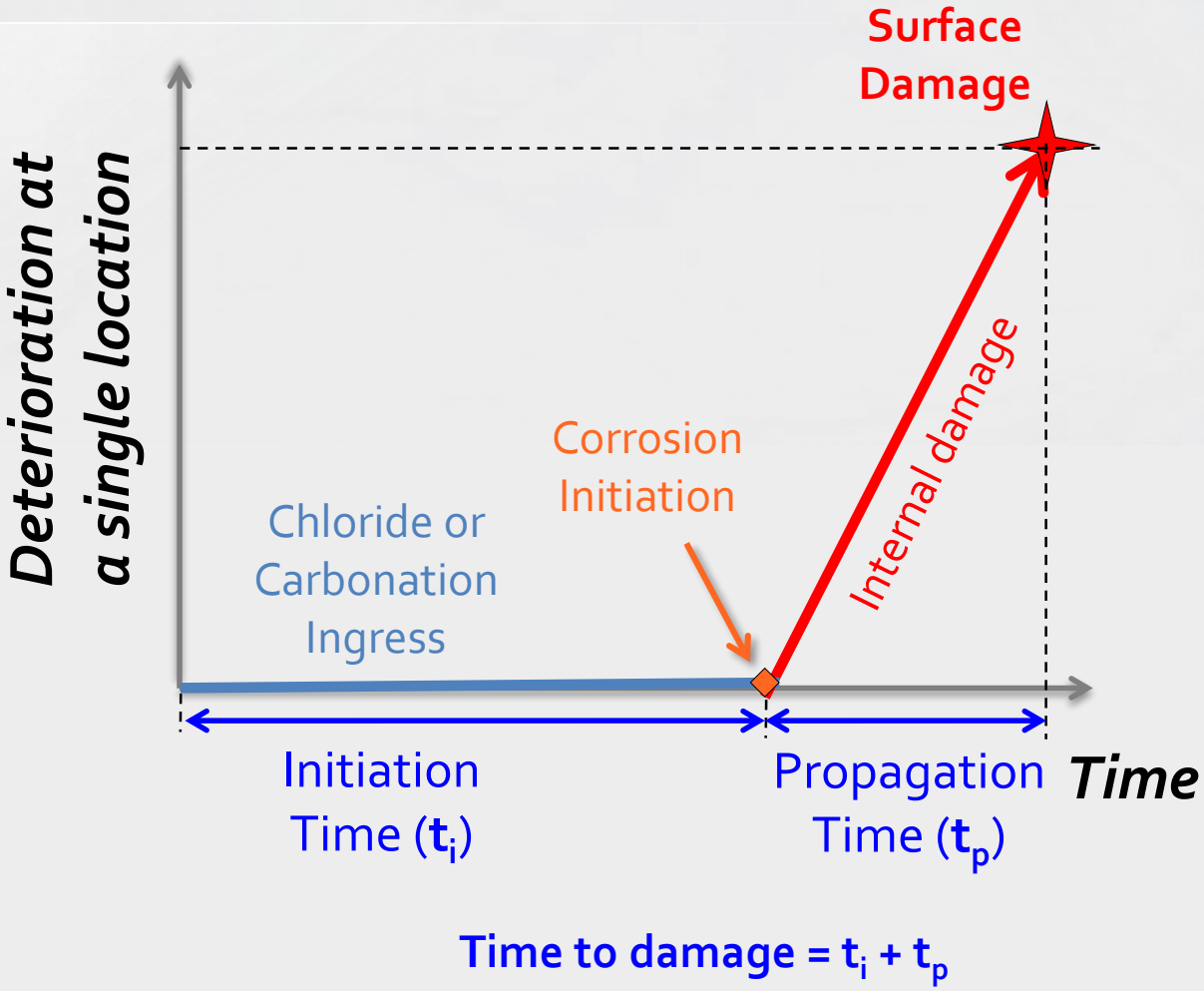


Service Life Modeling with Cracks

- Model: Level of corrosion-related deterioration versus time

- Chloride transport
  - Driving force: surface exposure
  - Mechanisms: diffusion, capillary adsorption, permeation
  - Resistance: concrete quality

➡ Reduced by Cracking



Modeling Chloride-Induced Corrosion

- **End of Service Life** =

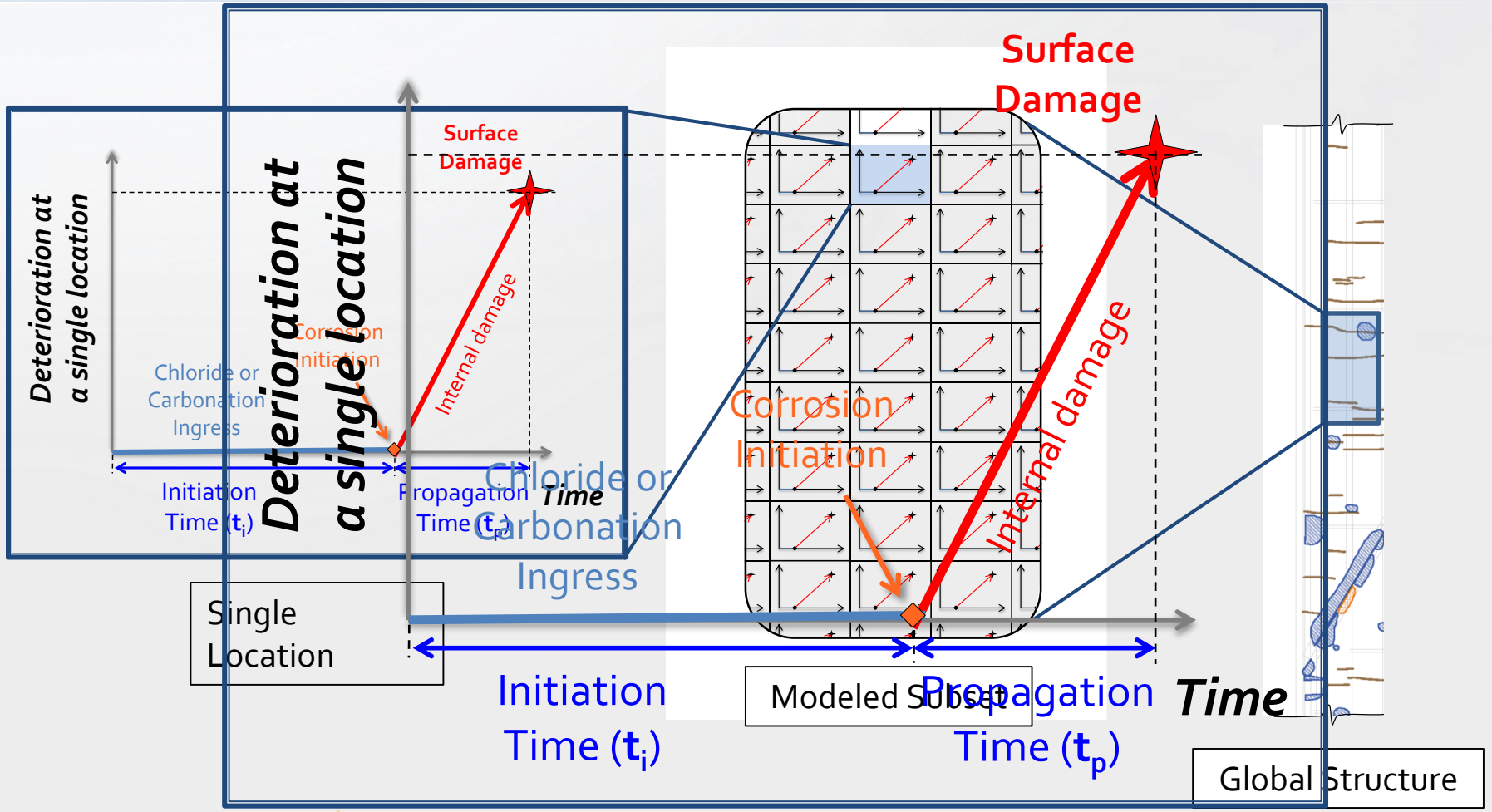
  Deterioration > Limit

  – Serviceability

  – Structural Integrity

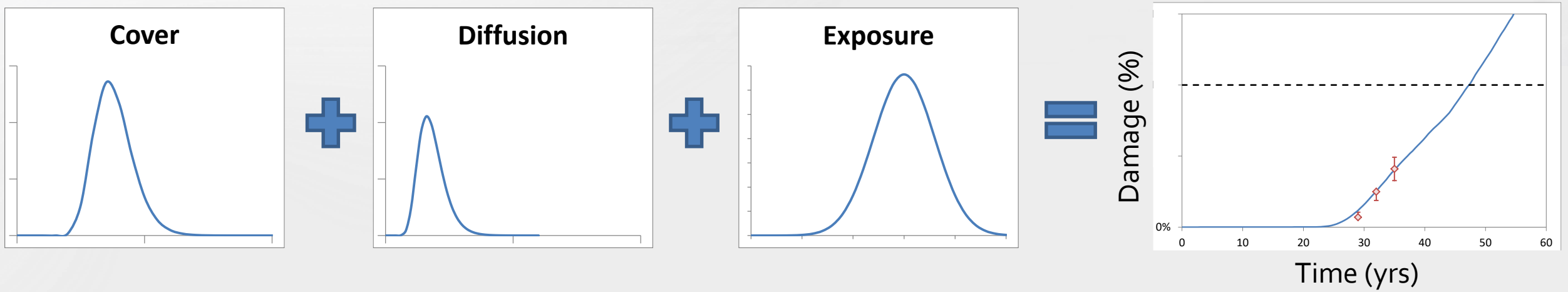
- ODOT Girders: Corrosion-induced concrete surface damage **> 15%**

Probabilistic Modeling

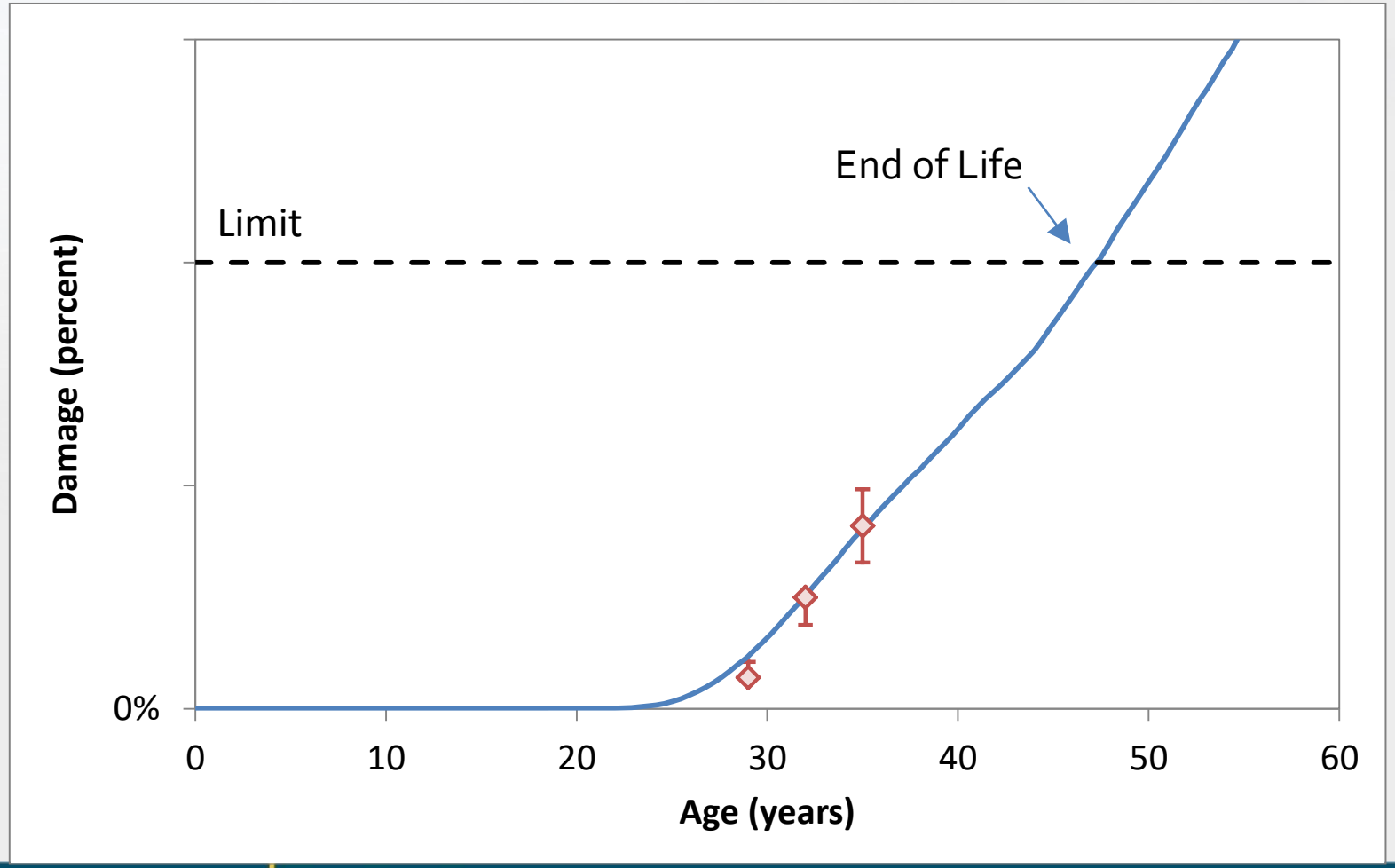


Probabilistic Approach

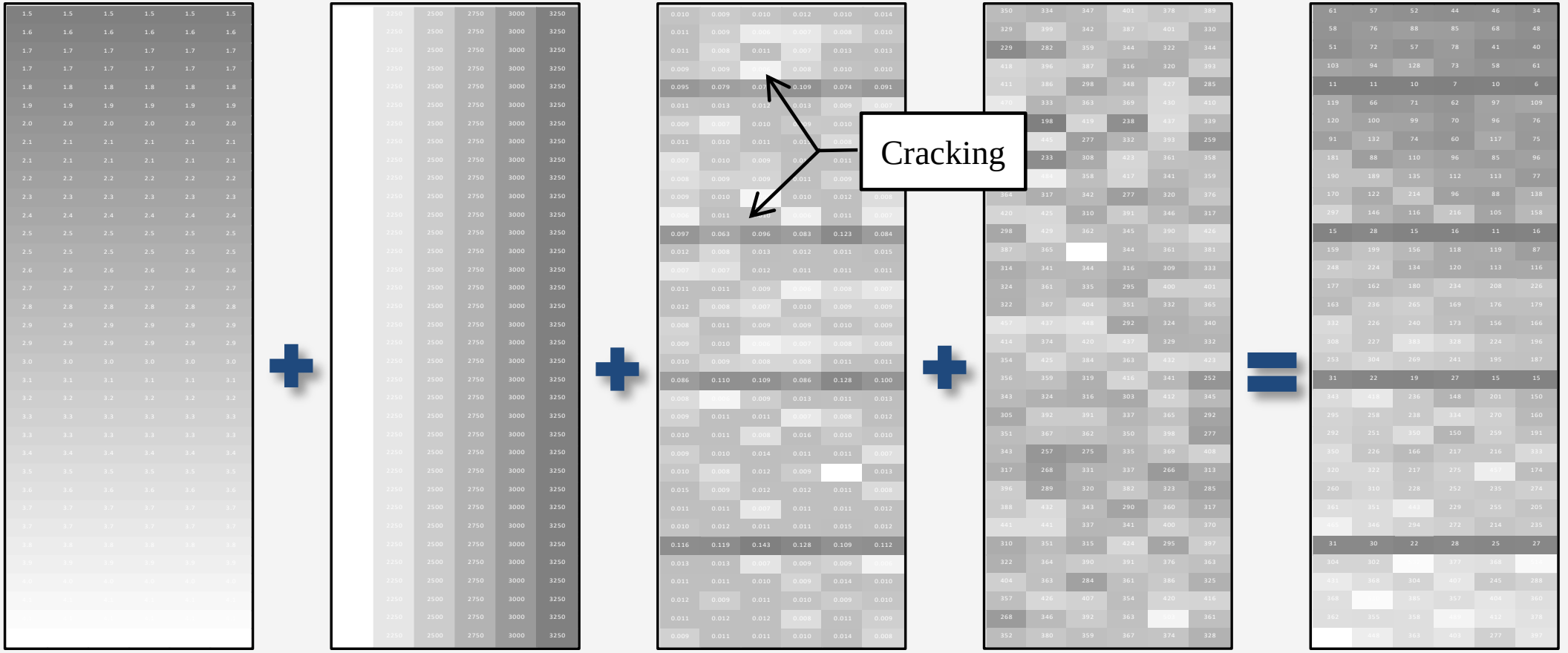
- Combinations of independent variables: Monte-Carlo Simulation



Probabilistic Approach



Probabilistic Analysis – Consideration of Cracks



Cover (Input)

Exposure (Input)

Diffusion Rates (Input)

Chloride Threshold (Input)

Initiation Time (Output)

Low Risk — *High Risk*

ODOT Girder Chloride Exposure

- Chloride tests on several bridges
  - Variable by geography and traffic density; joint condition
  - Three general chloride exposure levels:
    - Low exposure = 1,000 PPM
    - Moderate exposure = 2,000 PPM
    - Severe exposure = 4,000 PPM

ODOT Service Life Considerations

- Assumptions
  - Girder exposure
  - Concrete performance
  - Geometry (cover)

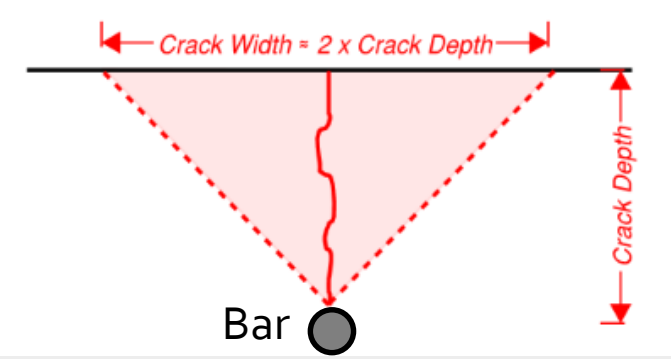
- Relative performance more important for ODOT
  - Allows cost-benefit evaluation of repair

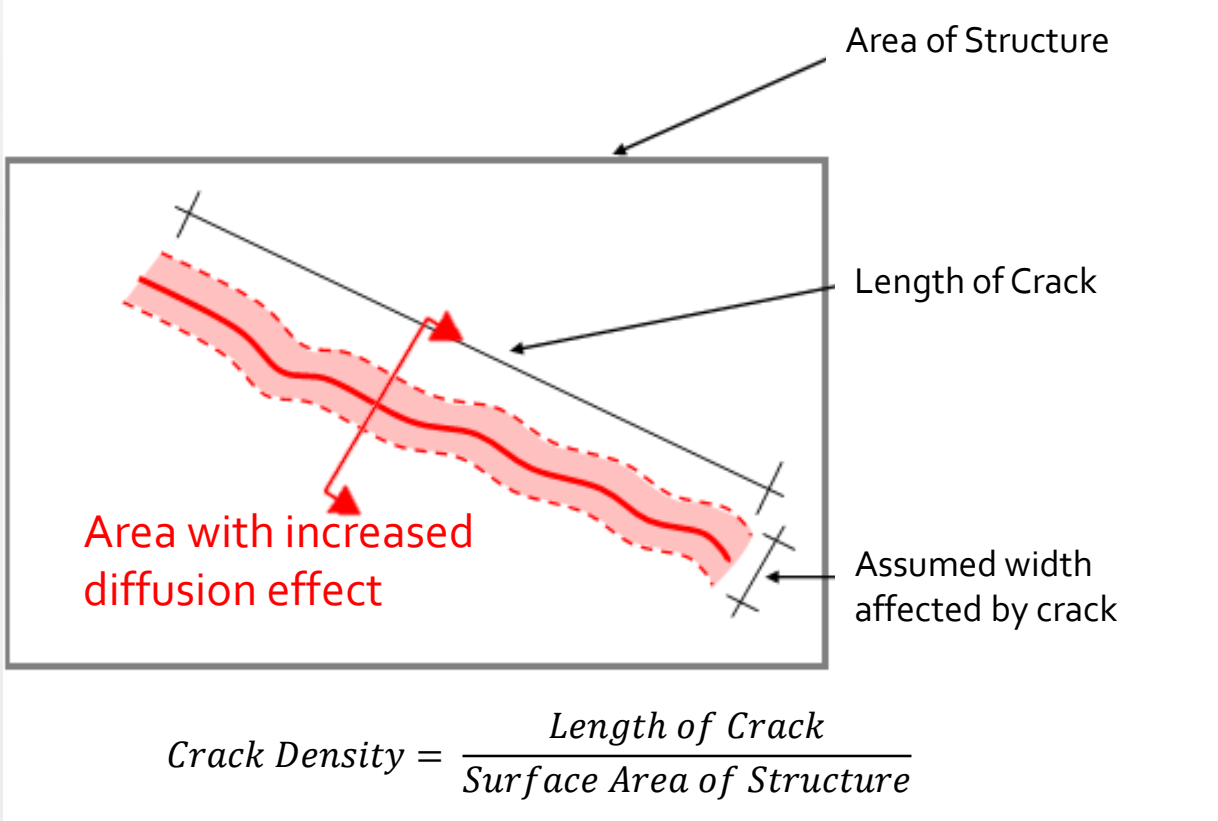
Parametric Study of Service Life

- Key factor: Cracking
- Factors:
  - Chloride exposure: Low, Moderate, or Severe
  - Crack density: 0 to 30 in^2/ft
  - Crack width: 0 to 12 mils
  - Two mixtures (two precasters)

Crack–Affected Surface Area

- Increased diffusion near cracks
  - Influence width equal to cover on each side of crack (45°)
  - ODOT: 1.5 in. concrete cover, so assume 3 in. of affected width

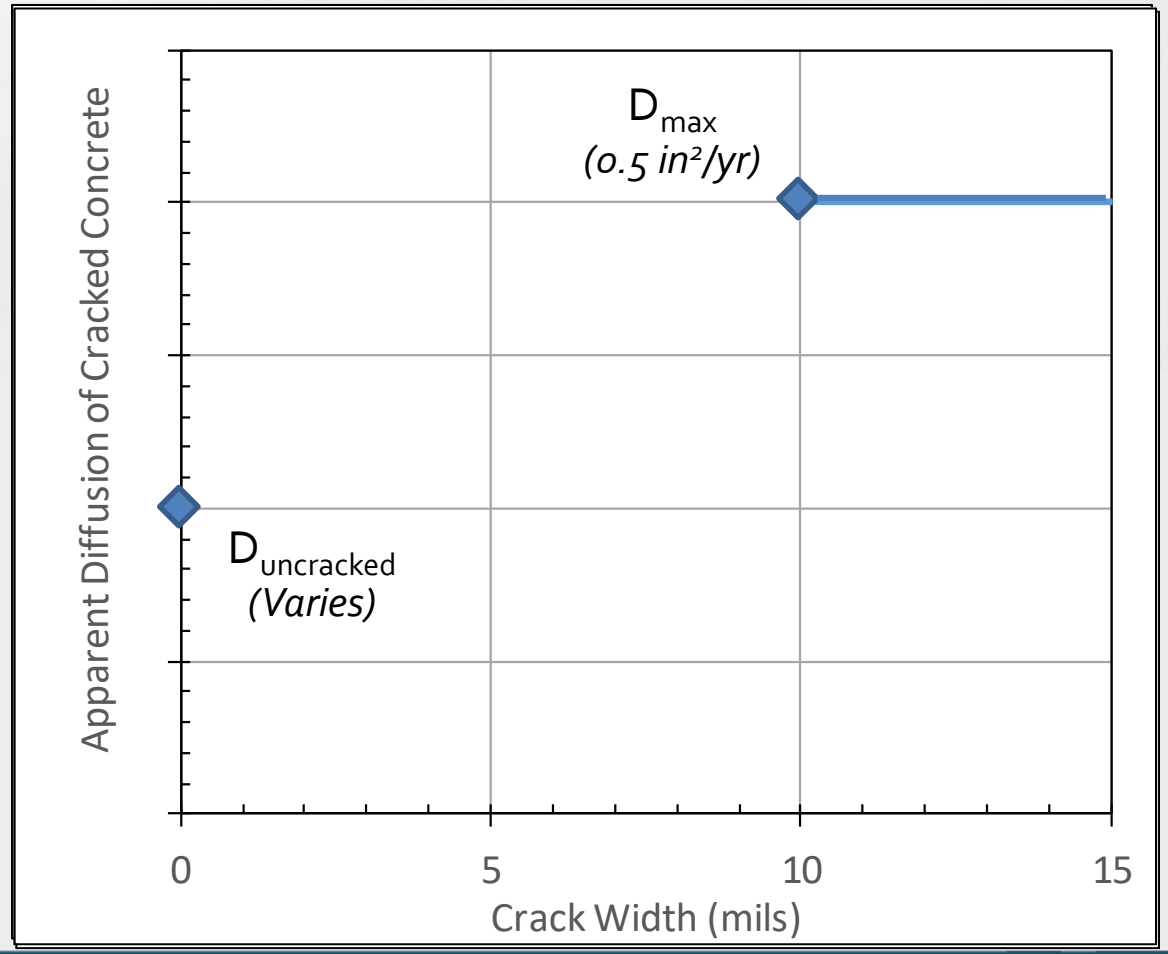




$$Crack\ Density = \frac{Length\ of\ Crack}{Surface\ Area\ of\ Structure}$$

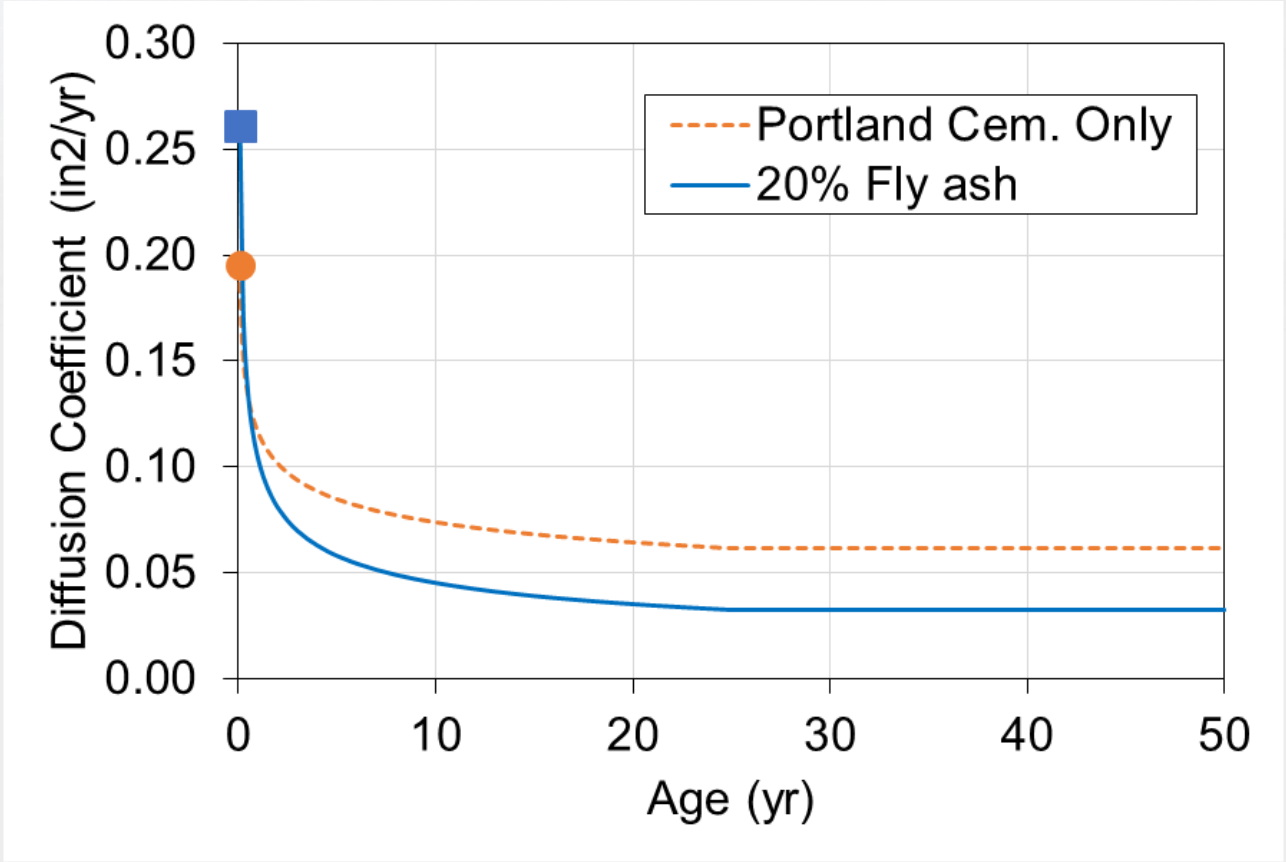
"Diffusion Coefficient" for Cracked Concrete

- Uncracked diffusion based on concrete mixture
- Large cracks (>10 mils): Max. diffusion of 0.5 in²/yr

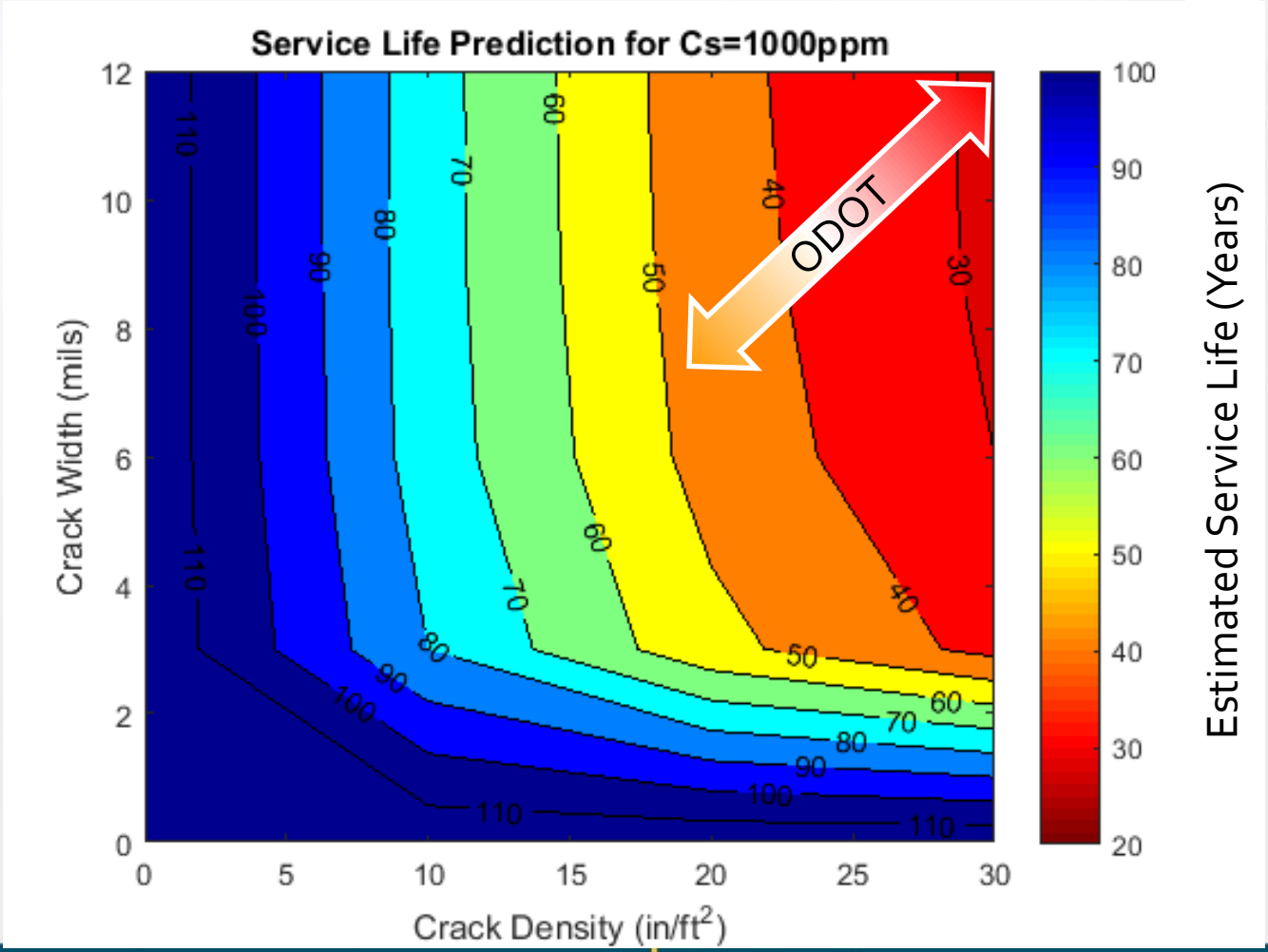


Diffusion Coefficient for Uncracked Concrete

- Empirical Model for Diff. Coef.
  - Mix 1:
    - Portland cement only
    - w/cm = 0.28
  - Mix 2:
    - 20% Fly ash
    - w/cm = 0.33



Predicted Service Life – Low Exposure

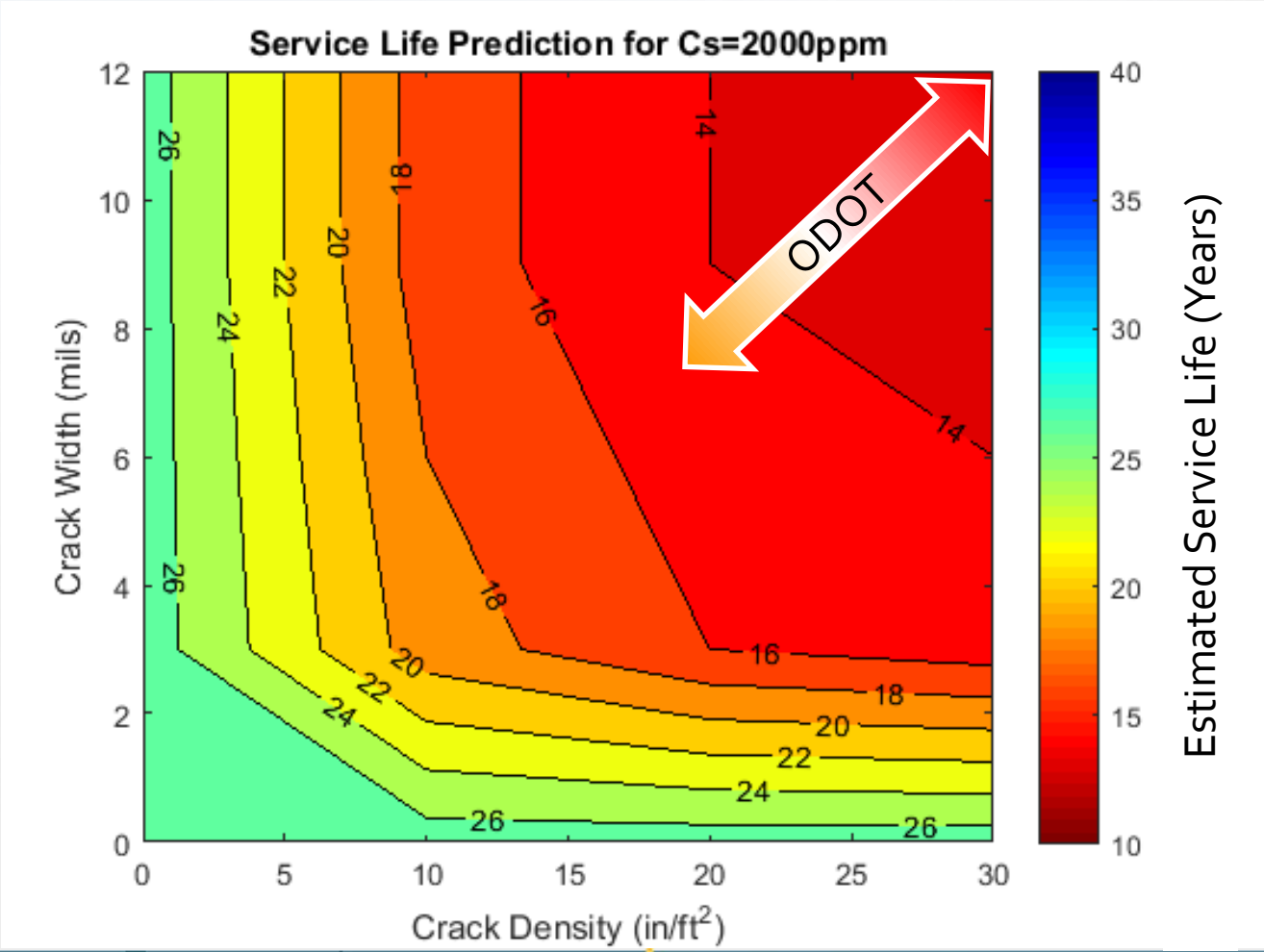


- SL reductions if both:
  - Crack density > 5 in/ft²
  - Crack width > 2 mils

Predicted Life

Exposure	Uncracked	Cracked (observed)	Potential Reduction
Low	100+ yr	~30 yr	70%

Predicted Service Life – Moderate (and Severe) Exposure



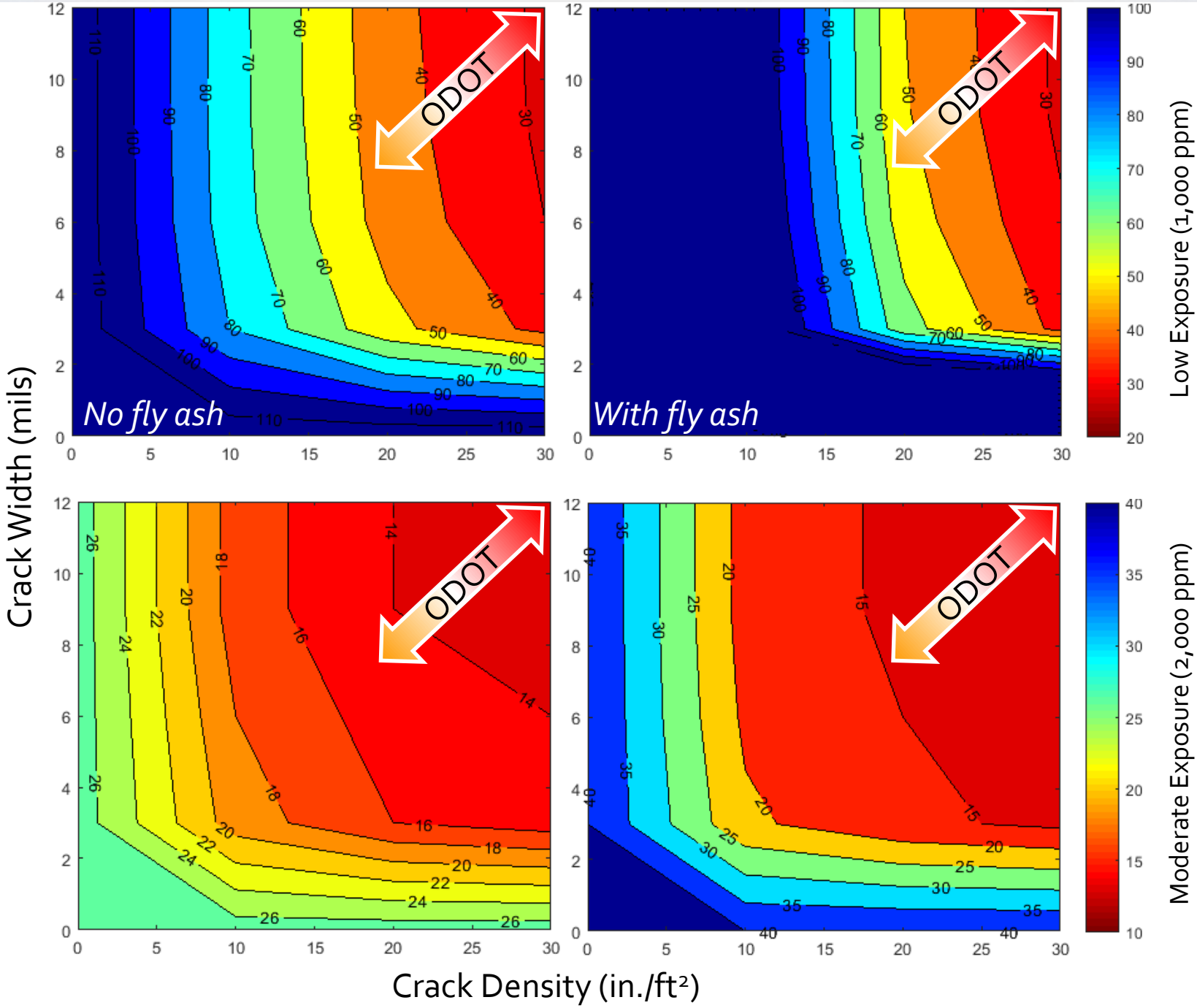
- SL reductions for nearly all crack width and density
- Relative magnitude of reduction less than low exposure

Predicted Life

Exposure	Uncracked	Cracked (observed)	Potential Reduction
Moderate	~30 yr	~15 yr	50%
Severe	~17 yr	~10 yr	40%

Influence of Mix

- In uncracked concrete, SCMs improved service life
- Cracks override benefit from SCMs



Crack Repair

- **Service Life Modeling ➡ Cracks should be repaired**

- Conventional options:
  - Epoxy injection, but unnecessary for anchorage zone (not structural in nature)
  - Silane, but most efficient when addressing small cracks (< 10 mils)

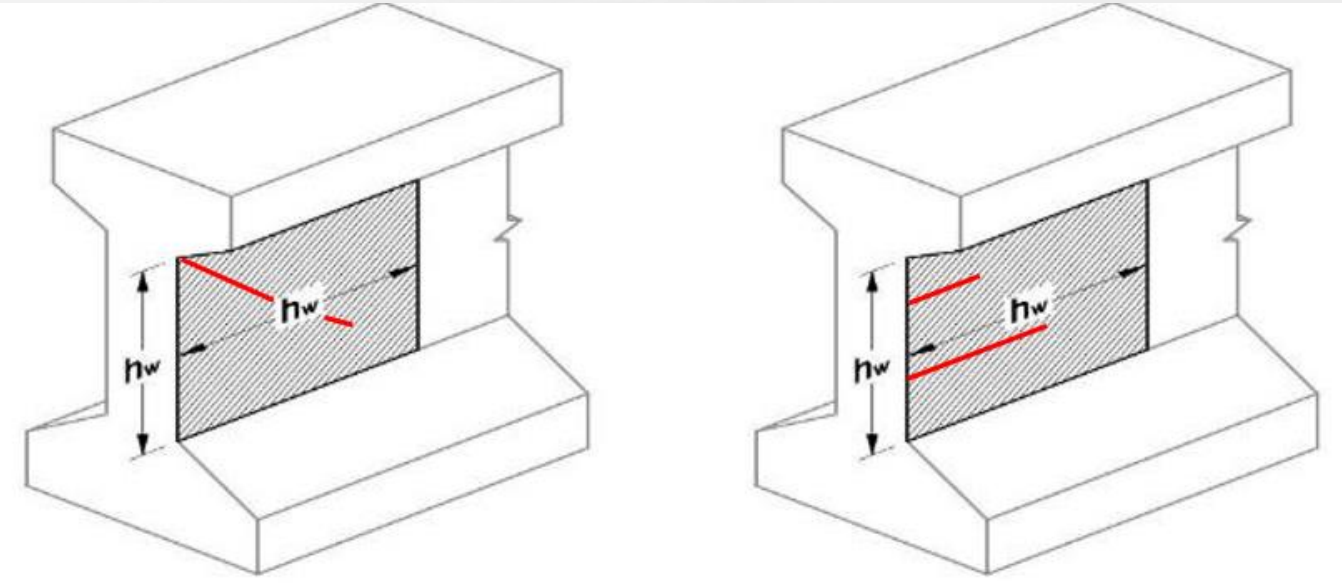
- ODOT: No current consensus strategy

Discrete Crack Seal

- For primary cracks (> 10 mils), local surface application:
  - Epoxy paste:
    - Rigid - trouble if cracks grow
  - Acrylic/silicone/polyurethane sealant:
    - Flexible - accommodate crack growth

Blanket Crack Treatment

- More helpful if > 10 in./ft² of cracking present
- Review need after addressing wide discrete cracks



Blanket Crack Treatment

- Epoxy/polymer-resin based surface sealers
- Silane with either acrylic paint or silicone resin coating
- High-build elastomeric polyurethane with aliphatic top coat

Implementation of Combined Strategy

- Ensure compatibility of discrete and blanket treatment systems

System	Discrete Crack Seal	Blanket Treatment
Rigid	Epoxy	Epoxy/polymer-resin based surface sealers
Flexible	Acrylic/silicone/ polyurethane "caulk"	Silane & acrylic/silicone coating; or High-build polyurethane w/top coat

Repair for New Girders

- Delay treatment until shortly before shipment or > 56 days if possible, due to crack growth
  - Flexible materials more forgiving
- Recommend treat all girders

Repair for Existing Girders

- Focus below expansion joints

Conclusions

- High density of cracking in webs at anchorage zones not structural, but likely to impact durability
- WJE performed modeling considering cracks to quantify relative impact on service life
- Combined crack repair strategy to address both narrow and wide cracks recommended

Thanks! Questions?

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