CONCRETE BRIDGE DETERIORATION

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Introduction

- Concrete bridge deterioration is one of the leading causes of highway structural deficiency.

- Possible mainly in two forms:

  Concrete distress

  Reinforcement corrosion

Bridge Concrete Deterioration

- Types of deterioration generally appearing in concrete:
  - Scaling
  - Spalling
  - Cracking
  - Abrasion damage
  - Mortar flaking
  - Alkali aggregate reactivity
  - Delamination
  - Freeze thaw
  - Sulphate attack

Scaling

Local flaking or peeling away of the near surface portion of hardened concrete

Common Causes:

- Poor air entrainment
- Improper finishing
- Deicing salts
- Surface softening

* Source: ACI Committee 116

Scaling

Surface scaling of concrete

Spalling

- Occurs when a segment of the concrete surface, frequently a rough circular or oval shape, is missing.
- Two common causes of spalling are:
  - corrosion of the reinforcement
  - improperly constructed or maintained joints
- Without a doubt, surface spalling is the most serious and troublesome type of bridge deck distress.

Spalling

Spalling caused by corroded reinforcement

Spalling

Joint deterioration

Cracking

- Many cracks form in the early stages of and worsen over time, while others form after the concrete has matured and the structure is open to traffic for some time.

Cracking

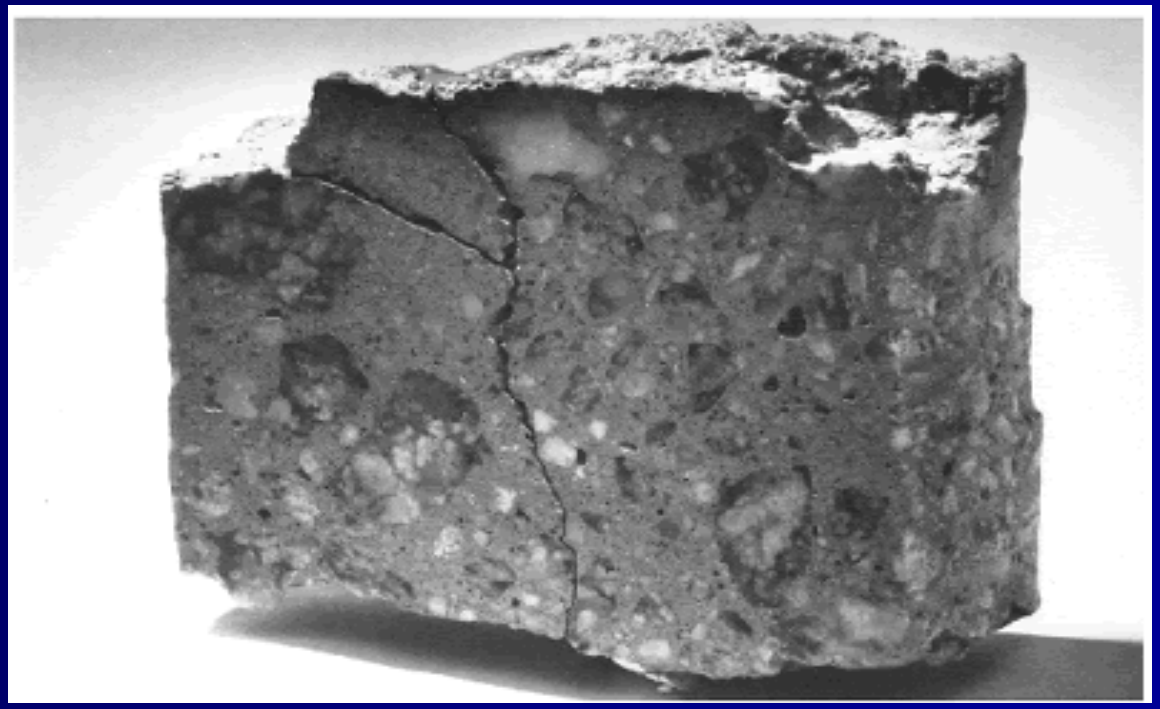
- Some of the most common types of cracks are:
  - Plastic Shrinkage Cracks
  - Drying Shrinkage Cracks
  - Settlement/Subsidence Cracks
  - Temperature Induced Cracks
  - Flexural Cracks
  - Shear cracks

Plastic Shrinkage Cracks

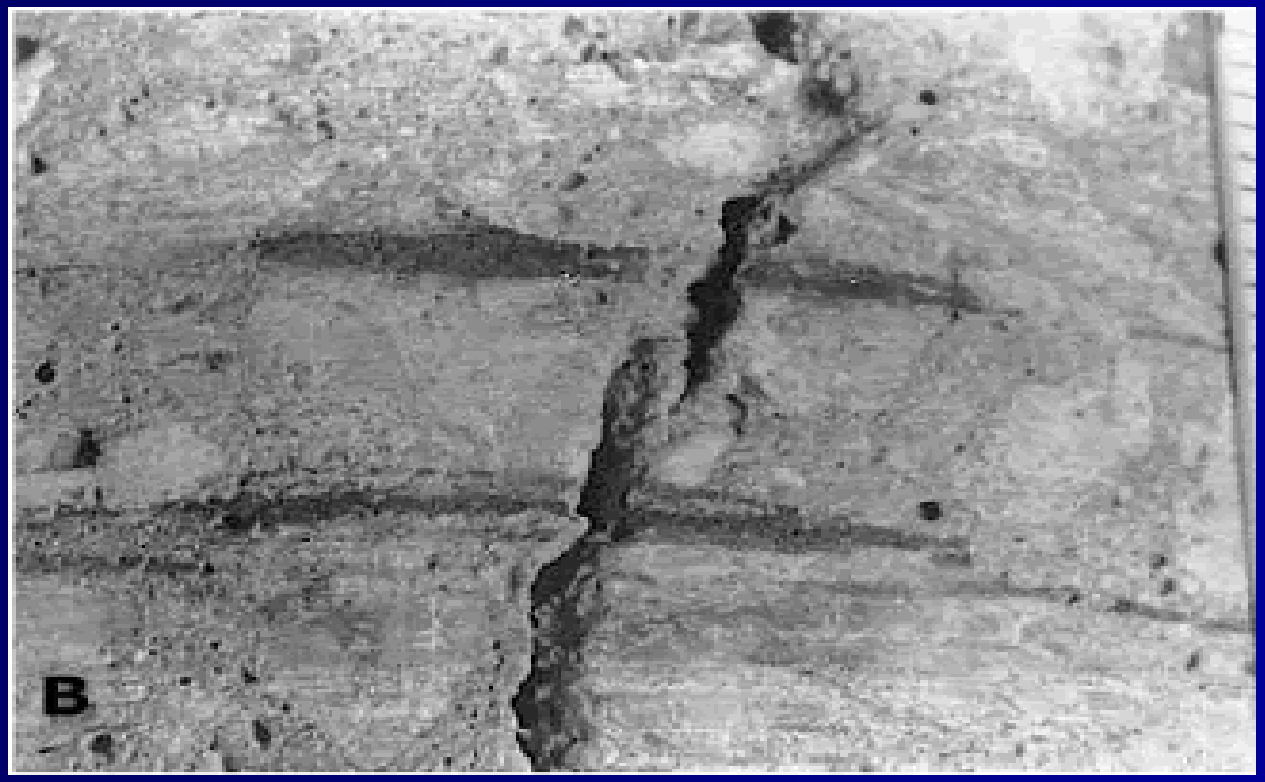
- Plastic shrinkage cracks form in the deck when the evaporation rate exceeds the bleed rate of newly placed plastic concrete.

- Extreme environmental conditions and high concrete temperatures increase the surface evaporation rate and thus increase the deck vulnerability to plastic shrinkage cracks.

Plastic Shrinkage Crack



Drying Shrinkage Crack



Flexural Cracks

- Can form when the concrete is in it's initial maturing stage just after placement as well as in service.

- If unshored, concrete in its plastic stage can develop flexural cracks in the negative moment regions over the interior supports of continuous spans due to the dead weight of the girders plus the newly placed concrete.

Flexural Cracks

- When the deck is in service, the addition of live loads can also cause cracking in the negative moment regions.
- Furthermore, gravity loading can cause under-deck cracking in the positive moment regions of both simply supported and continuous spans.

Deck Cracking

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Settlement/Subsidence Cracks

- These cracks form over and parallel to the top-most reinforcement as the concrete settles around the bars as it dries.

Temperature Induced Cracks

- Unrestrained concrete undergoes volumetric changes as it experiences temperature variations
- The mechanism that causes thermal cracks in decks is very similar to that which causes drying shrinkage cracks

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Abrasion Damage

- Abrasion damage in wheel tracks can be caused by studded tires and chain wear
- Such damage can also be caused by the blades of snow ploughs
- In addition, abrasion damage manifests itself as polishing of the aggregates which can lead to a slippery surface

Abrasion Damage

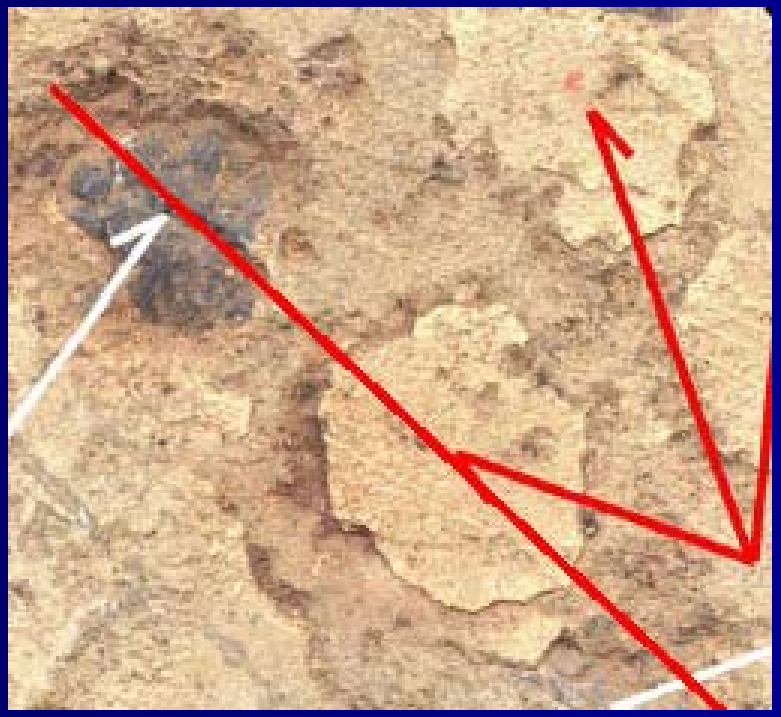
Mortar Flaking

- Loss of surface mortar from above the top side of near-surface aggregate particles due to

  - Prolonged finishing of thin surface mortar over the top side of near-surface aggregate particles

  - Inadequate curing

Mortar Flaking



Alkali Aggregate Reactivity

- Alkali Silica reactions (ASR)

Reactive silica in aggregate + cement alkalis = Gel → Expands = Cracking

Alkali Aggregate Reactivity

Alkali Carbonate reactions (ACR)

Dolomite in reactive carbonate rocks + cement alkalis =
Calcite + Brucite

As a result expansion by --- Moisture absorption of clay in the rock

---- Insitu formation of Calcite/Brucite

Expansion, cracking

Delamination

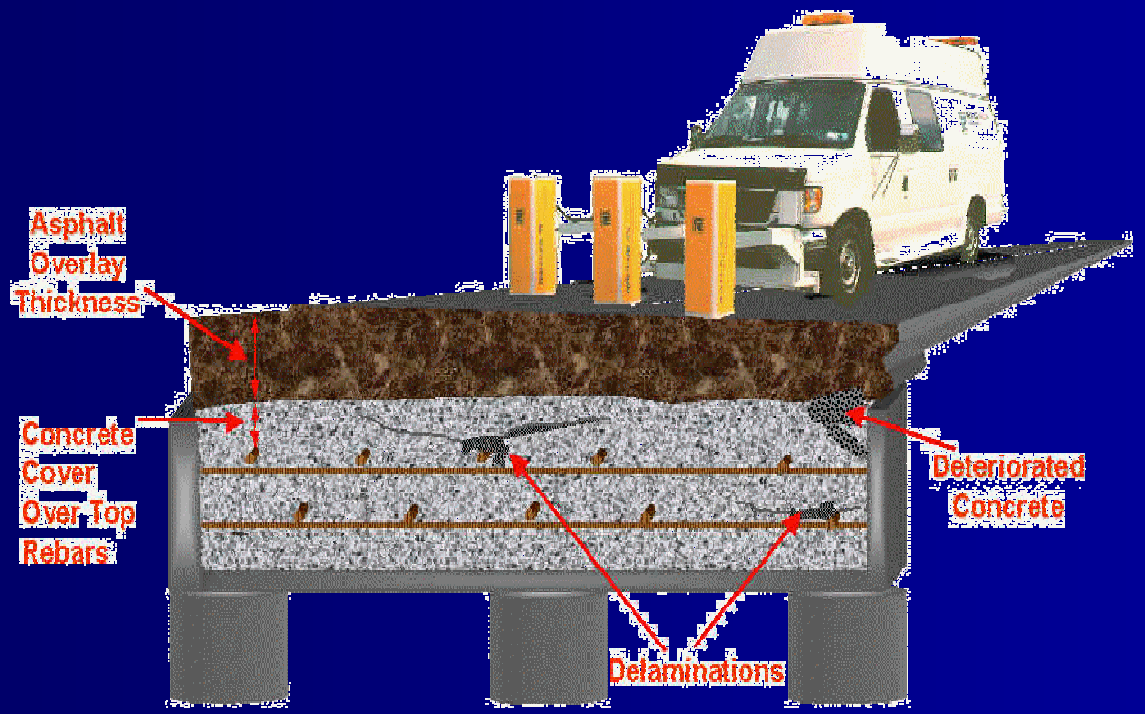
- Horizontal plane of concrete separation analogous to a skin blister that usually occurs at or just above the top reinforcement in the deck.

- Analogous to a skin blister that usually occurs at or just above the top reinforcement in the bridge deck.

Delamination

- **Common causes**
  - Air entrainment in concrete which will receive a hard machine trowel finish
  - Premature finishing before the cessation of bleeding
  - Prolonged finishing
  - Factors that increase bleeding duration, rate and capacity
  - Surface crusting, top-down stiffening, premature finishing
  - Corrosion of reinforcing steel in concrete
  - Cyclic freezing

Delamination



Delamination

Delamination by corrosion of reinforcing steel in concrete

Corrosion of Steel in Concrete Girder and Column

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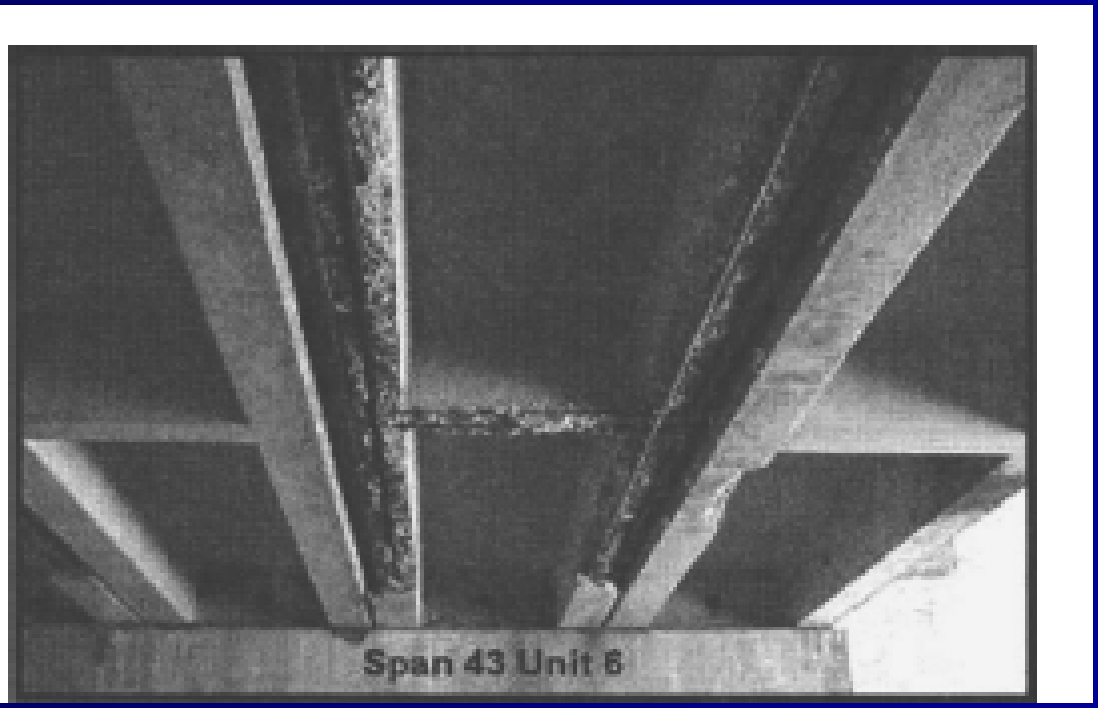

Girder deterioration due to corrosion of reinforcing steel

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Corrosion of Steel in Concrete Girder and Column

Concrete spalling by rebar corrosion in column

Acid Attack

Being alkaline in nature, exposure to acidic solutions causes loss of mass and loss of strength of concrete

Corrosion of column bases exposed to acidic solution

Summary

- Many components and processes make concrete bridges highly susceptible to deterioration.
- Good quality control in the beginning, together with adequate maintenance and inspection will help in deterioration control.