Concrete Floor Covering Failures

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Introduction

- *Background:*
  - *Contributors to failure*
  - *Mechanisms of failure*

- *Unique Floor Covering Failure Case Studies:*
  - *Alkali-silica reaction*
  - *Sulfate attack*
  - *Osmotic pressure*
  - *Chemical attack (alkaline hydroxide)*

Contributors to Failure

"The Commonly Accused Culprits"

- *Improper Application and Material Problems*
- *Vapor and Vapor Pressure*
- *Moisture (liquid)*

Application and Material Problems

- *Application Issues:*
  - *Slab construction/design deficiencies*
  - *Improper surface preparation*
  - *Installation at elevated moisture-vapor transmission rates*
  - *Improper mixing*

- *Material Problems*
  - *Material incompatibility*
  - *Improper formulation*

Vapor and Vapor Pressure

- *Vapor - " a substance in the gaseous state, as distinguished from solid or liquid matter"*
- *Water Vapor Pressure – caused by a water vapor gradient, e.g. movement from areas of high humidity to areas of low humidity*
  - *Moisture-vapor pressure in a floor slab is generally very low relative to a well adhered floor covering*
  - *Moisture-vapor emission rates can be assessed qualitatively (ASTM D4263 - plastic sheet method) and quantitatively (ASTM F1869 - anhydrous calcium chloride method)*
- *Moisture vapor can condense to water in a slab.*

Sources of Water in a Slab on Grade

- *Moisture - If the concrete is "dry" at the time of application and remains so during service of the floor covering system, most types of floor covering failures will never occur!*
- *Sources of Water – residual mixing water from the concrete, curing water, washing water, rainfall, condensation of water vapor, and water from slab substrate via hydrostatic pressure, capillary rise, or osmosis. (Ref. June/April 2003 Concrete International)*
- *Most floor coverings are sensitive to presence of moisture at application and some continue to be sensitive to moisture even after application and curing*
- *The availability of moisture can cause other mechanisms of distress to occur, which can be disruptive to floor coverings*

Mechanisms of Failure

- *Alkali-silica Reaction*
- *Sulfate Attack*
- *Osmotic Pressure*
- *Chemical Attack (alkaline hydroxide)*

Failure Mechanisms

Alkali-Silica Reaction (ASR)

- *A reaction between reactive siliceous aggregate particles and hydroxyls of the pore solution*
- *High alkali content of portland cement*
- *Reactive siliceous aggregate*
- *Sufficient moisture*

Failure Mechanisms

Sulfate Attack

- *A reaction between sulfate ions normally from an external or internal source and calcium aluminate and calcium hydroxide of the cement paste*

- *Sulfate attack can cause expansion, cracking, and crumbling of paste*

Failure Mechanisms

Osmotic Blistering

- *Associated with osmosis, in which a solvent (water) passes through a semi-permeable membrane (concrete surface) from a dilute solution to a more concentrated solution*
- *Liquid volume increases as osmotic pressure builds up, causing debonding/blistering*

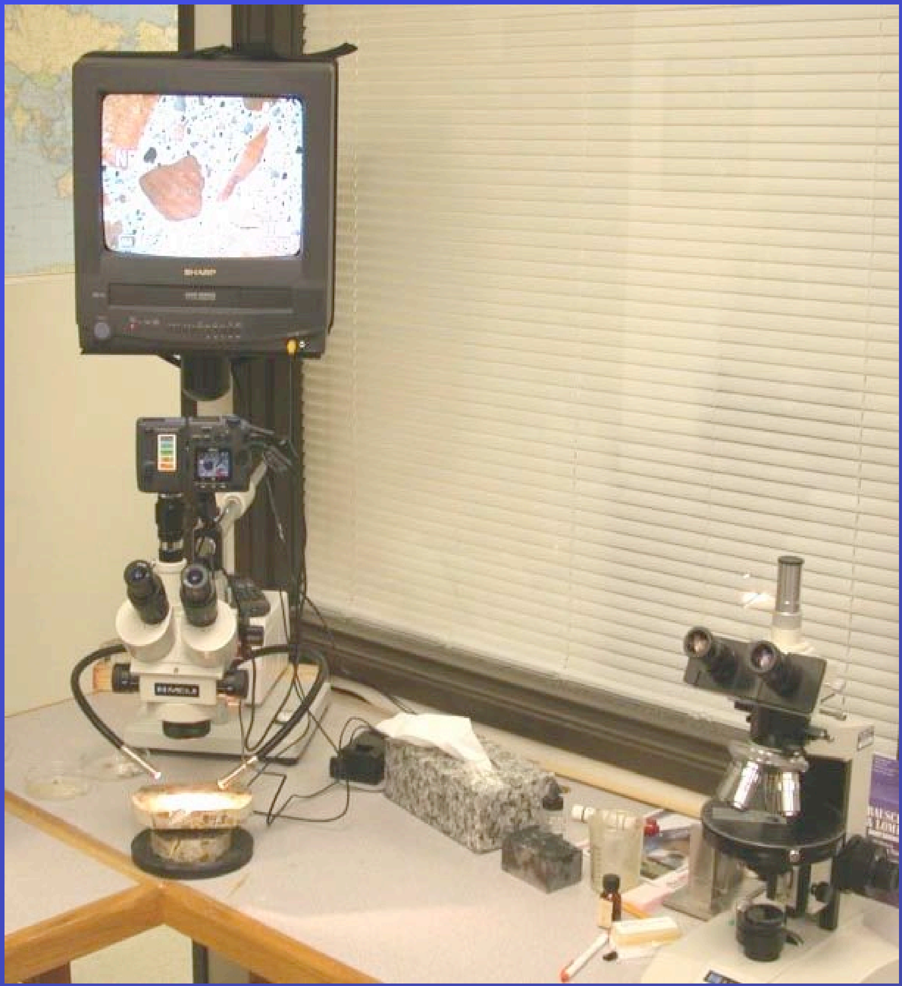
Failure Mechanisms

Chemical Attack (Saponification)

- *Portland cement and wet portland cement concrete have a high pH typically ranging between 13 and 14*
- *Calcium, sodium, and potassium hydroxide are soluble constituents of portland cement*
- *Non-carbonated surfaces or surfaces contaminated with transported alkaline hydroxides can result in a high pH environment that can cause degradation of some adhesives*

Typical Investigation Methods

- *Condition survey (look, touch, smell…)*
- *Moisture-vapor emission testing (ASTM F1869)*
- *Pull-off testing (ASTM D4541, ACI 503R)*
- *Concrete Petrography - To estimate mix proportions and identify problems associated with mixing, finishing, and deleterious distress mechanisms*
- *Chemical studies for determining pH and compositional characteristics of concrete surfaces (ASTM D4262, XRD/SEM-EDX)*



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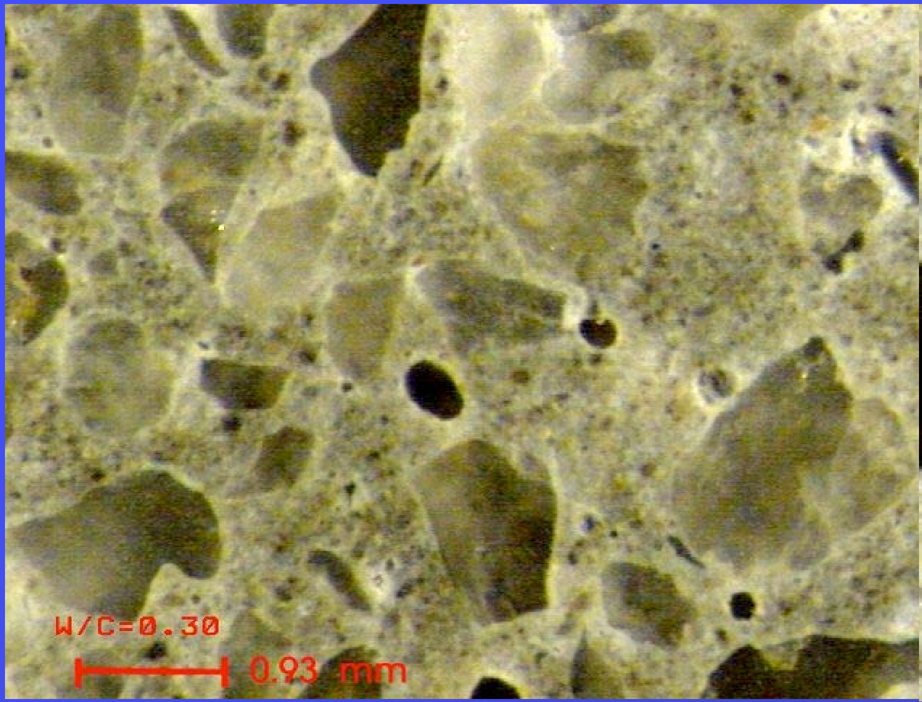
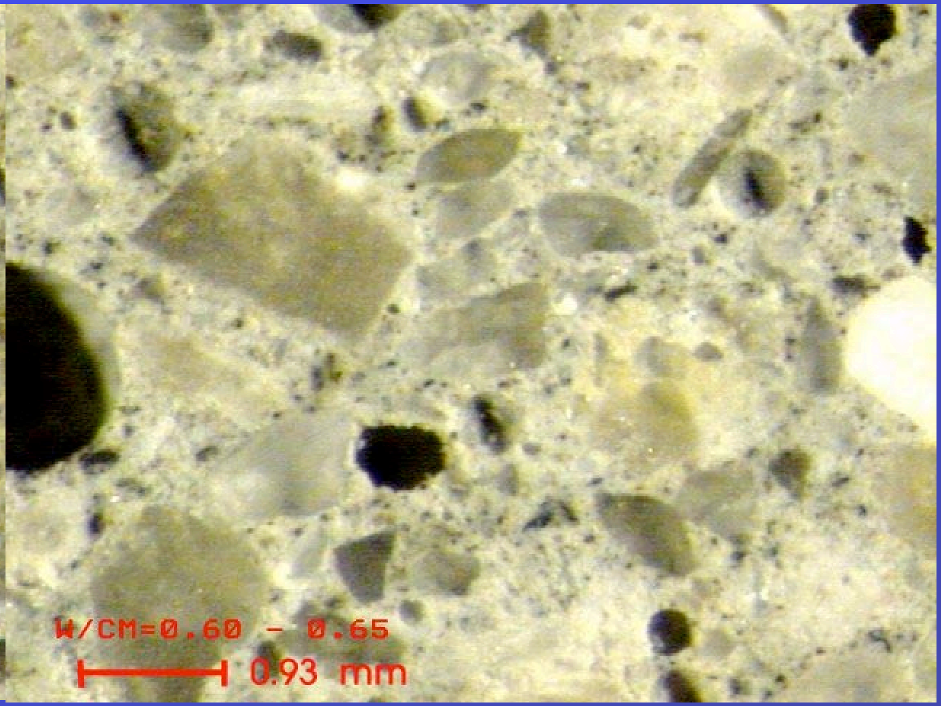
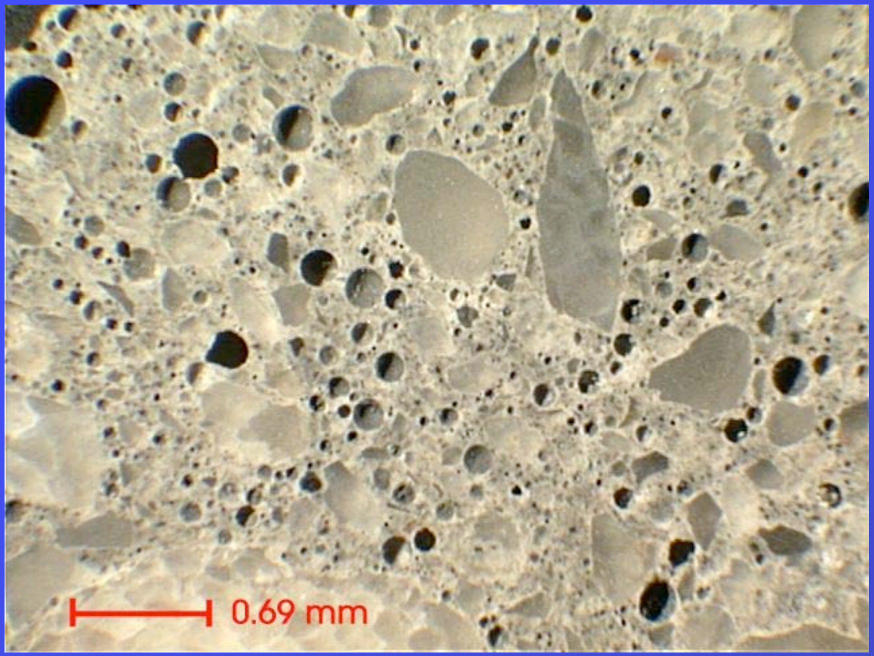
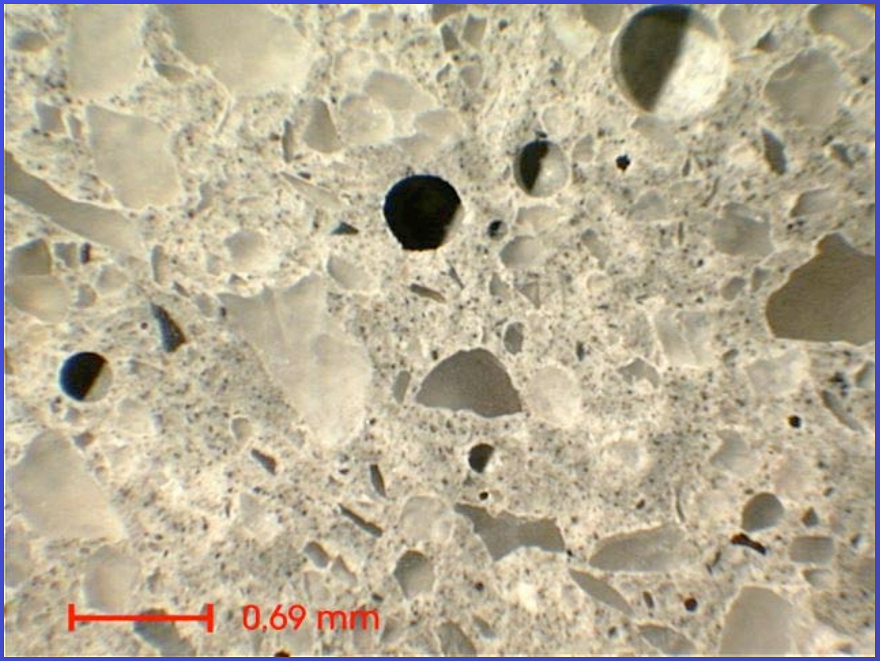




Air voids





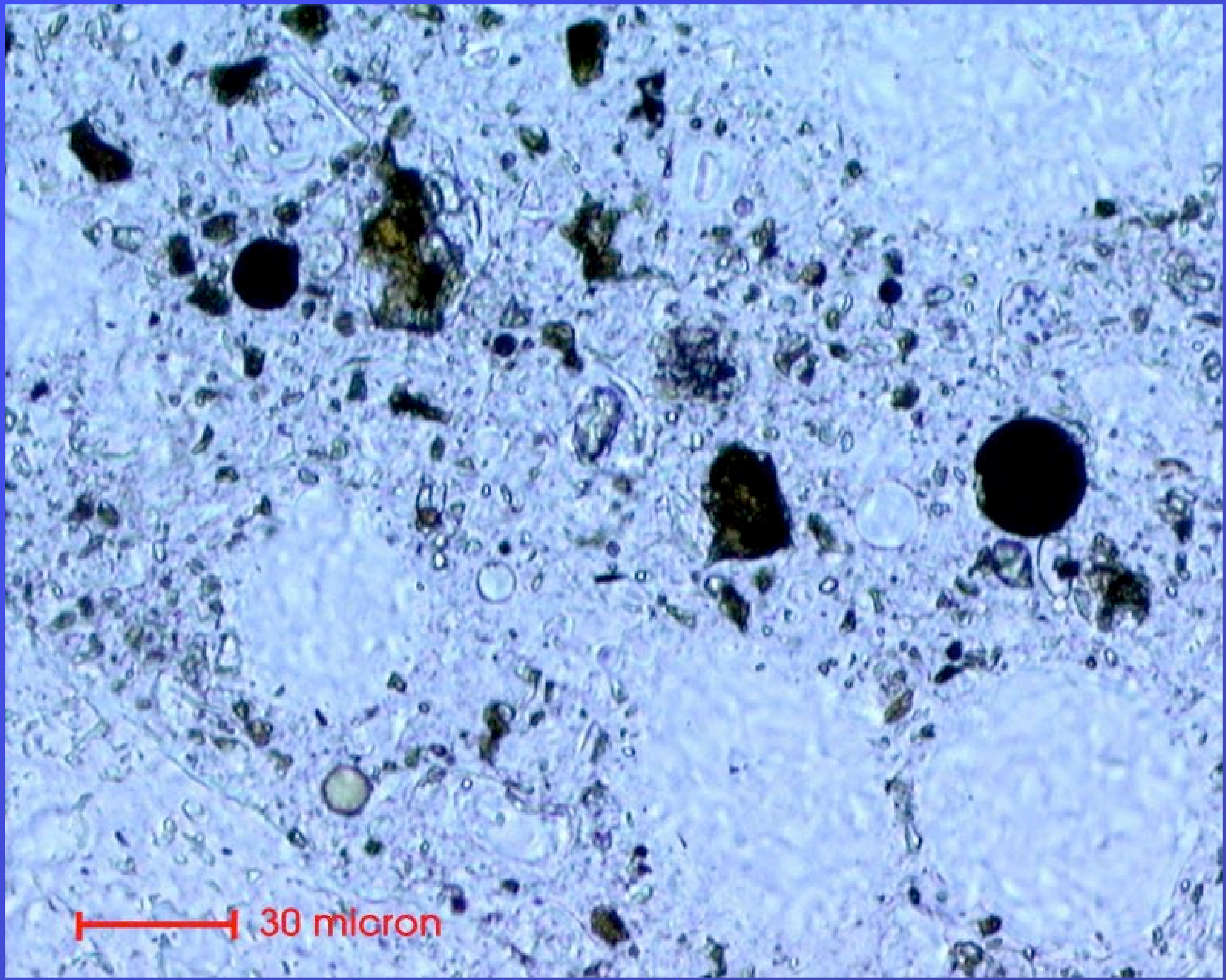
Case Study No. 1 - ASR Induced Floor Covering Failure

General Observations:

- *Epoxy coating applied on a two-year-old concrete slab with vapor barrier underneath*
- *Scaling and blistering observed within several months of application*
- *Cores were taken and examined petrographically*
- *Concrete was of good quality*
- *Near-surface ASR was identified involving fine rhyolite particles*
- *No ASR detected at the interior of the concrete*

Epoxy floor system

cementitious

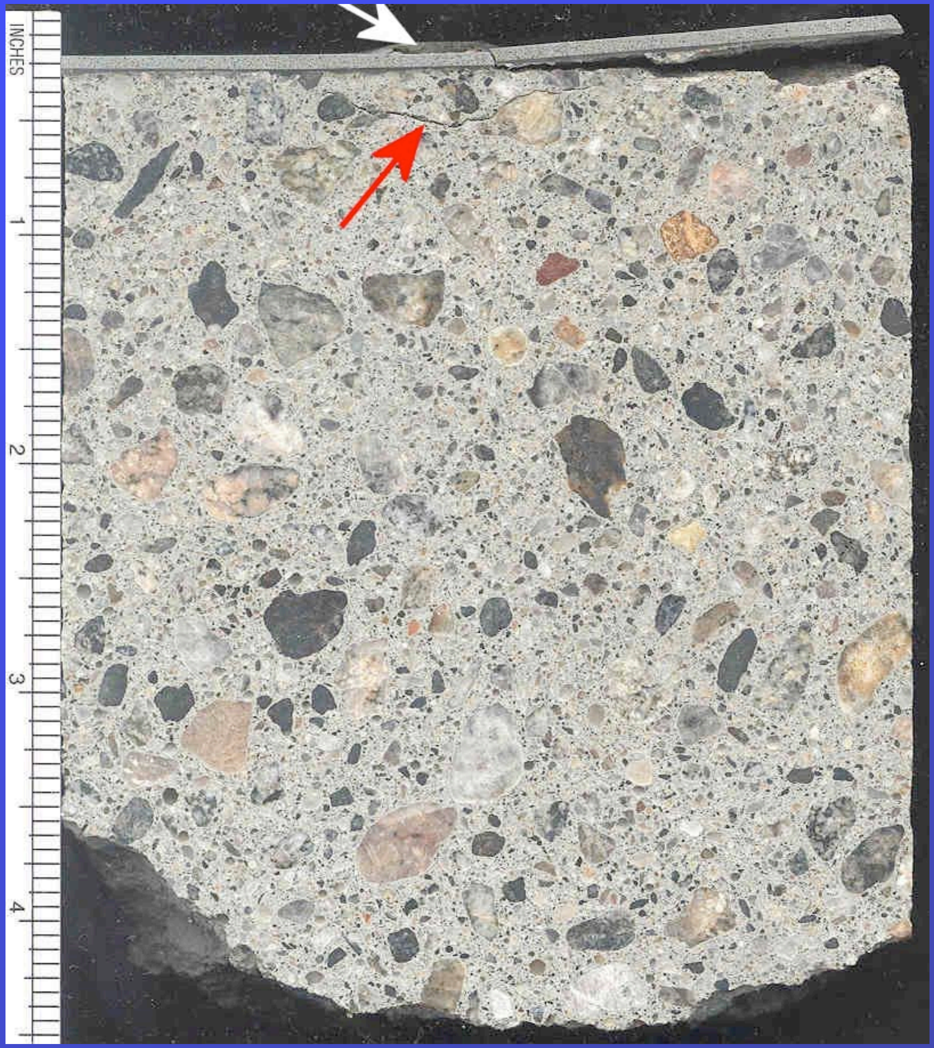


Region of debonded epoxy

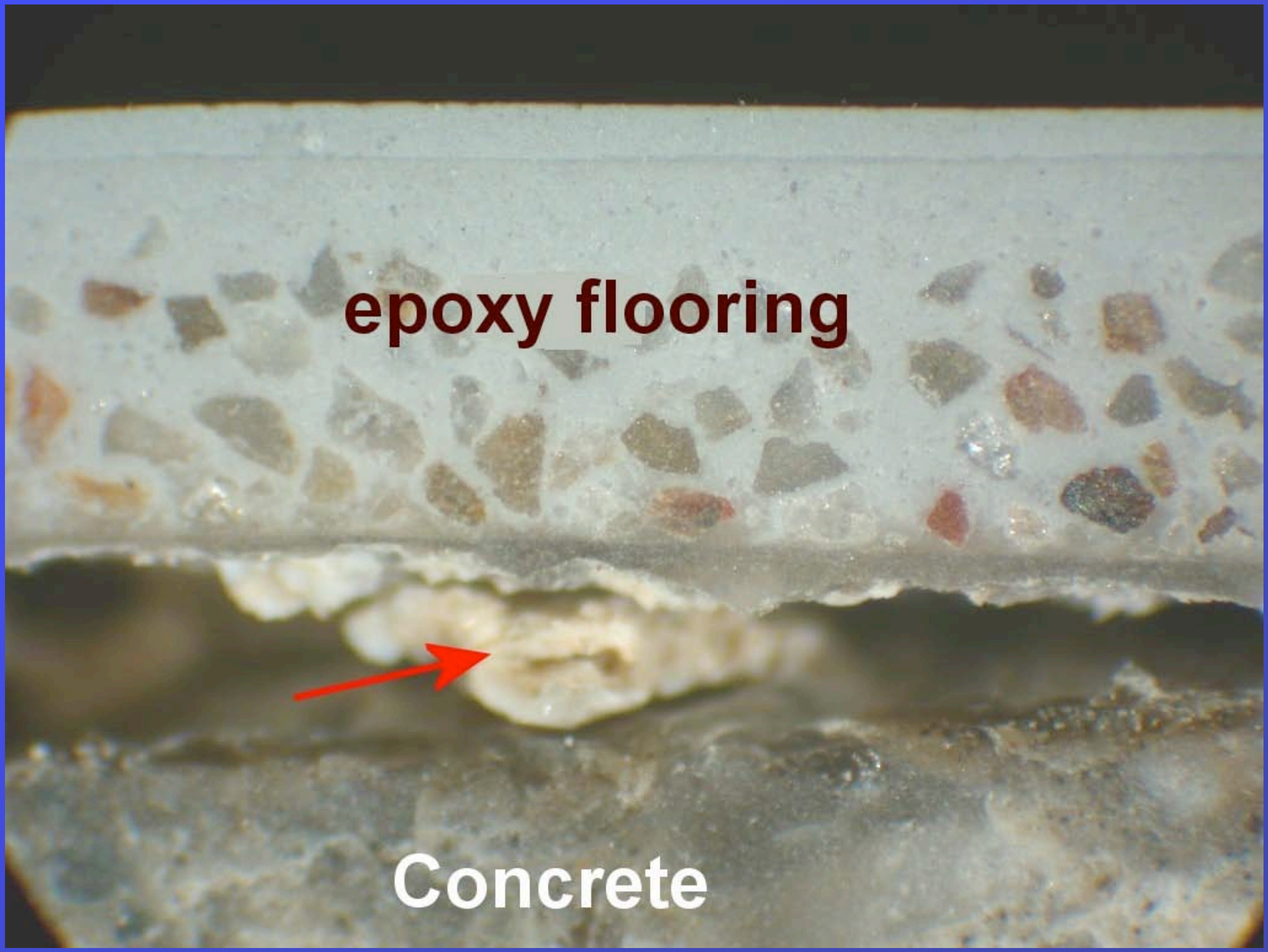
Concrete entrance

Typical surface scaling in exterior concrete

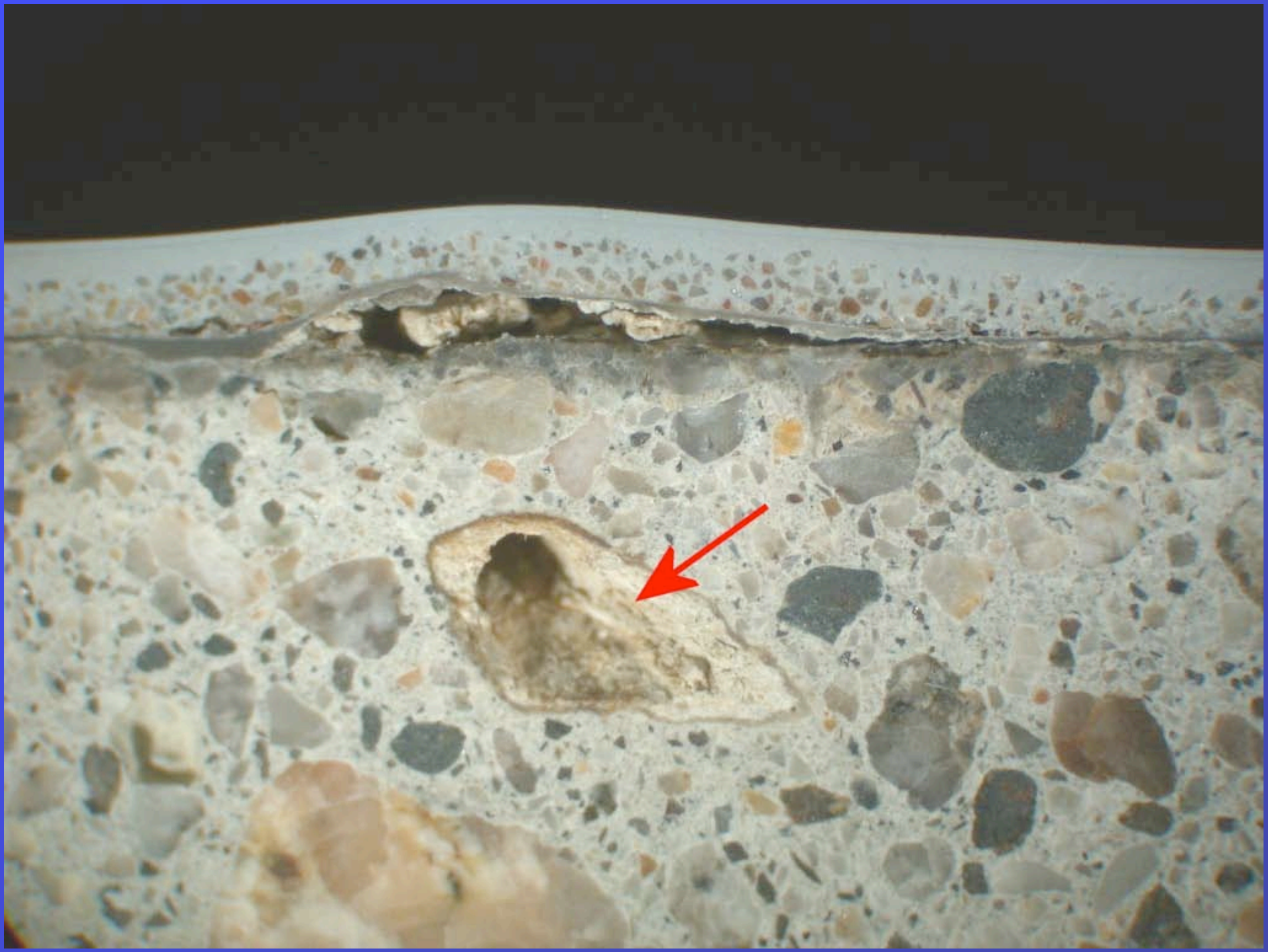
Sample cross-section at disbonded area



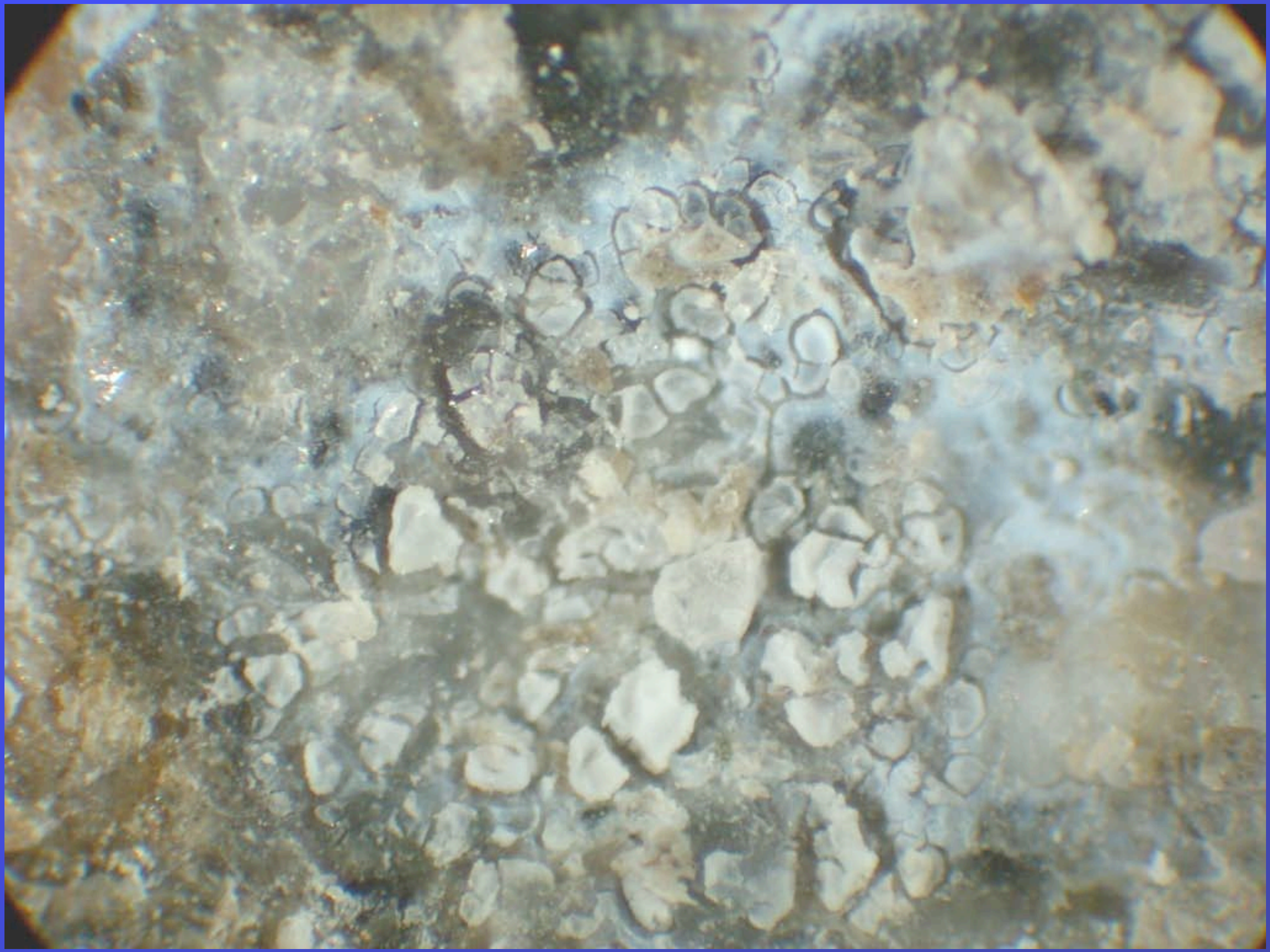
ASR gel at interface



Reactive aggregate near surface



ASR gel on concrete surface



ASR Induced Floor Covering Failure

Probable causes of near-surface ASR:

- *Segregation resulting in reactive aggregate concentrated only in the near-surface region*
- *Significant moisture gradient with high near-surface moisture content*
- *Alkali gradient*

ASR Induced Floor Covering Failure

Chemical testing: Acid soluble and water soluble alkali content

Depth (in.)	*Na_2O_{eq} (acid soluble)*	*Na_2O_{eq} (water soluble)*
0 to 1/2	*0.18%*	*0.05%*
3-1/2 to 4	*0.16%*	*0.031%*

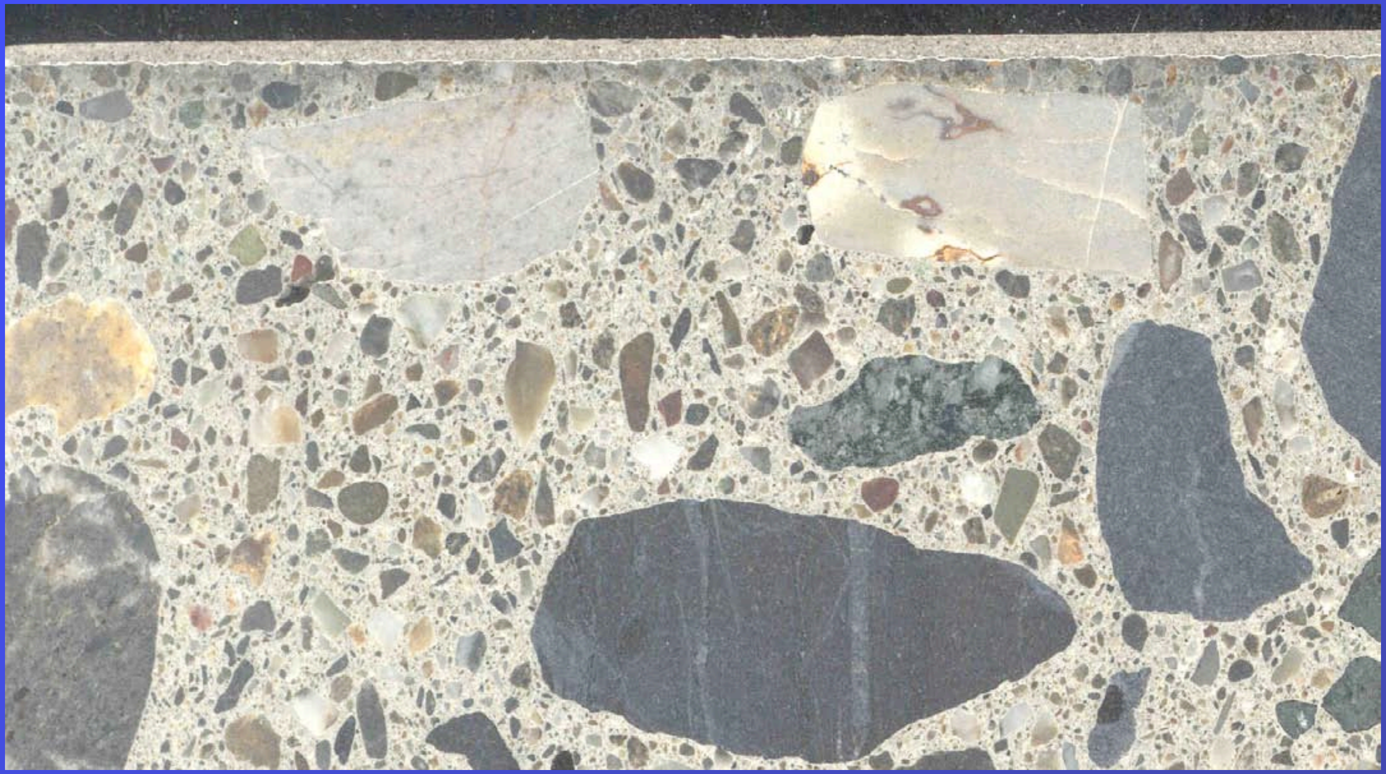
Bleed water and/or upward moisture movement transported alkalis to the near-surface region of the concrete.

Case Study No. 2 - Floor Covering Failures due to Sulfate Attack

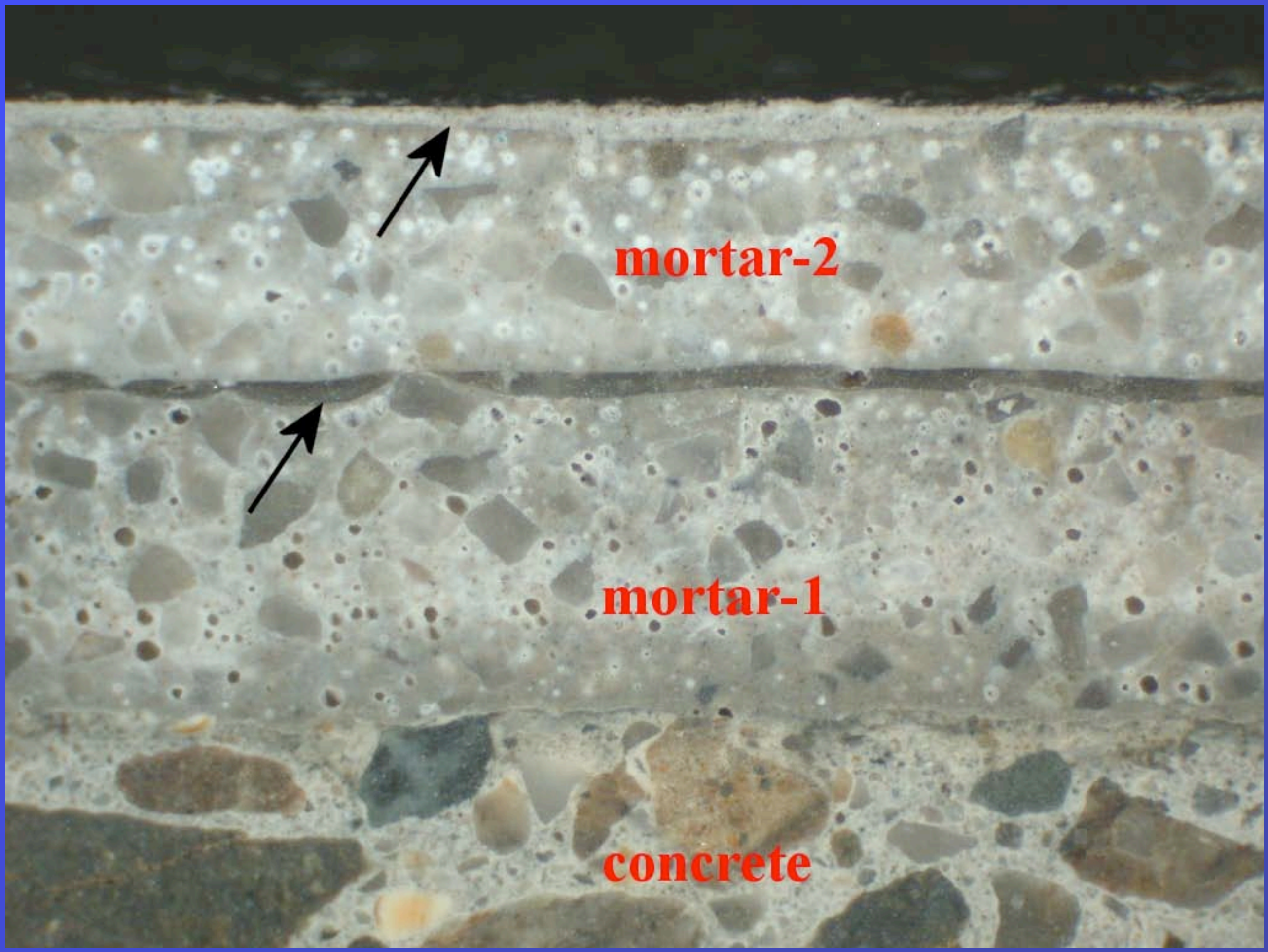
General Observations:

- *Vinyl tiles and sheet vinyl were installed on a slab-on-grade less than two years old*
- *Localized debonding occurred within a few months*
- *Petrographic examinations were performed on concrete cores taken from the slab. The concrete was normal.*
- *A shrinkage compensating mortar was present above the concrete*
- *Vinyl floor covering was installed with an adhesive that was applied with a notched trowel*
- *Abundant ettringite deposits were observed between the strips of adhesive and in the leveling mortar*

Concrete with leveling mortar

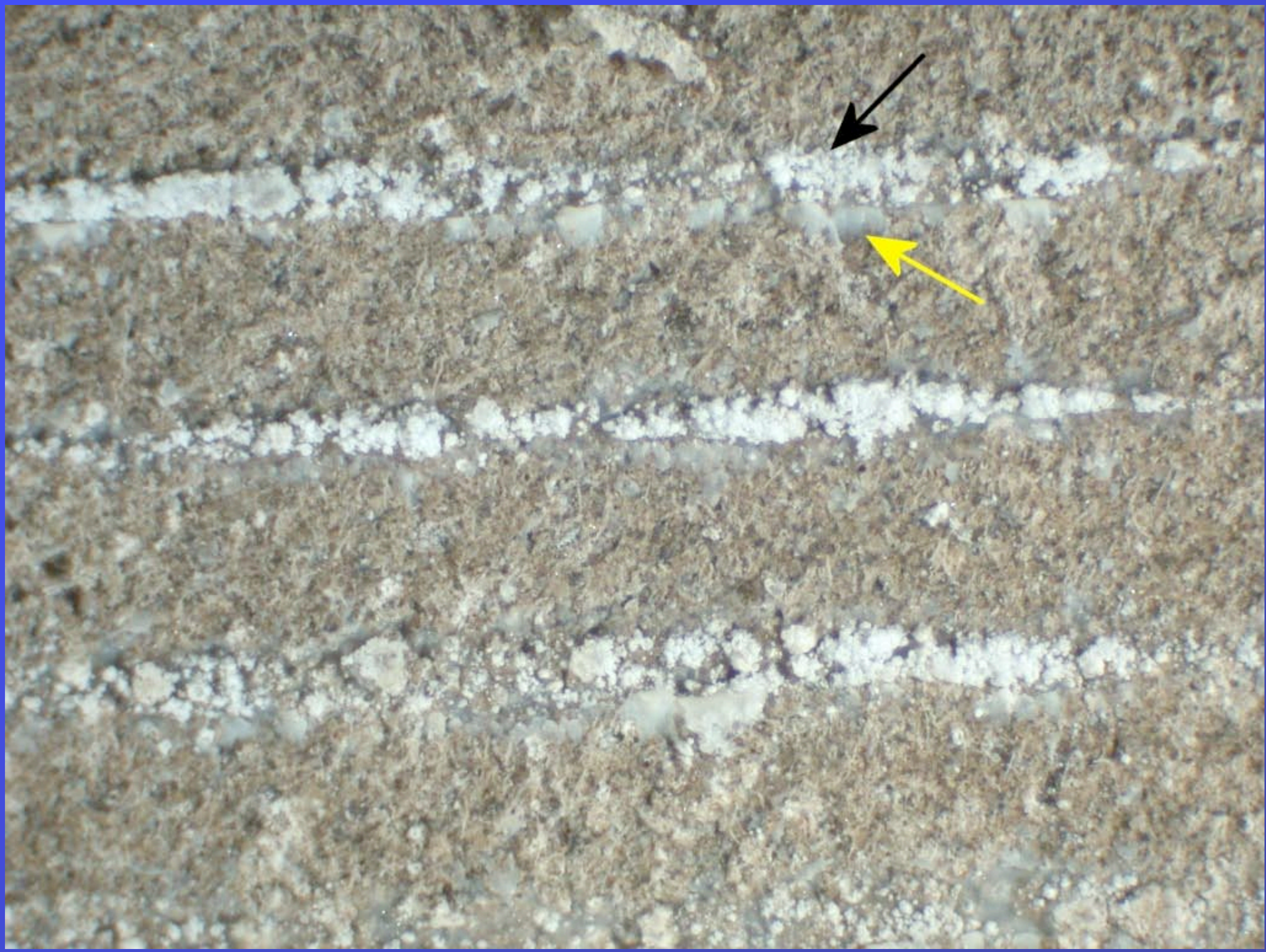


Multiple layers of leveling mortar



Band of ettringite in leveling mortar

Ettringite along adhesive strips



Ettringite and adhesive

Floor Covering Failures due to Sulfate Attack

Cause of Failure:

- *The shrinkage compensating mortar contained abundant calcium aluminate and calcium sulfate*
- *Moisture in the adhesive resulted in dissolving and reprecipitation of these components, forming ettringite in the interface*
- *The resulting internal sulfate attack caused the debonding of the vinyl flooring*

Case Study No. 3 - Floor Covering Failure Caused by Osmotic Blistering

General Observations:

- *A six-year-old polymeric coating in a wastewater pit exhibited debonding and blistering on the walls and floor of the pit*
- *Coating included a thin epoxy base coating and a "high-build" polymeric top coat with a total applied thickness ranging between 60 to 80 mils*
- *Surface preparation by sand blasting*
- *Moisture desiccation employed by forced-air dehumidifiers*
- *Moisture-vapor emissions exceeded manufacturer's recommended limits at time of application*

Case Study No. 3 - Floor Covering Failure Caused by Osmotic Blistering – cont'd

General Observations:

- *Application followed all other manufacturer's recommendations*
- *Petrographic examination indicated that the concrete was of good quality*
- *Blisters were often fluid-filled and under pressure*
- *Disbondment observed between epoxy base coat and concrete and between top coat and epoxy base coat*
- *Indication of possible formulation problems*

Breach of coating

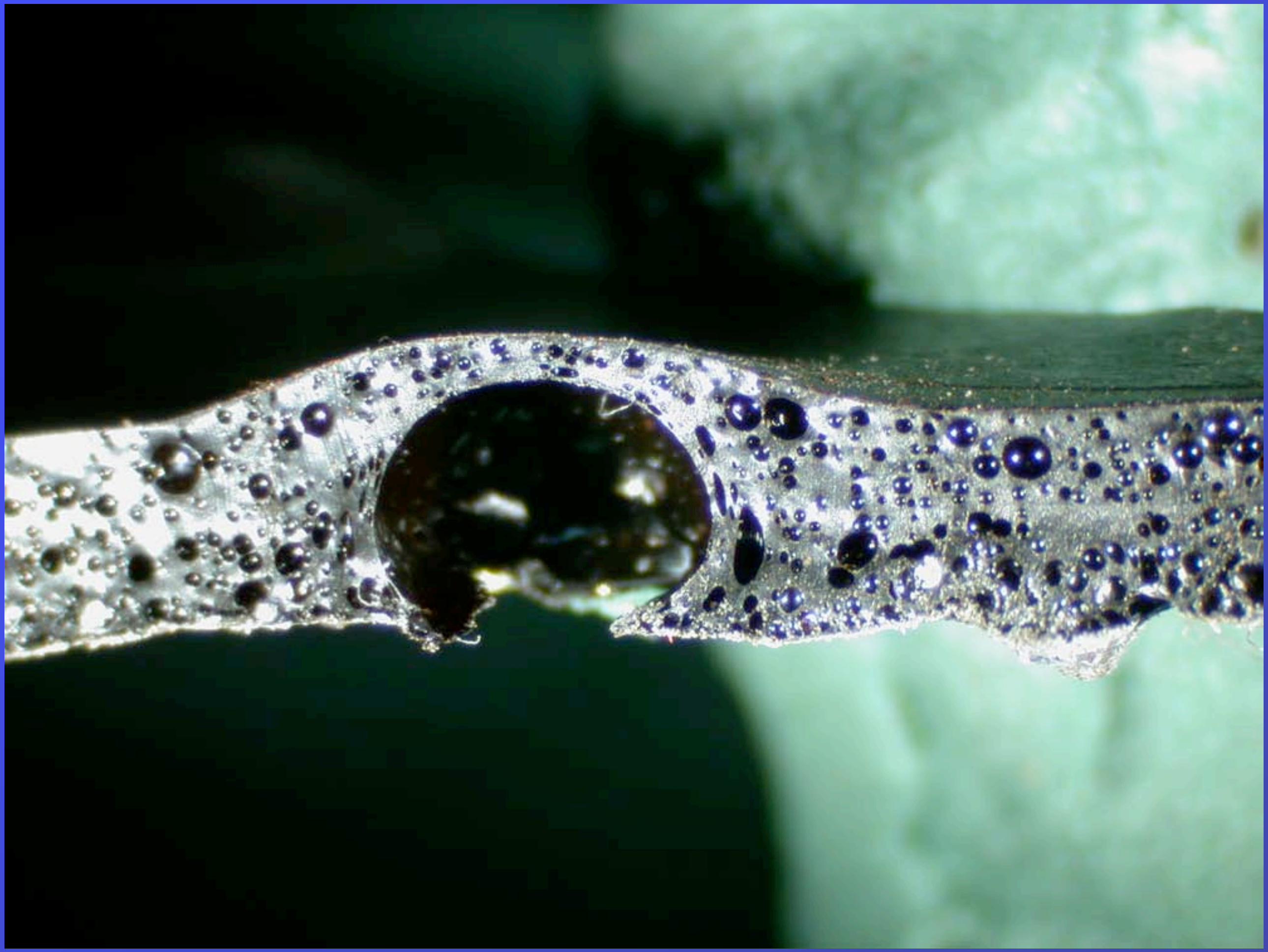
Typical fluid-filled blisters

Blisters under the ceiling

Holidays below the coating

Blisters on a core from the floor

Voids in coating indicating possible material problem



Blister between top coat and epoxy base coat

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Liquid from blister

FPA

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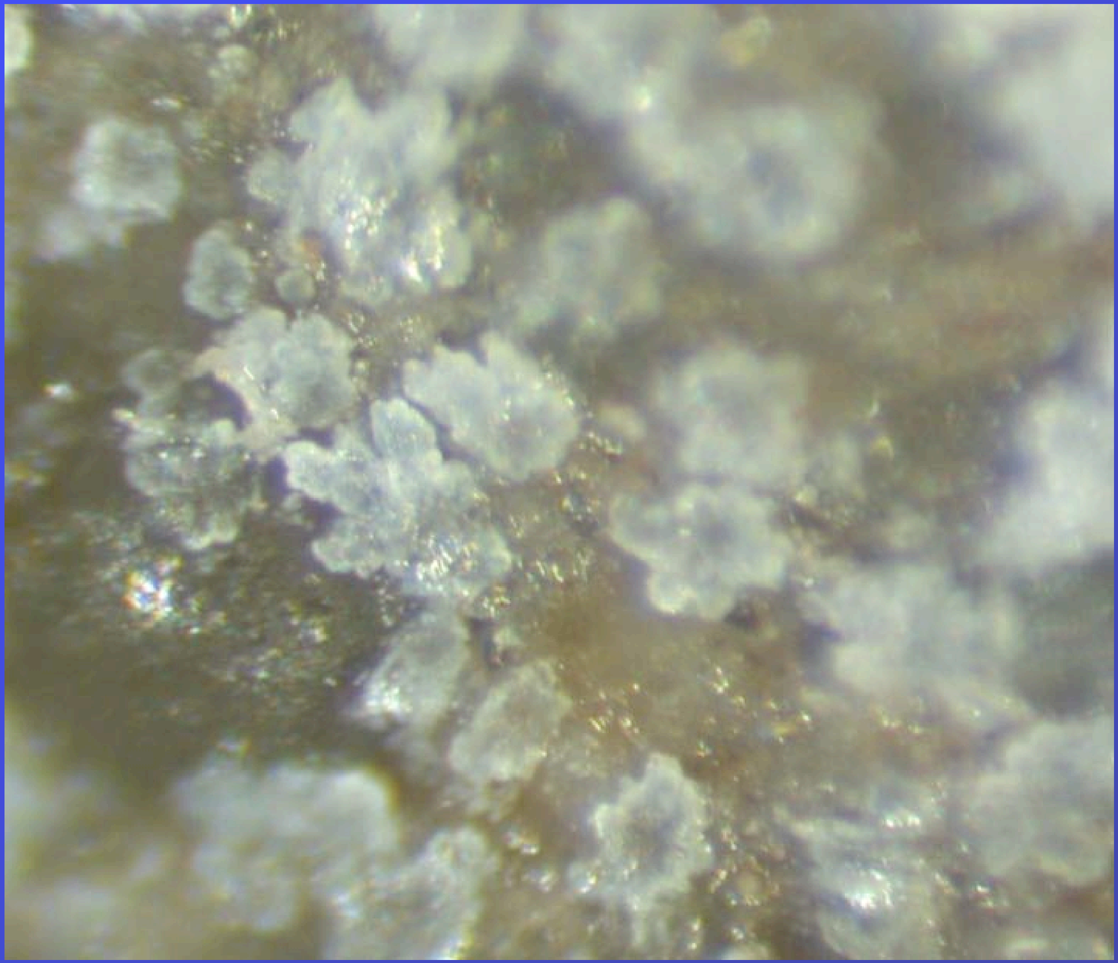
Crystals from evaporated blister fluid

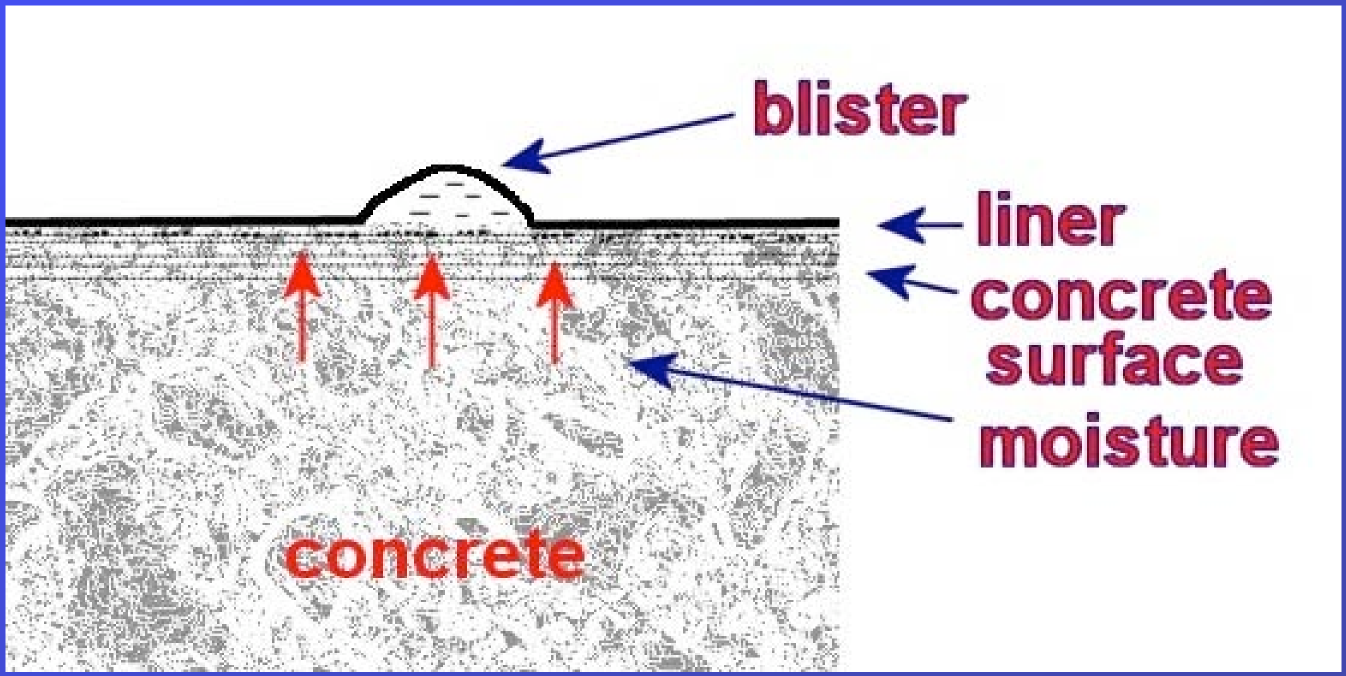


FPA

WJE

Mechanism of Osmotic Blistering

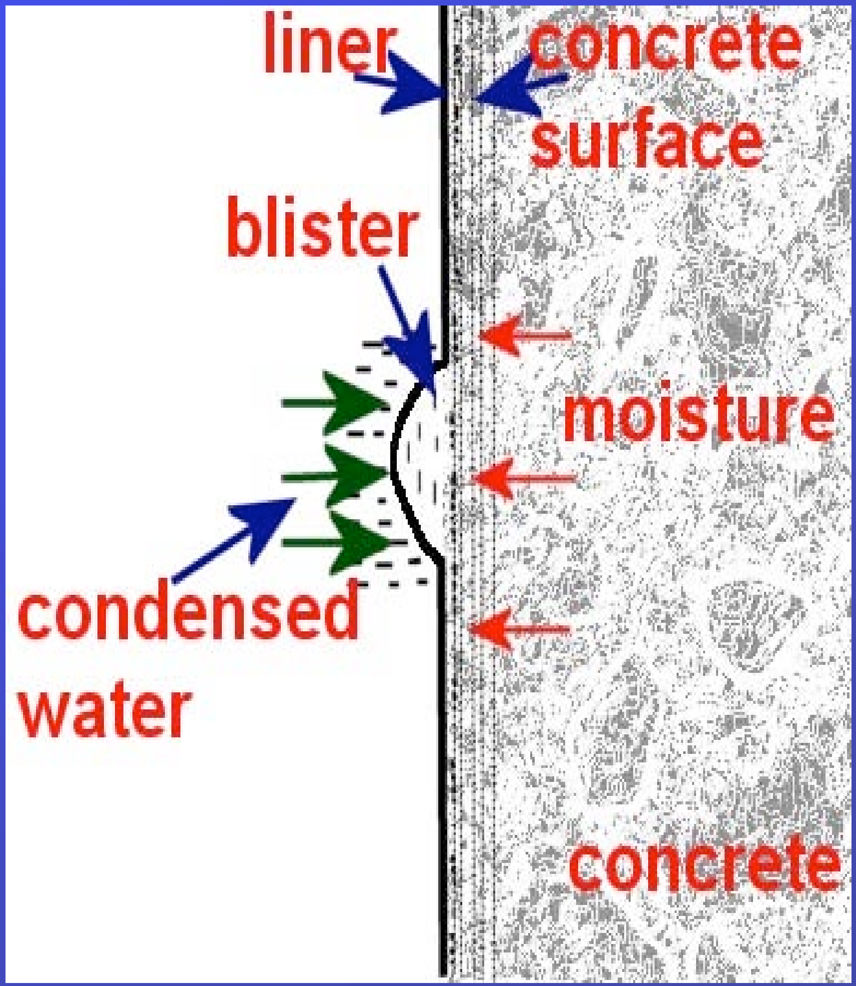
On the floor and wall surfaces, the coating and/or the primer acts as a semipermeable membrane. Contaminants from the concrete, or solvents from the coatings left on the concrete surface, and moisture inside the concrete form the osmotic blister.



Floor Covering Failure Caused by Osmotic Blistering

On the floors and walls, both the concrete surface and the coating and/or the primer act as a semipermeable membrane. Contaminants are likely from concrete or coating solvents.

Condensed water from tank or moisture in concrete are likely contributors to the osmotic blistering.

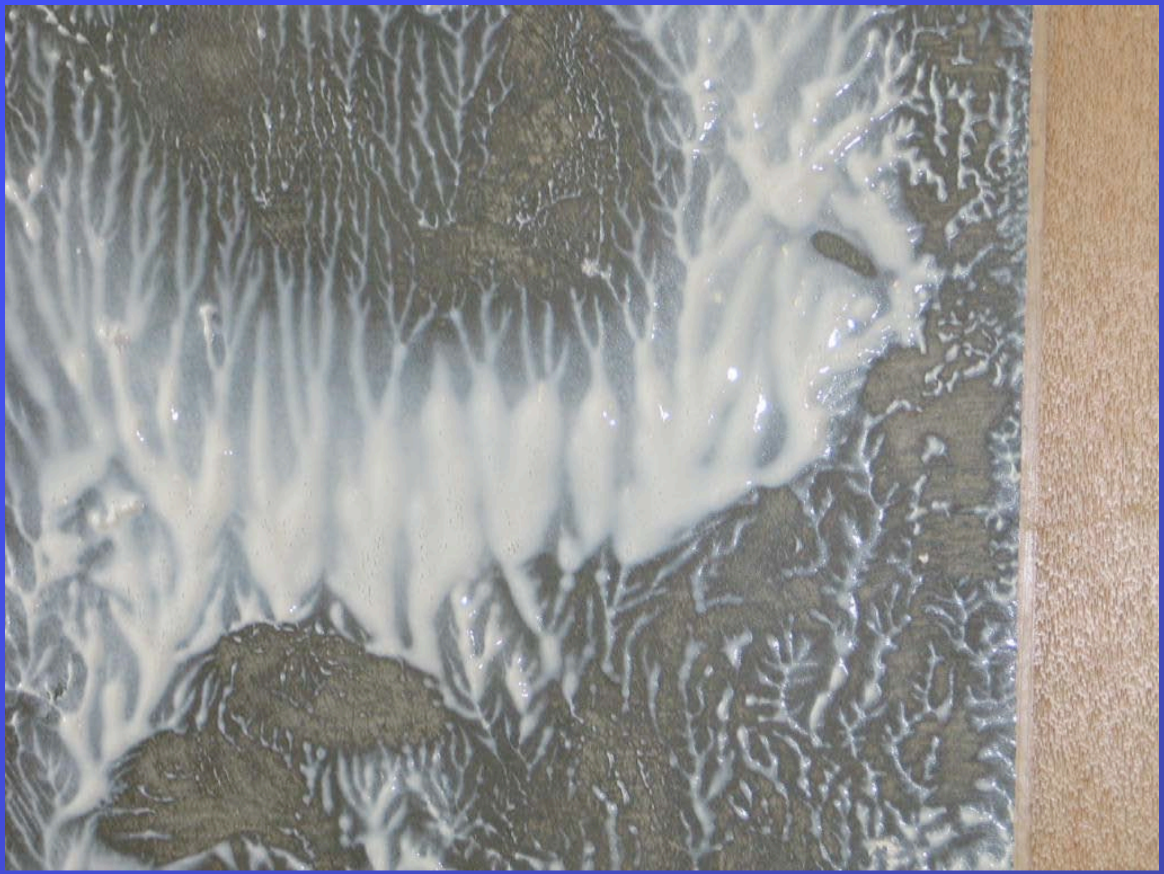


Case Study No. 4 - Floor Covering Failure Caused by Chemical Attack

General Observations:

- *Laminated rubber-like sheet installed with a water-based adhesive;*
- *A relatively new installation (less than one year)*
- *The slab was directly underlain by a layer of sand with 6 mil vapor retarder located beneath the bed of sand*
- *The sand had an approximate 11 percent moisture content; and*
- *When removed, adhesive was found to have liquidized due to a high moisture and alkali condition causing saponification of vinyl acetate-based polymer and phthalate ester plasticizing components in the adhesive*

Liquidized adhesive



Discussion and Conclusions

- *Free moisture and moisture-vapor emission is often not the sole contributing cause to floor covering failure*
- *Moisture and condensed vapor emissions can provide necessary moisture for a variety of problems including near-surface ASR, sulfate attack, osmotic blistering, concrete-borne chemical attack, and other forms of distress mechanisms*
- *Manufacturers' moisture-vapor emission limits may not always guarantee against these types of failure mechanisms*
- *Use of floor covering systems that are vapor barriers should be properly designed before installation*

Thank You!