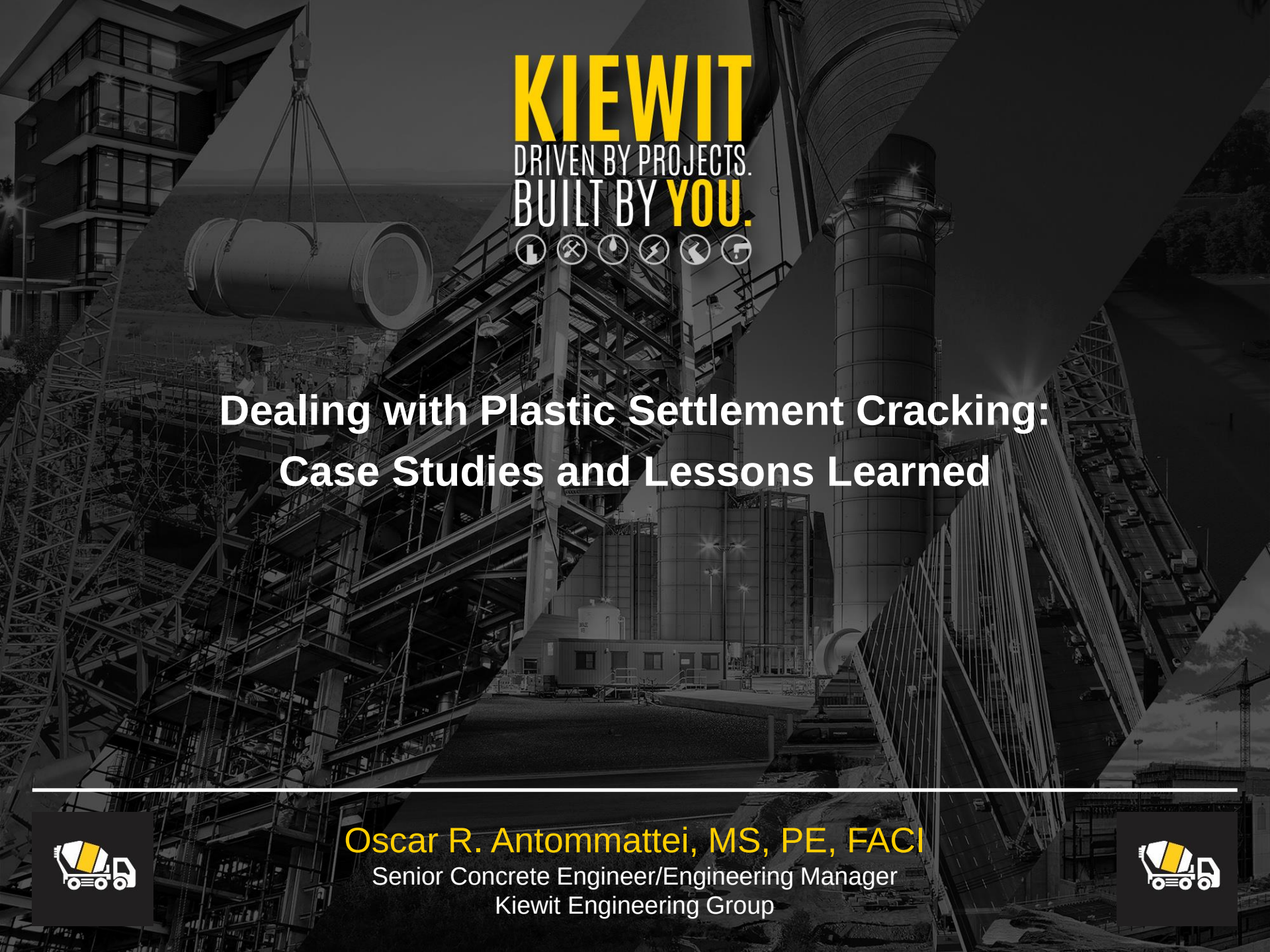

Dealing with Plastic Settlement Cracking: Case Studies and Lessons Learned

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Outline

- Introduction
- Fundamentals
- Case Studies
- Lessons Learned
- Closing Remarks

Settlement Cracking

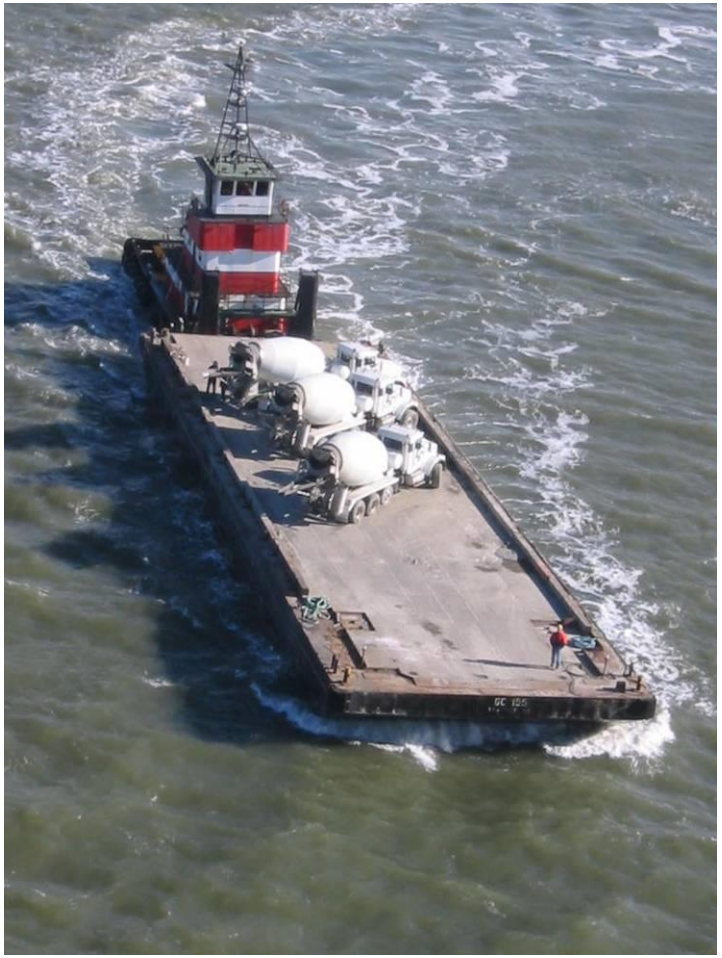
INTRODUCTION

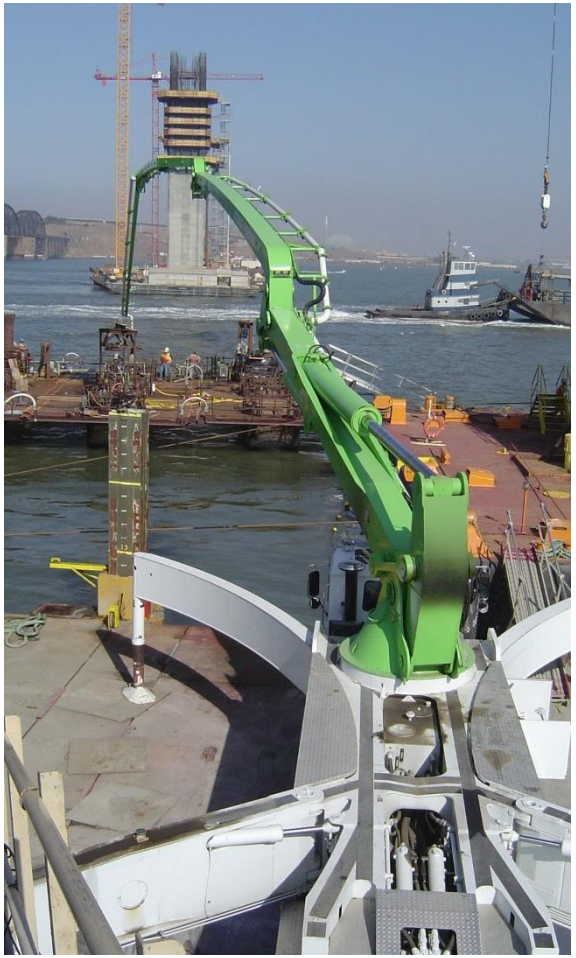
Kosciusko Bridge

Goethals Bridge

Trunk Highway 53

Bayonne Bridge

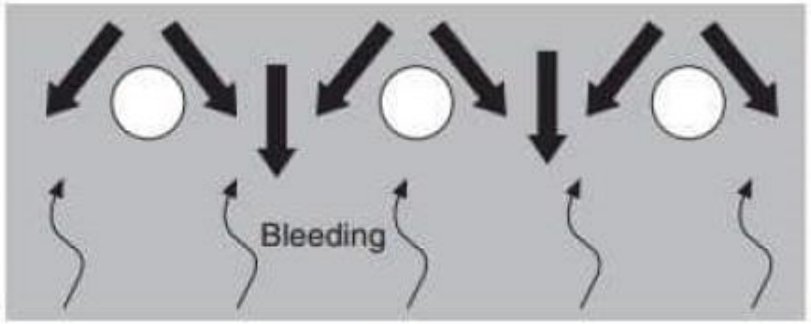




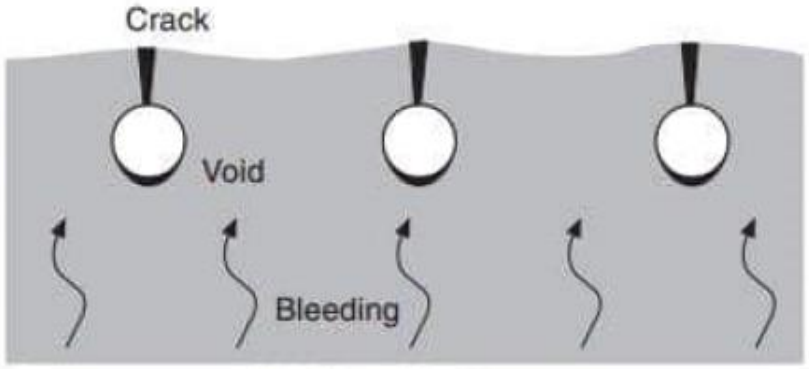
Settlement Cracking

FUNDAMENTALS

Plastic Settlement Cracking



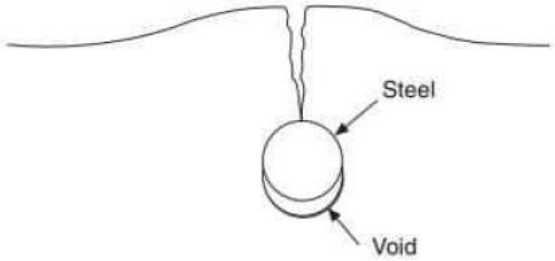
(a) Initiation



(b) After a few hours

(a) Elevation

(b) Plan



ACI 224R – Control of Cracking

8.4—Settlement

Settlement or subsidence cracks develop while concrete is in the plastic stage after the initial consolidation. Settlement cracks are the natural result of heavy solids settling in a liquid medium. Settlement cracks occur along rigidly supported elements, such as horizontal reinforcement, form ties, or embedments. Sometimes concrete will adhere to the forms. A crack will appear at these locations if the forms are hot at the top or are partially absorbent. Cracks often appear in horizontal construction joints and in bridge deck slabs over reinforcing or form ties with only a few inches of cover (about 75 to 125 mm [3 to 5 in.]). Settlement cracks in bridge decks can be reduced by increasing the concrete cover along with mixture proportioning that minimizes bleeding and settlement. Properly executed late revibration can be used to close settlement cracks and improve the quality and appearance of the concrete in the upper portion of such placements, even though settlement has taken place and slump has been lost (ACI 309R). Use of a low-slump concrete is also recommended to help prevent settlement cracks in bridge decks and slabs.

Dakhil et al (1975)

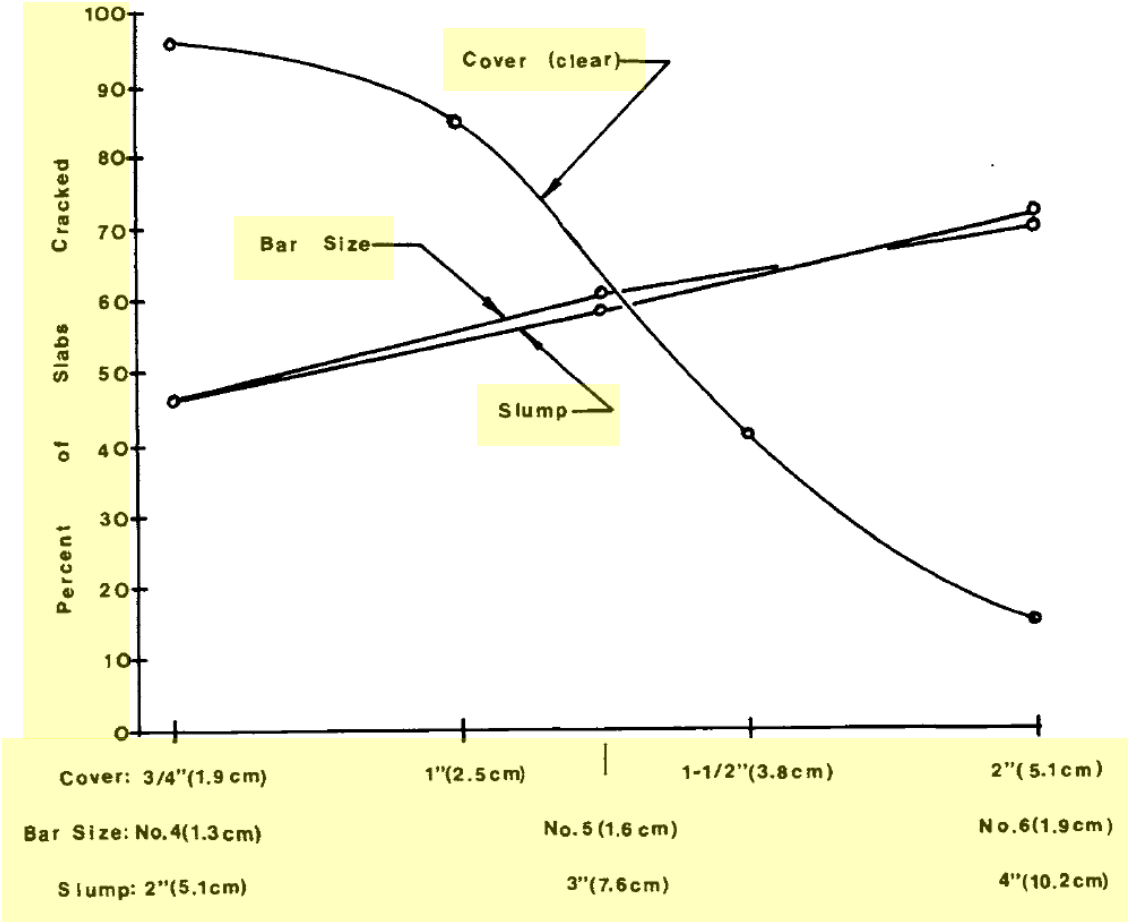


Fig. 2—Cracking as a function of bar size, slump, and cover

Darwin et al (various year)

Table 6.40 Investigated factors that may affect bridge deck cracking

Factor	Higher paste content	Higher slump	Higher compressive strength	Maximum daily air temperature	Higher daily air temperature range
Concrete behavior that influences cracking	Drying Shrinkage, thermal contraction (heat of hydration)	Settlement cracking	Creep	Plastic shrinkage, thermal contraction	Thermal contraction

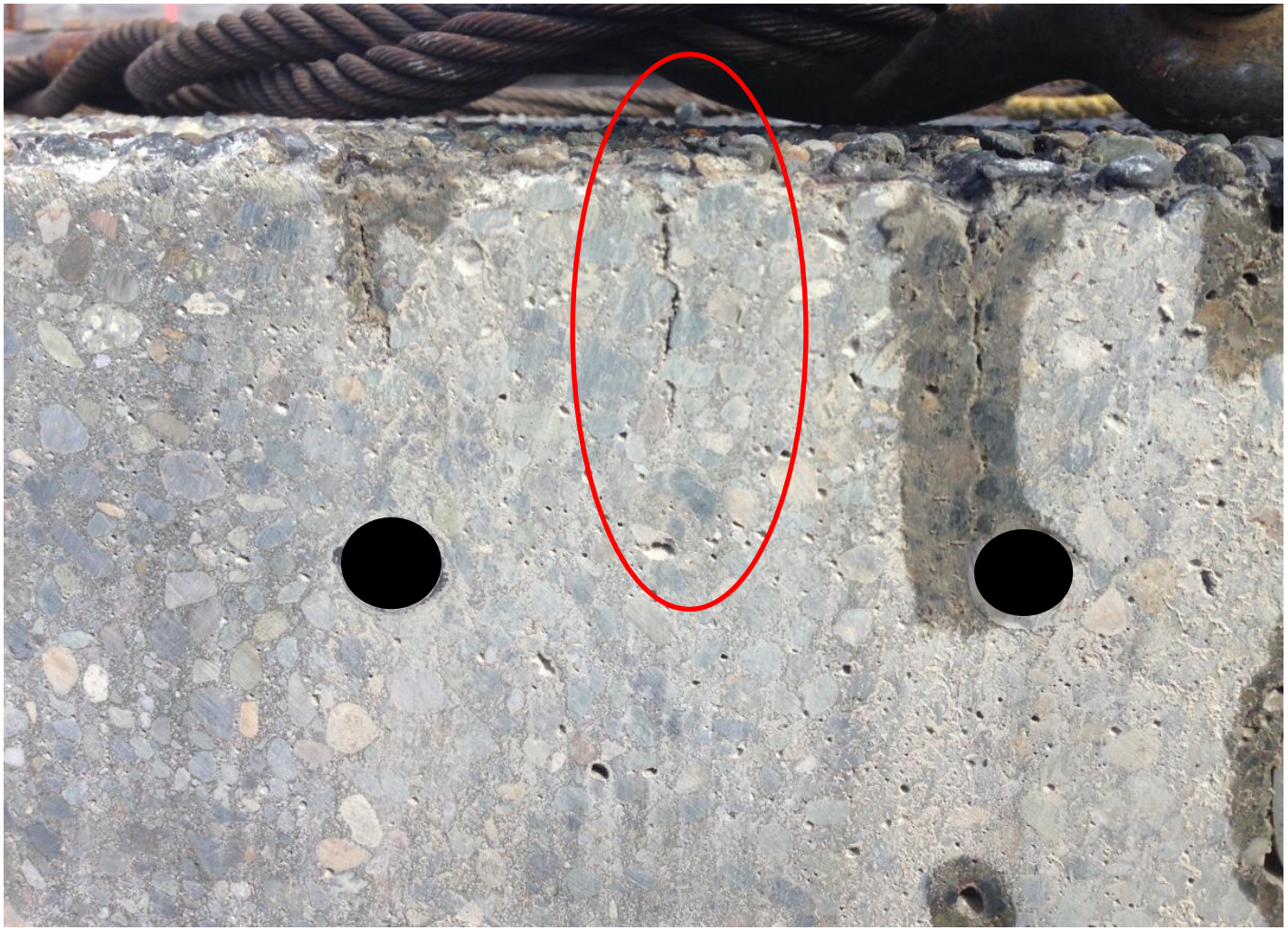
3. Concrete with a cement content between 500 and 540 lb/yd^3 (296 and 320 kg/m^3) and a water-cement (*w/c*) ratio of 0.44 or 0.45 is recommended for bridge deck construction.
4. The maximum allowable slump for future LC-HPC bridge placements should be limited to 3½ in. (90 mm) at the truck and 3 in. (75 mm) on the deck.
5. The compressive strength for concrete in bridge decks should be limited to between 3500 and 5500 psi (24.1 and 37.9 MPa).

Settlement Cracking

CASE STUDIES

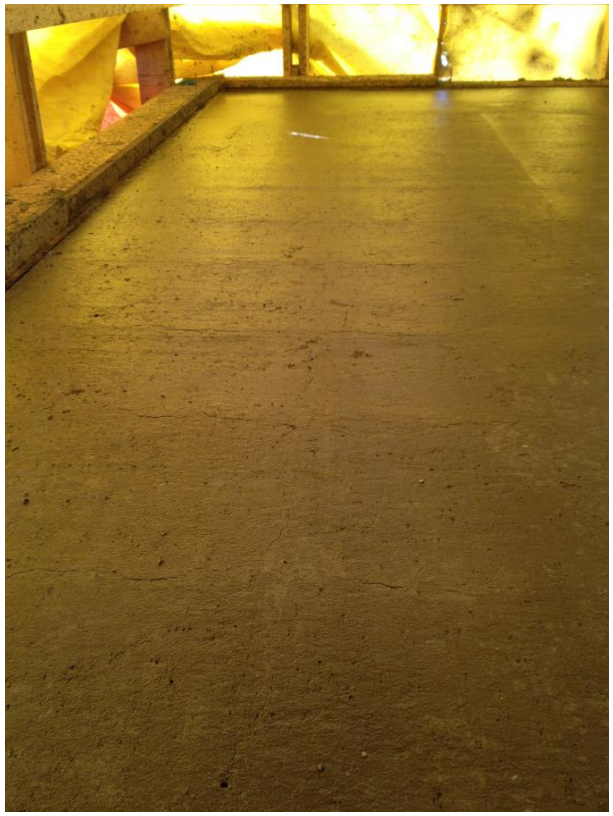
Thin – HPC – SCC

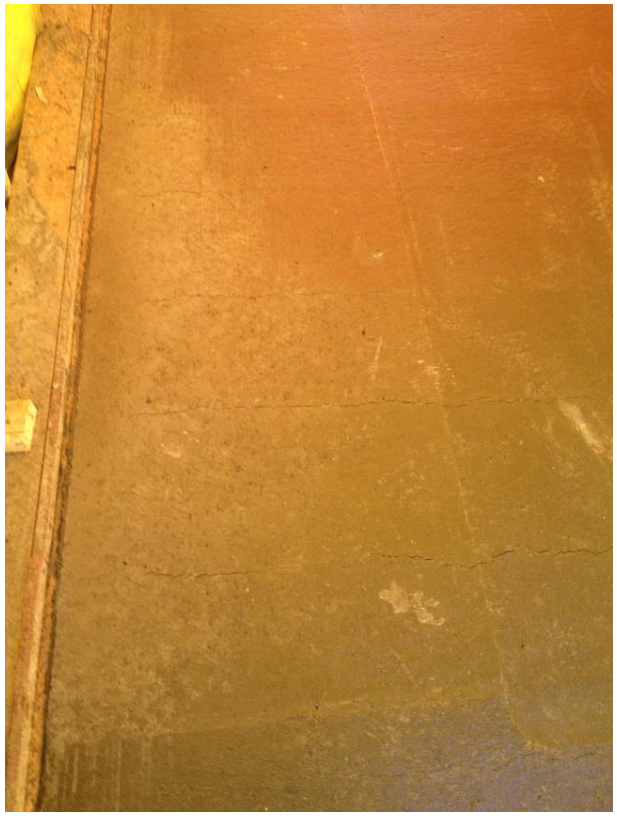
Thin – HPC – SCC



Thin – HPC – SCC

Thick – Mass – Low Slump (< 4 inch)

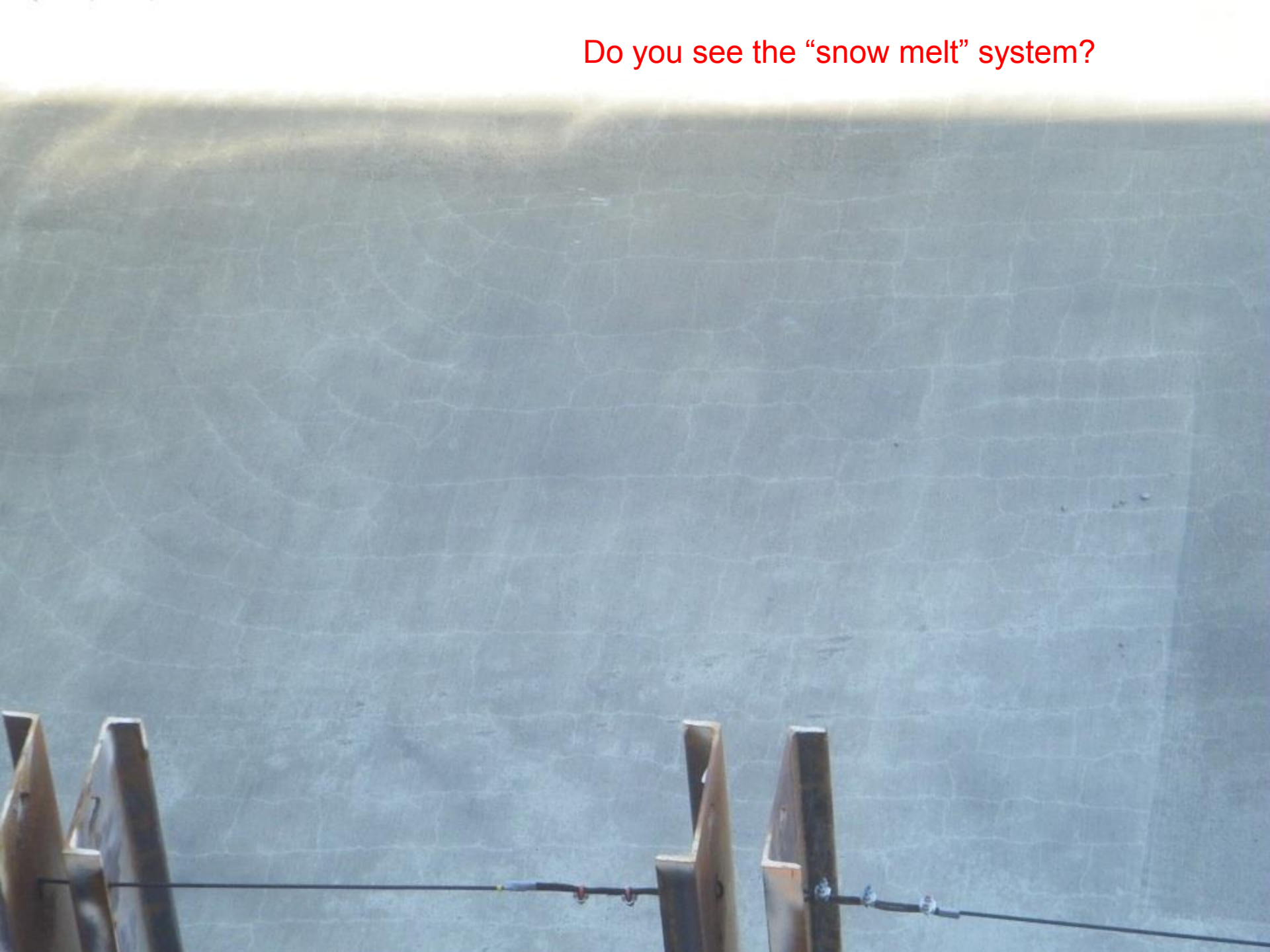




Thick – Mass – Low Slump (< 4 inch)

Thick – Mass – High Slump (6 - 8 inch)

Do you see the “snow melt” system?



Settlement Cracking

LESSONS LEARNED

Lessons Learned

Based on the case studies…

- Plastic settlement cracking should be visible within the first 24-48 hours after the concrete sets. May be easier to identify after concrete dries and cools down.
- Risk of plastic settlement cracking increases for:
  - ✓ Concrete having a delayed or longer set time, in particular when exposed to low temperatures
  - ✓ Larger (thicker) sections
  - ✓ Embeds or rebar close to the top surface resulting (small cover)
- No correlation observed with:
  - ✓ High or low slumps

Settlement Cracking

CLOSING REMARKS

Closing Remarks

- Limitations from research can result in misleading actions when the knowledge is used outside of the research scope.
- Knowledge from research can misrepresent the intent of durability performance requirements, in particular to meet constructability of 100+ year service life bridges.
- The potential risks for plastic settlement and slump requirements needs to be evaluated on a case-by-case basis in consideration to the local material properties, mixture proportions, performance requirements, design criteria and construction demands.
- Risk of plastic settlement cracking is not limited to one single and simplified variable such as slump.
- Design, construction, materials and weather conditions will directly affect the risk of plastic settlement cracking in construction.

Thanks!