NHI Innovations Webinar – Controlling Cracks in Concrete
Responses to Additional Questions

1. What is the effect of dense gradation on the cracking prevention?

Darwin: Dense gradation, more often referred to as optimized gradation, aids crack control because it allows more aggregate (and less paste) to be used in concrete for the same slump.

2. What is the biggest factor to more cracking today, compared to 1930 or 1940?

Khan: Adopting and using new materials without researching enough into their unintended consequences.

Streeter: Tough question as there are many variables. Change in materials is one reason – for example, cements from the 30's and 40's were natural cements that had good durability. Changes in production, over the decades, have resulted in different material characteristics that result in different performance. In the last 10 – 15 years cement production and resulting characteristics has changed significantly because of the collection of flue gases / particles, with the baghouse fines or collected stack products being placed back into the cement since disposal is not an option. Another reason, in my opinion, is the change in designs – I see cracking from how / where we use the material in different ways rather than an increase of cracking in traditional applications. I don't see a difference in the cracking of simple span structures when comparing 50 year old decks to 2 year old decks but I do see much more cracking on multi-span decks. I believe this is a flexure issue tied to the design, not a change in the material.

Darwin: Two factors: 1. The use of more finely ground cement, which results in higher early strength but also more shrinkage for the same water loss because of the finer pore structure it produces in the cement paste. 2. The use of higher slump concrete, which often results from the use of concrete with a higher quantity of cement paste. The higher cement paste content results in more shrinkage cracking, and the higher slump (independent of the cause – more paste, or use of a water-reducer) results in more settlement cracking in structures like bridge decks.

3. Do you recommend the use of PVC sheet under the slab on grade?

Khan: Yes, if practical. It does help prevent the migration of moisture and other deleterious substances from subgrade to the slab.

4. Please speak to the pouring sequence for continuous multi-span bridge decks.

Streeter: Recommend placing positive moment areas first, allowing concrete to develop sufficient strength, then placing the negative moment areas. This reduces the stress development in the top of a deck slab over piers.

Lwin: The need for pouring sequence is based on the size of pour, bridge deck geometry, and especially crack control. As mentioned in the presentation, concrete has low tensile strength, and concrete cracks when the modulus of rupture is exceeded. For multi-span bridge decks, the designers establish pour sequence such that any concrete pour will not cause tensile stress in excess of the modulus of rupture in previous pour(s). The pouring sequence should be shown on the contract plans.

5. How have stainless steel bars in concrete pavements and bridge decks result in cracking? Are there more cracks or less?

Khan: From the standpoint of corrosion, certainly stainless steel bars are more resistant to corrosion and would thus result in less corrosion-related cracking.

Streeter: Typically we don't see a difference in general bridge deck cracking related to type of reinforcing (provided the consideration of embedment length, splices, etc… are handled properly). Epoxy is the only material where there is obviously a longer embedment / overlay necessary because of the epoxy. Still, we don't see a difference in cracking of decks regardless of black, epoxy, galvanized, or SS reinforcing.

Darwin: Stainless steel will reduce cracking due to corrosion.

6. Any new thoughts on placement given the cracking problems seen now?

Streeter: Not sure what differences in cracking are being considered as problems now. We've seen the same cracking in decks for the last 10 – 15 years. The problem cracking is transverse, full width, full depth cracks that develop after a period of loading. I believe this is related to flexure and not a material issue. We've seen fewer and finer cracks using HPC than we did with conventional concretes (assuming all construction practices were properly followed).

Darwin: Not quite sure what "placement" refers to. Cracking caused by materials and construction procedures is far greater than cracking caused by the placement sequence on a bridge deck. If the question deals with placement, as in moving concrete from the truck to the bridge deck rather than the order of placement on the deck, the use of under-powered pumps that can't handle 2 to 3-in. slump concrete is a primary problem. Higher slump translates into more settlement cracking.

Lwin: Proper placement and curing are two very important factors in the control of cracking in concrete. The ACI monograph (ACI 305) as shown in one of the slides in Topic 2 provides guidelines for determining the optimum placement conditions. Curing should be started as early as practicable.

7. Is using lightweight aggregate in the mix beneficial for internal curing and reducing shrinkage?

Khan: Yes. However, understand that beneficial effect of lightweight aggregate and internal curing is an area of active research with limited field applications. The following publication is a good reference on the subject: Bentz, Dale P.; Pietro, Laura; and Roberts, John W., "Mixture Proportioning for Internal Curing," Concrete International, February 2005, pp. 35 – 40. Also, I believe Ohio DOT has some field applications of this concept.

Streeter: NY has been experimenting with internal curing concrete for bridge decks. We're still getting the same cracking as without internal curing concrete but it takes a few more months to develop. This lends to my belief that the cracking is more related to the flexure and stress development than it is to a specific mixture. Internal curing is a good practice for concretes that don't get wet curing but we always wet cure decks so I don't see is as cost effective or reducing the cracking of decks.

Darwin: Yes, but the real payoff comes when you combine a small percentage of lightweight aggregate with slag cement as a partial replacement for portland cement. The key is to do this while keeping the total paste content below 26% (25% is better) of the concrete volume.

8. Wouldn't the use of larger aggregates increase the settlement process of hitting the reinforcement and therefore increase the cracking?

Khan: Concrete with large and heavy aggregates is prone to plastic settlement.

Darwin: Larger aggregate particles have less surface area for a given volume of aggregate and, therefore, allow for greater workability with a given volume fraction of paste or the same workability at a reduced volume fraction of paste. Settlement is not affected. The spacing between reinforcement, however, must be large enough so that it does not affect concrete placement or consolidation. Typically, bar spacing equal to 4/3 of the maximum size is satisfactory.

9. Any comments on fiber concrete deck overlay?

Khan: Use of fibers in concrete, including deck overlays, is generally helpful in reducing cracking.

Streeter: We've seen some situations where fibers reduce the size of cracks but resulting in more cracks. Finer cracks would be less likely to allow ingress of water and chlorides but I'm not sure if the greater frequency of the cracks is any better even though they are finer.

Darwin: Our experience with overlays, which in general tend to exhibit high cracking because of the restraint provided by the existing concrete, is that fibers have not had a measureable effect on the density of cracking.

10. Mid and high range plasticizer, are they really the same product but just different dosages to obtain desired slump?

Khan: No, these are different products. Please refer to the following ACI document for more detail: "Chemical Admixtures for Concrete," ACI Education Bulletin E4-03, American Concrete Institute, 2003, 12 pp.

Streeter: The newer polycarboxylate admixtures are all the same base product, just the dosage rate changes resulting in the difference workability characteristics. Evaluation in our labs indicates good performance with these types of water reducers at low, mid, high, and SCC dosage rates.

Darwin: There are a range of products that can be used. They require different dosages to obtain the same slump, but they also have different effects on other concrete properties such as the air void system (which can be adjusted) and compressive strength.

11. How do you, or do you, specify using a well graded aggregate gradation?

Streeter: NY plagiarized the work of Dr Darwin and KS DOT and have trial specifications in use for well graded mixtures. I'll let Dr. Darwin explain the process more thoroughly.

Darwin: For our low-cracking bridge decks, we specify a well-graded aggregate by specifying (for the total aggregate gradation) that the percent retained on each sieve fall between two specified sizes and that the gradation be obtained using a recognized optimization procedure.

12. Is it necessary to use wet burlap on bridge seats (3' x 3' x 3' x 40' long)?

Khan: Whatever procedure can assure sufficient curing, which is the process of maintaining desirable moisture and temperature in concrete, is fine. Typically wet burlaps work well, including bridge seats.

Streeter: I strongly encourage the use of wet curing wherever possible. Not all locations can accommodate continuous wetting but placing wet burlap then covering to prevent evaporation is the second best option. The more any concrete can be cured the less shrinkage there will be because strength development is greater and less internal stress development that can result in cracking.

Darwin: Good curing is helpful for all concrete, but using wet burlap on a bridge seat will not affect the deck.

13. How is Type K cement beneficial for mitigating cracking?

Khan: Type K, which is shrinkage compensating cement, makes the concrete expand in a way that it counteracts the shrinkage of concrete, and thus reduces cracking.

Streeter: NY investigated performance of Type K cement use from bridges produced for the interstate in the 60's. End result was the same cracking developed on Type K decks as did on Type I or II. The problem with Type K is that the mix design requires much higher w/c ratios and thus the potential for cracking.

Darwin: Type K cement has seen differing levels of success in bridge decks and more consistent success in slabs-on-grade. The key is to properly design the slab/deck – a design that includes the selection of the quantity of reinforcing steel to retain the compressive stresses that are developed by the expansion.

14. Do you feel that MMA can effectively repair deck cracking?

Khan: Methyl -Methacrylate (MMA) is one of the several products used in repairing deck cracks.

Streetrer: From what we have seen in NY, use of methacrylate products will repair cracks. For true shrinkage cracks, the cracks are filled and "glued" back together. If the cracks are working and the result of flexure, we often see new cracks develop adjacent to the original crack that was repaired – this indicates that the cracks are not a material issue but a flexural issue and I don't know of an effective means to repair working cracks except for flexible overlays which typically have a shorter service life and a perpetual maintenance requirement.

15. Discuss use of flyash (25 - 30%) to counter effects of reactive aggregate.

Khan: The use of flyash does help mitigate alkali-silica reactions (ASR). Refer to the following publication for more details: Farny, James A. and Kosmatka, Steven H., "Diagnosis and Control of Alkali-Aggregate Reactions in Concrete Diagnosis and Control of Alkali-Aggregate Reactions in Concrete," Concrete Information, Portland Cement Association, 1997, 24 pp.

Streeter: NY has an elaborate aggregate screening system that has been in use for 40 years to assure reactive aggregates, when used, will not be detrimental to the concrete due to ASR. We're using FA at 20% substitution for cement presently without issue; however, we are cautious of strength gain in colder weather, requiring testing of cylinders stored with the cast element be tested prior to loading.

16. Are crystalline density enhancing products used for crack control (e.g. Xypex)?

Khan: Without reference to any specific product, yes.

Streeter: No regular / typical use of such products in NY. Most products that we have experience with tend to act as water-proofing materials, with durability subject to mixture design and construction practices.

17. How is the 50% threshold level determined under mechanical loading?

Khan: Understand the strength capacity of the structural element, and then limit the loads within 50% of the maximum capacity. Strain gages can be used for actual measurements.

18. What is the optimum way to deal with retaining walls cracks?

Darwin: Use contraction joints. That way you have selected the crack location and have a joint that can be maintained.

19. Do you allow any loading of the decks during the curing period?

Khan: Certainly not a good practice, particularly at early ages.

Streeter: NY specs allow for early construction loading based on cylinder testing / evaluation. The requirement that allows for early deck loading (both construction and full legal loading) is covered in section 557-3.14 of our standard specifications.

Darwin: Not in any way that would disturb the curing. So, generally no.