Reducing Cracking in New Bridge Curbs, Project: 26962P

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Introduction

Early-age cracking has become a routine occurrence on many NHDOT single span, concrete, bridge curbs. Cracks that develop early on in a curb's life exposes the concrete to potential accelerated damage at a young age which may reduce the useful life of the curb. The **objective** of this study is to document cracking on several bridge curbs in order to find ways to reduce the propensity of cracking, particularly in the first year after placement.

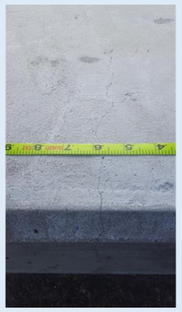
Curb Survey Procedure

For each curb surveyed during the study a tape measure was extended the length of the curb. The total length of the curb along with the location of guardrail posts was recorded. The location of each crack was also recorded in addition to two index values that describe the cracks characteristics. Bridges placed during the study were visited multiple times over the course of one year.

Cracking Indices

The two indices that were assigned to cracks are the length index, which categorizes a cracks relative length compared to the curb, and the intensity index, which categorizes a cracks width. The length index is on a scale from 1 to 3 with 1 being a short crack and 3 being a long crack. Similarly, the intensity index is on a scale from 1 to 3 with one being a narrow crack and 3 being a wide crack.

Length Index 1



Length Index 2

Length Index 3

Intensity Index 1

Intensity Index 2

Intensity Index 3

Calculated Values

Several additional values were calculated from the crack data. The first is the severity index which combines the length and intensity index into a single value.

$$Severity\ Index = \sqrt{LI * II}$$

The second calculated value is the average uncracked length, AUL, which normalizes the amount of cracking based on a curbs length to allow easier comparison between curbs of different sizes.

$$AUL = \frac{Curb\ Length}{1 + (Number\ of\ Cracks)}$$

Additionally, the volume of each individual crack can be approximated from the length and intensity indices. The sum of all the estimated crack volumes can be normalized to the entire curbs volume to compare cracking to other curbs on a volume basis.

$$Normalized\ Crack\ Volume = \frac{\sum(A_w * A_A)}{L}$$

$$A_w = Approximate\ Crack\ Width$$

$$A_A = Approximate\ Crack\ Area$$

$$L = Curb\ Length, inch$$

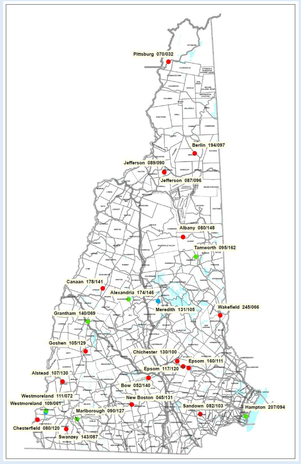
Sites Visited

During the study 23 bridge sites were visited. Six of the sites were placed during the study and the remaining were existing.

Red: Existing curbs (placed prior to study)

Green: Curbs constructed during study

Blue: Curbs constructed during study using recommendations developed from the study



Variables Tested

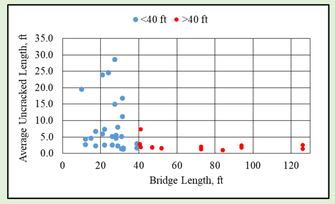
Two variables were tested on new bridge curbs during the study. One curb on a bridge would remain a control and the second curb would have a variable applied to it. One variable was a 14-day wet cure duration compared to a traditional 7-day wet cure. The second variable tested was changing the Portland cement concrete mix from NHDOT AA to NHDOT A. The NHDOT AA has a specified 28-day compressive strength of 4000 psi compared to the NHDOT A which has a specified 28-day strength of 3000 psi.

Results and Discusssion

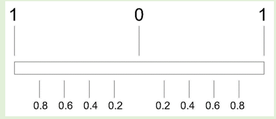
Since ACI 224R-01 was used for determining the intensity index values, any intensity index value of 1 is of reasonable width for concrete exposed to deicing salts. By recording the number of cracks of a given length and intensity index in a matrix as show below, it can be seen that 83% of the cracks observed are of reasonable width.

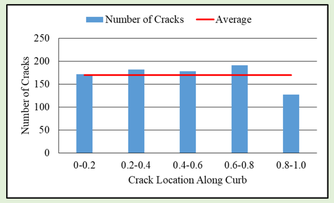
Intensity Index	Length Index 1	Length Index 2	Length Index 3	Total
1	525	64	116	705
2	22	14	100	136
3	0	0	8	8
Total	547	78	224	

The results from the bridges surveyed during the study indicate that bridges over 40 ft in length tend to have more cracking then bridges less then 40 ft in length. The graph below shows the increased amount of cracking (decreased AUL) between bridges over 40 ft in length (red) and under 40 ft in length (blue).

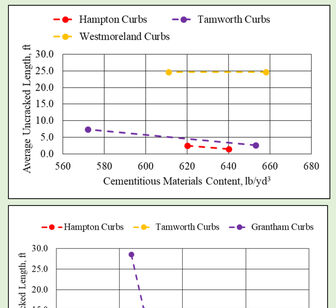


Additionally, the amount of cracking at various locations along the curb are different. By placing cracks into one of five categories corresponding to their relative location from the middle of the curb it can be seen that the ends of the curb experience less cracking then the rest of the curb.

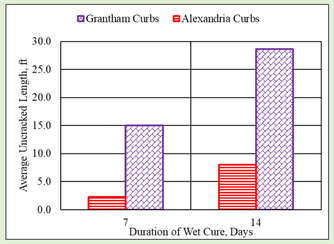




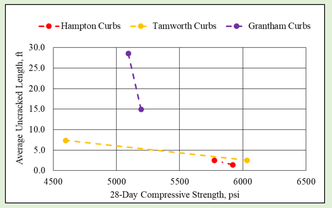
Early anecdotal observations suggested that guardrail post locations exhibited more cracking. When looking at the percentage of cracks that form near guardrail posts compared to the percentage of the curb that is near a guardrail post it can be seen that cracking appears randomly distributed with respect to post location.



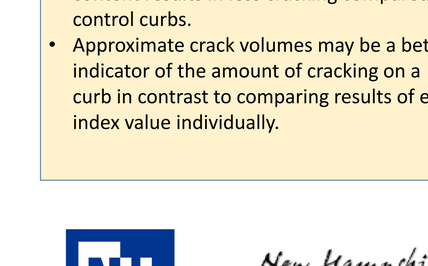
When looking at the variable and control curbs for the wet cure duration, it can be seen that curbs exposed to the longer wet cure have less cracking.



The differences in PCC mix between control and variable curbs show that mixes that have a lower 28-day compressive strength and cementitious materials content exhibit less cracking.



By looking at the approximate volumes of cracks that form along the curb and normalizing the sum of all the approximate crack volumes to adjust for variations in curb length similar patterns exist for bridge length which suggests cracking is worse on longer bridges then shorter bridges. Similar patterns exists for normalized crack volumes as the other items shown in this results section.



Conclusions

Based on the research conducted in this project the following conclusions can be made about cracking on single-span, concrete, bridge curbs:

- Approximately 4 out of 5 cracks on bridge curbs are of reasonable size according to ACI 224R-01
- Curbs on bridges over 40 ft in length have more cracking compared to those on bridges less than 40 ft in length
- The amount of cracking at the ends of the curbs is less than the amount of cracking compared to the rest of the curb.
- Guardrail posts have no appreciable effect on cracking.
- A 14-day wet cure duration on curbs results in less cracking compared to control curbs with a 7-day wet cure duration
- A PCC mix with a lower 28-day compressive strength and lower cementitious materials content results in less cracking compared to control curbs.
- Approximate crack volumes may be a better indicator of the amount of cracking on a curb in contrast to comparing results of each index value individually.

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