Visual Examination of Structural Damage In Wisconsin

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• THIS REPORT must necessarily be based on field observations by maintenance personnel of damage to structures caused or contributed to by the use of de-icing agents for winter maintenance, inasmuch as Wisconsin does not have any significant technical data on this particular subject.

Before proceeding further and as background information, it is desirable to outline Wisconsin's current winter maintenance policies regarding the use of de-icing agents. Before 1956 only abrasives, predominantly sand mixed with sufficient salt to prevent freezing in stockpile were used. This abrasive mixture was used only on predetermined hills, curves, and intersections; ice on level straightaways was removed solely by mechanical means. In 1956, the State Highway Commission recognized the demands by motorists for safe all-weather driving conditions and adopted a so-called "bare pavement" policy on the entire 11,000 mi of the State trunk highway system. To achieve the inherent objectives of this policy, it was necessary to adopt the use of straight chemicals; therefore, the use of abrasives rapidly diminished. The present policy calls for application of straight rock salt at temperatures of 25° or higher and salt-calcium chloride mixtures at lower temperatures. The chemicals are applied at an approximate rate of 400 lb per mi depending on conditions. At the present time, 75,000 tons of salt and 3,000 tons of calcium chloride are used per winter, depending on the climatic conditions. Abrasives as such are used quite sparingly and only when traffic conditions require immediate traction that cannot be provided by straight chemical applications.

The use of salt, although highly effective for winter maintenance operations, has not been without some problems. Not only have the corrosion alarmists raised loud cries of protest in some instances but the concrete pavements have undergone more surface deterioration in the past five years than for the several years before the use of salt. This paper will center on the observations of surface damage to bridge decks in Wisconsin over the past five years.

Perhaps the outstanding fact uncovered is the obvious lack of any set pattern or factor that can be pinpointed as the major trouble spot. There are a number of structures built in the early 1930's that show no sign of surface scaling; on the other hand, a few that were built within the past five years are displaying evidence of serious deterioration. There seems to be little correlation between structures on major traffic arteries and those on secondary highways, even though higher traffic volumes normally require more frequent chemical applications. There are structures showing scaling only in certain spans of a multi-span arrangement, whereas others exhibit such scaling uniformly throughout the structure length.

Generally, surface scaling starts on the bridge floor at or near the curb while the curb faces and sidewalk surfaces also start to show some deterioration. Most of the scaling noted to date is concentrated in an area about 4 ft wide toward the centerline from the outer edge of the superstructures. There are notable exceptions to this but generally this area shows the most serious deterioration. This appears logical because melted snow or ice flows laterally outward from a crowded roadway or is splashed outward by passing vehicles. Sand, snow, and other debris tend to build up near the curb and obstruct the flow to the floor drains, particularly on structures built on a relatively flat grade. The salt brine then concentrates in this area and trouble develops.

Since 1947, air-entrained concrete has been used exclusively for bridge decks. Although it is true that such air-entrainment apparently increases the resistance to frequent freeze-thaw cycles and the resultant surface scaling, air-entrainment alone cannot

provide the answer. The lack of accurate field control of air content has been noted in a number of cases where scaling has been observed on decks constructed with air-entrained concrete. In one instance, the air-entraining agent was somehow omitted entirely from the mix in one span that now shows very serious deterioration when compared to adjoining spans. In other cases, it has been determined that the air content was below the minimum specified in the contract. It is therefore concluded that air-entrainment, unless rigidly controlled during construction operations, is only partially effective. The maintenance organization is presently leaning toward the theory that air-entrainment, together with an increase in cement content to produce higher density concrete, will provide the maximum resistance of the deck concrete to surface scaling.

Besides the apparent lack of accurate control of air content during construction, there are other phases of construction operation that in some cases may have been carelessly performed, and that may have partially contributed to the scaling problems. Among these are (a) improper placement of reinforcing steel (in that the cover provided is insufficient); (b) poor consolidation of concrete at construction and expansion joints; (c) careless finishing operations, particularly overfloating, resulting in a thin surface coat of mortar that easily pops off and exposes the coarse aggregate to additional deterioration; and (d) lack of accurate screeding and finishing to grade, resulting in shallow pockets or "bird baths" at the gutter line permitting ponding of water and salt brine. Each of these factors or a combination thereof has been noted in certain cases of scaling on structures in Wisconsin. A general upgrading of inspection standards with additional emphasis on contractor's workmanship would minimize this aspect of the over-all problem to a considerable degree.

The maintenance section recognizes that a scaling problem does exist in the State, although it is not felt to be as critical as indicated to maintenance engineers from other states and steps have been taken to minimize further damage to the structure floors.

In some instances, when scaling begins to appear along the gutter line, a strip seal coat approximately 3 to 4 ft wide has been placed over the full structure length. On some lower traffic highways, the entire bridge floor has been scaled when scaling has appeared over the entire area. Silicones have been and are used as preservative treatment during construction operations but field observations would indicate that such treatments have not been particularly effective. Therefore, experiments with other types of surface treatments such as linseed oil, rubberized asphalt seal coats, and in some extreme cases epoxy coatings, have been undertaken to minimize further damage.

The field maintenance forces are operating under strict instructions to clear all bridge floors and sidewalks of snow, sand, or other debris immediately following each storm as soon as conditions permit to keep snow melt and salt brine flowing freely to the floor drains. This involves expensive hand shoveling and sweeping, but the cost is worth it if additional surface deterioration can be forestalled in the process. For the record, there has been a marked slowdown in the rate of deterioration when conscientious effort has been exerted to keep the bridge floors clean.

The field observations have led to the conclusion that a number of factors are involved in the problem of damage to bridge floors through the use of de-icing agents and it would not appear logical to assume that any single factor can be considered as the sole cause. Additional research in a number of areas is necessary to evaluate the problem properly and provide an answer, if an answer can be found.

Discussion

C. C. OLESON, Principal Research Engineer, Portland Cement Association, Research and Development Laboratories, Skokie, Ill.—The author's paper is a fine contribution to studies being made on highway pavements and structures. The Illinois Highway Department has long been one of the largest users of concrete and has been a leader in divising methods and safeguards that would insure a high-quality, durable product. The author has described some of these methods as well as some of the work involved in studying concrete samples removed from pavements and bridge decks. Among other procedures, the highway department laboratories have developed a rapid test for determining whether or not concrete is air-entrained, involving the application of hydraulic

pressure to a core. A similar piece of equipment has been built in the Portland Cement Association laboratories and has been found quite satisfactory in measuring total amount of air in the sample.

The method customarily used in the PCA laboratories to measure air in hardened concrete is "linear traverse," in which a slice from a core is polished, and examined microscopically to obtain the number and size of air bubbles, percentage of paste plus air, and aggregate content.

Studies of hardened concrete from pavements and bridge decks have been very helpful in determining why scaling has taken place in some cases and not in others. The author reports complete agreement with the Portland Cement Association in finding that scaling is related directly to the absence of adequate air-entrainment in the concrete.

In spite of the overwhelming evidence to show that air-entrained concrete is well protected against scaling, there are occasional reports that concrete presumed to be air-entrained has scaled. The PCA has always been ready to cooperate in making an an investigation of any such case, thought it has yet to find adequately protected concrete that has actually scaled.

This discussion is presented as a supplement to the author's remarks to describe an investigation in which thin scaling was found on pavement concrete that was intended to be placed with ample air-entrainment protection. It is shown that unless special steps are taken, current methods of measuring the air content of hardened concrete will not indicate the amount or distribution of entrained air in the portion most vulnerable to weather and de-icing chemicals— the top ¼ in.

This study was made on two cores removed from a four-lane concrete pavement, one of the cores being from a lightly scaled area, the other from another lane and the same station where there was no scaling. The construction records showed that there was as much as 6 percent entrained air in the fresh concrete. Vertical slices were cut from each of the cores; air content, bubble count, and spacing were measured by the standard linear traverse method. Each core showed essentially the same air content, over 5 percent, with satisfactory bubble characteristics. Because this did not explain the light scaling, the remaining segments of the cores were used for study of the surfaces. For this purpose the segments were cut near the top to give surface slices. The wearing surface was then ground down just enough to produce a plane surface that could be polished and examined. Only the sand aggregate was exposed on these surfaces. The fine aggregate was measured at the same time as the air, so as to arrive at the amount of paste at the top. This procedure has given results more consistent with the actual performance of the pavements.

The top surfaces, being deficient of coarse aggregate must be considered as mortar, and for comparison with the interior of the concrete that contains coarse aggregate the measured air in the surface is recalculated to "equivalent" percent of air and voids per inch on a concrete basis.

Core 1, from the lightly scaled area, showed at the surface 3.7 percent air, with 10.23 voids per in., and a paste plus air percentage of 52.3 percent. At ½ in. below the surface, these figures were 4.6 percent air, 7.24 voids per in., and 33.5 percent paste. On an "equivalent" basis, the recalculated figures for the surface were 2.4 percent air and 6.5 voids per in.

Core 2, from unscaled concrete (about 20 ft away from Core 1), showed 7.6 percent air, 29.1 voids per in., and 50.5 percent paste and air, on the surface. At ½ in. below the surface, these measurements were 6.3 percent air, 15.71 voids per in., and 28.7 percent paste and air. On an "equivalent" basis, the recalculated figures for the surface were 4.4 percent air, and 17 voids per in.

This investigation showed that the surface of Core 1 was deficient in air and number of bubbles per inch and Core 2 was adequately protected. Measurements on vertical sections from the cores showed over 5 percent air and about 10 bubbles per in. for both cores, indicating well-protected concrete, but gave no information on the exposed wearing surface.

Generally, when cores are submitted for study, there are almost no records on procedures used for finishing the concrete. In the above case, a photographic record supplemented with personal observations of placing and finishing techniques was available.

The pavement was built with transit mix concrete in late October. Two percent $CaCl_2$ was added during mixing; measured slump was 3 in. Hand methods were used for placing and finishing, and as an aid in final finish, water was sprinkled lightly on the surface.

Because the extent of scaling on this pavement is small, probably not more than 20 sq yds (or less than a mixer load of concrete), it is reasoned that for this particular area an unusual amount of water may have been used on the surface and the entrained air was literally "washed out" of the concrete top layer. Examination after two winters shows that there has been no progressive scaling; i.e., the inadequately protected surface has been lost and the remainder of the concrete remains durable.

This investigation may help to explain those infrequent cases where there is almost positive evidence that air-entrained concrete was used but scaling has developed. Unless there is adequate air in the surface layer, the concrete may be vulnerable to frost scaling.