A Survey of Air-Entrained Structures in Illinois

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• IN 1960 the Illinois Division of Highways initiated an investigation into the disintegration of concrete bridges. It was observed that relatively new, as well as older, bridges were suffering from this malady. This was surprising and particularly disturbing, because presumably almost every bridge constructed since 1947, was built with air-entrained concrete.

The use of air entrainment was required for structures in 1947 after a thorough study of the literature, observations at the Portland Cement Associations' exposure farm, and extensive tests in the State's laboratory had shown the effectiveness of entrained air in resisting the effects of weathering, and particularly of ice-removal salts. A year later, this was required for pavements also. Of course air entrainment was not accepted as a panacea for all the ills of concrete but it contributed greatly to its general health.

Although in 1951 there was a rash of scaling on pavements built in 1949 and 1950 in the city of Chicago, microscopic study of samples of concrete taken from scaled and unscaled areas in these pavements showed conclusively that, wherever scaling was present, the air content of the concrete was less than 2 percent and the bubble count was less than 2 per linear in. Since that time, three other cases of scaling in pavement, three in bridges and one in curb have been studied. In every case where scaling occurred, there was less than 2.5 percent air. The air determination in these cases was made by the high pressure method and, therefore, there is no information on bubble size or distribution. These results showed that, even with reasonably good inspection, concrete for some reason does not always end up with proper air entrainment.

For this reason an air test is now required for every batch of concrete before it is placed in the deck, gutters, hubguards, and sidewalks of a bridge, these being the areas that become exposed to ice-removal salts.

In outlining the investigation referred to earlier, the first step should be to inspect bridges built with air-entrained concrete to determine (a) the extent to which disintegration has developed (b) whether the distress, as in the past, is associated with lack of air; (c) what remedial measures might be taken to regard the disintegration already started; and (d) what preventive measures should be taken on new structures. Also an investigation of bridges built before 1947 in which air entrainment was not a requirement is now being considered.

The first phase of the investigation, which involved the inspection of all the bridges built from 1947 to 1959 inclusive, was completed this year, and a preliminary analysis has been made of the data collected. This report is on this phase.

For the second phase 68 bridges were selected, five to ten in each highway district, which are to be given a detailed survey by a special task force consisting of one representative each from the State's Bureaus of Design, Construction, Materials, Maintenance, and Research and Planning. Cores will be taken from scaled and unscaled areas in each structure for air-content determinations.

In connection with the third and fourth phases, limited laboratory tests of certain protective coatings are under way, but major efforts along these lines will not be made until the completion of phase two, when there will be a clearer picture of what direction to take.

Inspection of the bridges included in phase one of this investigation, a total of 879, was conducted by personnel from the districts in which the bridges were located, following directions issued by the Bureau of Materials. They were instructed to report by adjective ratings the degree of scaling, aggregate popouts, surface pitting, hairline cracks, larger cracks, and leaching, separately for the deck, gutter, hubguard and sidewalk. The report also included certain construction information and sources of materials. Of the 879 bridges, 376 have undergone some sort of modification since their original construction. These modifications include widening and the addition of a bituminous surface.

The data were placed on IBM cards to facilitate analysis. A preliminary analysis was completed late in September.

The 376 bridges that were modified subsequent to their construction were analyzed separately from those that underwent no reconstruction (referred to here after as "modified" and "original" bridges, respectively).

Of the 503 original bridges, 6 to 13 percent showed scaling in varying degrees in the deck, gutter, hubguard, and sidewalk. As an example of the degree of scaling in the deck, 5 percent had light scaling, 3 percent medium scaling, 4 percent heavy scaling, and 1 percent was classified as threatening structural failure. The degree of scaling in the gutter, hubguard, and sidewalk was similar to that in the deck.

Aggregate popouts were present in 11 to 54 percent of the structures. In the deck, 26 percent showed a few scattered popouts, 18 percent showed numerous popouts, 6 percent were classified as excessive, and in 4 percent the popouts had caused failure of the surface. These conditions had occurred in approximately the same degree in the hubguard and sidewalk. For some reason the degree was much less in the gutter.

Leaching through the cracks and the formation of stalactites had occurred to a considerable degree, 19 percent of the decks showing calcium carbonate deposits in cracks and 6 percent showing stalactites.

The condition of the modified bridges was similar to the original bridges except for the decks surfaced with bituminous concrete and therefore, not examinable. These decks however, showed leaching and stalactite formations to about the same extent as those without this surfacing.

Although there is no conclusive evidence that ice removal salts are responsible for damage to the structures, in fact there are some contradictory data, nevertheless there are some significant indications that warrant discussion. First, laboratory investigations have shown that sodium chloride and calcium chloride have damaging effects on concrete. There appears to have been a marked increase in scaling on bridges in recent years coincident with a greatly expanded use of ice-removal salts. At least the problem has become more apparent. For example, in the years 1948 to 1953, the Division purchased about 30,000 tons of rock salt and 12,000 tons of calcium chloride. In the following six years, 1954 to 1959, purchase of these materials rose to 190,000 tons for each.

Perhaps of real significance is that about the same percentage of the bridges constructured during the latter period have suffered damage as have those built in the earlier period, although on the average one group is six years older than the other. Of course, another explanation may be that, due to increased use of ice removal salts in recent years, the newer bridges more likely have had heavier applications of salt during the first six months after construction, when it is known even air-entrained concrete has not developed its maximum resistance.

Some of the data are contradictory. Illinois is a long state, extending from Wisconsin on the north to Kentucky on the south, a distance of approximately 400 miles. As would be expected, winter conditions within the state vary considerably from north to south. Generally speaking, the depth of snow and the number of storms per year decrease from north to south, and likewise, more ice-removal salts are used in the north than in the south. A review of the rock salt purchases for the past five years shows that 65 percent was for the northern half of the state and 35 percent for the southern half.

It would be expected therefore that bridges in the southern part of the state, because they receive less salt, might show less damage. However, the survey data do not reveal this, not even when northernmost districts are compared with the southernmost districts. In general, about the same percentage of bridges show damage in both locations. It may be that the data are obscured by other factors.

It is hoped that the more detailed inspection in phase two will show whether this is true. Phase one did not cover the magnitude of the damage in terms of area involved. It may be that when this is evaluated significant differences will be revealed geographically.

As matters now stand the reasons for disintegration of concrete bridges are based largely on speculation. One thing is certain, however; it is a serious problem that deserves intensive study by highway departments, related research agencies, and the manufacturers of ice-removal materials.

All-out efforts must be made to improve and assure the quality of concrete used in structures and pavements. Protective coatings and inhibitors need to be developed. Design engineers should give consideration to features that would improve drainage and facilitate removal of brine and cinders from the bridge surfaces. Greater care must be given during construction to avoid practices that degrade the quality of the concrete. Greater attention must be given to maintaining structures, particularly in the field of preventive maintenance. The search for ice-removal agents that are less corrosive must be intensified.

The AASHO Committee on Research Activities, in cooperation with the Highway Research Board, has given high priority to a research project on the subject of ice and snow removal. It is of the utmost importance that concerted efforts be made toward implementing that project.