Restoration and Protection of Damaged Concrete

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The New York State Thruway Authority, during the past five years, has done considerable work in restoring disintegrated concrete on pier caps, abutments, pavements, curbs, sidewalks, and large areas of concrete structure slabs. New methods and materials have been developed that are felt to be very satisfactory and are flexible in their application.

New exacting techniques have been developed for waterproofing various parts of the Thruway structures, including both existing concrete and concrete restorations. The methods employed and materials used should be of interest to those faced with similar problems of deteriorating concrete structures.

• SINCE THE THRUWAY was first opened to traffic in the summer of 1954, over 12,666,000,000 mi of vehicle traffic have been logged on the entire system. This traffic must be kept moving at Thruway speeds during all seasons. The most difficult period, in items of weather, is from November through April when icing conditions can and do occur. In the winter of 1959-1960, 50,000 tons of salt and 44,000 cu yd of abrasives were used to combat these conditions. Straight rock salt is usually used at the beginning of a snowstorm. Under conditions of freezing rain, the salt is mixed with sand in equal proportions. Storms in the 15° to 25° range are treated with 3 parts salt, 1 part calcium, and 4 parts sand, by weight.

Cinders are not used except near Buffalo where they are plentiful and less expensive than sand or slag.

Generally speaking, the application of de-icing agents in such quantities has had little detrimental effect on the concrete roadway pavement. This is chiefly because all such pavement was constructed with concrete containing from 4 to 6 percent of entrained air.

The structures tell a different story, however. All except those built near the end of the construction program were constructed of concrete containing straight portland cement and natural cement in a ratio of 7 to 1. The resulting air-entrainment from the natural cement used in this mixture is perhaps 2 to 3 percent and is not enough to afford the desired protection from saline solutions. Those structures containing the greater percentages of air display markedly greater resistance to damage.

One other contributing factor to the rapid deterioration of bridge pavements was the fact that these pavements were constructed as 4-in. thick wearing courses on previously built structural concrete decks. It was impossible to prevent salt water from infiltrating either the longitudinal or transverse pavement joints, from whence it found its way underneath the pavement to all parts of the bridge deck which it promptly proceeded to attack. Twofold damage was experienced. If the salt solution was strong enough, chemical deterioration resulted. If weak, freezing occurred and cracking of the thin pavement overlay resulted. The cracks afforded additional opportunity for subsequent infiltration.

In organizing Thruway maintenance forces, the need was recognized for including a bridge maintenance group designed to cope with the problem. This group was tooled and trained to handle preventive and corrective maintenance and has now caught up with and arrested the progressive deterioration of concrete in nearly 800 bridges. It is expected that the damage can now be kept under control. In the absence of established precedents, common sense was used to develop the methods that have been employed and subsequently proven effective.

In 1955, a joint sealing program was started employing the best elastomeric sealants available and using refined techniques for cleaning and application. It was thought that by sealing the joints water could be kept away from the structural slabs. It soon developed, however, that the pavement was breaking up more rapidly than anticipated. This was accompanied by signs of saturation of the structural slabs with eventual disintegration predicted. Substructures also were affected, particularly in the bearing pedestals.

In 1957, a treatment was developed to counteract the effects of infiltration. Joints were sealed wherever such sealing appeared to be desirable. Sometimes, however, considerable areas of broken or disintegrated pavement had to be removed, and in many cases the pavement was removed from the entire structure. This was replaced with asphalt concrete, after first sealing the structural slab. Squeegee coats of a Sika-Seal type of sealer and squeegee coats of Jennite J-16 type of coal tar pitch emulsion have both been used for this purpose. However, the coal tar pitch emulsion is preferred because the primer used with it appears to secure a better bond to concrete.

Sand was incorporated in the slurry to help secure an adequate mechanical bond with the asphalt concrete overlays. Weep holes were also drilled in all bridge decks to provide a means of escape for water trapped under the pavement. These were drilled with $1\frac{1}{2}$-in diameter diamond core drills at all locations where water could be intercepted. In a number of locations considerable areas of structural slab had to be replaced. This was done by removing the old concrete, retaining the existing reinforcing bar system and pouring new concrete structural slab. In all situations where structural slab was uncovered or rebuilt, it was sealed before applying the new asphalt concrete pavement.

The $1\frac{1}{2}$-in. asphalt concrete top course that was applied to the bridge proper was extended over the approaches for usually not less than 50 ft. This extension of the asphalt pavement provides a roof over the concrete approach slabs which invariably were settled and cracked, allowing salt water to get at the abutment back walls and bridge seats. When the asphalt concrete pavement was completed, it too was sealed with sealants of the bituminous type. Most preferred was coal tar pitch emulsion, Jennite J-16, or Penelastic P-16, with silica sand added to provide skid resistance and a mechanical keying action.

The coal tar pitch emulsion slurries applied to date have been laid down with hand squeeges. The cost of such an application was initially some \$0.65 per sq yd. Due to refinement of handling, mixing and application techniques, and cumulative experience, most recent costs for this application are approximately \$0.35 per sq yd. During the course of this winter, it is expected that a 12-ft slurry box will be constructed that will result in the advantages of hand application but which should further reduce the cost.

As early as 1956 it was evident that a number of bridges were suffering damage to substructure concrete in the form of disintegrating pier caps, bridge seats, and abutment back walls. "Jet-crete" machines were purchased for each of the four Thruway divisions and repairs of these damaged areas were started. Almost from the beginning, wet water has been used in all "Jet-crete" restoration work. For the past four years lightweight aggregate of the expanded shale type, manufactured under the trade name of Haydite, RT or A Grade, with a gradation of 0 to $\frac{1}{4}$ in. has been used with excellent results. It has been found that wet water promotes good bond and durability when used for soaking down the prepared concrete faces and in the concrete mix itself. Deynor, Multiwet 50, a multiphase concentrate that reduces surface tension to about 30 dynes when mixed 1 to 1,000 by volume, was used. Even more important, the wet water mix makes the "Jet-crete" workable to the extent that curved surfaces and arrises can be restored and new concrete faired into existing planes with little troweling and shaping. Its use reduces rebound and the quantity of water required. The finished work is pleasing in appearance and has excellent durability. Observation of test cores of "Jet-crete" have justified it as a general medium for restoration work. One of the principal advantages of wet water is that all the cement is apparently hydrated at the time of application. Because of this, the use of wet water has also been extended over the past two years for use in transit mix concrete where larger quantities are required, such as in replacing large deck and substructure areas.

Lightweight aggregate is used for two reasons:

1. It can be obtained ready graded in about any desired range of gradation.
2. It obviates the use of aggregates that are similar to those used in the initial construction and that may have contributed to the original failure.

In view of the relatively small quantities used it is felt that the slight added cost is justified. Once all portions of the substructures have been restored they are protected with a sealant that has been developed and that appears to be effective. This is mixed as needed. The formula is approximately as follows:

Sika Seal	5 gal
Penetrol	3½ gal
Flake aluminum paste	7 lb

The mixture is varied from time to time to adapt the material to prevailing temperatures by increasing the amount of Penetrol as temperatures drop so that workability can be maintained. It can be applied readily in rather cool weather (spring and fall) which greatly extends the season over which it may be used. Because of its effectiveness and pleasing appearance it is applied generally to all pier caps, pedestals, and abutment faces where it will be seen. Areas such as abutment back walls and bridge seats are most frequently treated with Sika Seal with enough Penetrol added to make the mixture workable at the temperatures encountered at the time. In any event, the two materials are not only compatible but seem to derive benefit from each other as the Penetrol acts as a wetting agent to obtain better penetration of the highgrade sealants found in the Sika Seal. The flash point is also raised to safer levels. Most applications are made with paint rollers, which reduces the cost of labor considerably.

To counteract the effects of salt brine and water leaking through the bridge expansion joints to the piers and abutments, painting practices for the steel members in the structure have been modified. All surfaces of interior stringers are now painted with a combination of Sika Seal and Penetrol in the belief that it will outlast any ordinary paint and also in recognizing that these out-of-sight areas do not warrant the cost of painting with a pigmented vehicle. Railings and outer surfaces of fascia beams are painted with aluminum paint which consists of Penetrol with red iron oxide for a primer and with aluminum paste added on the job for the finishing coats.

The bridge maintenance organization has grown up with the treatments that it has developed. Further experimentation will continue to mark its activities, as it is expected that new ideas and techniques will continue to be explored. The materials and methods now in use comprise what is believed to be a reasonably effective method for counteracting the damaging effect of water and brine on the vital parts of structures. They appear to have brought the rate of deterioration under control and will continue to be used until a better solution to the entire problem is evolved.