

Rehabilitation of Deteriorated Bridge Slabs

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A review is presented of the methods utilized by the Central Maintenance Engineering Division of The Port of New York Authority to rehabilitate concrete bridge decks, improve riding surfaces and provide maximum protection against effects of deicing chemicals and the elements.

•THE PORT of New York Authority, a bi-State agency, was established in 1921 by New York and New Jersey. The Authority, beside other responsibilities, performs functions relating to the coordination of transportation throughout the Port District, including the planning and future development of that requiring the cooperation of the two States.

The Authority operates the following interstate vehicular crossings: George Washington Bridge, Holland Tunnel, Lincoln Tunnel and three bridges connecting Staten Island to New Jersey. These bridges are the Bayonne Bridge, famous for its arch span-type construction, and the Goethals and Outerbridge Crossing Bridges, both of truss-type design. These bridges are all more than 30 yr old and are constructed with concrete roadways varying in design, including the supporting structural steel members. Roadway maintenance procedures followed over the years have varied. Chemical deicing agents have been used for approximately 20 yr to assist in ice and snow control. Chemical attack, freeze and thaw cycles, traffic wear, and expansion and contraction factors have made numerous bridge deck repairs necessary.

Port Authority bridge deck maintenance rehabilitation projects presently under way or recently completed were planned to follow procedures utilizing the latest maintenance engineering technology. In each case a bridge roadway is studied as to past maintenance history and present structural condition, and the most feasible economical rehabilitation procedure is determined to provide necessary repairs, maximum preventive maintenance controls and a proper roadway surface. Diversification in construction techniques resulted from differences in original construction design, variation in traffic conditions, availability of roadway for construction purposes and construction costs.

Individual problems relative to bridge deck deterioration required further investigation to set the scope of each project. These problems included: (a) extent of concrete cement deterioration; (b) patterns of internal planes of concrete failure, both horizontal and diagonal; (c) extent of polishing surfaces; (d) condition of reinforcing steel; (e) condition of supporting steel members and steel forming composite designs; (f) locations and extent of joint failures; and (g) location and extent of concrete failures on underside of bridge slabs.

Two methods of replacement of deteriorated bridge deck concrete are presently specified. An epoxy patching compound consisting of a coal tar epoxy resin binder and clean sharp sand, mixed in proportion of 1:4, is installed as a surface patch with a limiting depth of approximately 1 in. Before placement, the perimeter of the patch is saw cut and the patch area is painted with liquid epoxy coal tar. In all other areas, portland cement concrete is specified. There are variations in the mix design of the concrete depending on requirements of bridge deck design or on construction limita-

TABLE 1
CONCRETE DESIGN

Type	Wt Cement (lb)	Slump (in.)	Air (%)	Water (gal)	Water Reducing Additive (lb)	Metallic Agg. (lb)	Aggregate (lb)	
							Fine	Coarse
Shallow patch	94 ^a	3	3-6	5 ^b	-	-	126	227
Full slab	94 ^a	3	3-6	5 ^b	-	-	155	280
Non-shrink	658 ^c	1	5-6	30	3.5	120	1,000	2,000

^aType III. ^bGal/bag of cement. ^cType I.

tions. When concrete must be installed where traffic conditions limit working hours, high early strength cement and accelerators are specified. Early set is also considered when designing a mix to limit vibration effects of active bridge decks or when working days are limited

by scheduling requirements. Before pouring concrete, patch perimeters are saw cut and patch areas are coated with a polysulfide epoxy adhesive. Shallow concrete patches are installed unless deterioration is extensive and a full slab thickness replacement is required. The control of shrinkage in concrete where large areas of patching is encountered has required the use of additives such as iron filings, water-reducing agents, retarders and plasticizers. These mixes are similar to that used by the New Jersey Turnpike Authority. Designs of various concretes used and aggregate gradations for these concretes are given in Tables 1 and 2.

Two methods of waterproofing concrete bridge decks are presently specified. A grit tar system used most extensively consists of a prime coat of emulsified coal tar applied at the rate of 0.01 gal/sq yd, followed by an emulsified coal tar, especially formulated and mixed with sand in the proportion of 3 parts emulsion to 2 parts of sand, by volume, and spread at the rate of 0.50 gal/sq yd. The treatment is applied to either air-blown or sand-blasted surfaces. An epoxy coal tar coating mixed with sand has also been installed to a limited degree as a concrete sealer. Present lower costs and the important properties of short setting time and durability of this coating will result in its greater use in future projects.

Joint sealing is considered of primary importance in waterproofing bridge decks. Critical joints are presently sealed with a polysulfide joint sealer and established procedures require contractors to supply technically qualified supervision in working with this material. Proper mixing techniques must be closely adhered to, and temperature must be closely controlled. To obtain properly sealed joints, an evaluation must be made of the structural strength of the bonding surfaces. Polysulfide joints are normally specified to be sandblasted before installation. The actual design of the joint itself is considered important to obtain maximum life. A rubber asphalt joint filler is installed in areas not sealed with the polysulfide filler.

Bridge roadway pavements placed over a waterproofed concrete deck vary with requirements. Asphaltic concrete is used where the original construction of a bridge allows a thick pavement overlay or where it is permitted or required by curb heights and drainage patterns. Improvement in drainage, roadway profile, load distribution, control of reflection cracks, wear characteristics and skid resistance are all factors governing the use of this material.

TABLE 2
AGGREGATE GRADATION USED IN CONCRETES

Concrete Type	Passing Sieve (% by wt)													
	Fine						Coarse							
	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	1½ in.	1 in.	¾ in.	½ in.	¼ in.	No. 4	No. 8	
Shallow patch:														
Min.	95	75	45	25	10	0	-	-	-	-	100	85	10	0
Max.	100	95	80	60	30	8	-	-	-	-	100	30	10	-
Full slab:														
Min.	95	75	45	25	10	0	100	90	60	-	-	15	0	-
Max.	100	95	80	60	30	8	-	100	80	-	-	40	5	-
Non-shrink:														
Min.	-	90	82	20	0	0	-	100	-	95	-	30	0	0
Max.	100	100	100	60	10	2	-	-	-	100	-	50	5	-

TABLE 3
AGGREGATE GRADATION OF STONE-
FILLED SILICA SAND ASPHALT^a

Sieve Size	Total Passing ^b (%)
3/8 in.	100
No. 4	85 - 100
No. 8	69 - 85
No. 30	40 - 59
No. 50	34 - 40
No. 100	9 - 18
No. 200	3 - 8

^aAsphalt cement, 85 - 100 penetration.

^bCombined aggregate including filler.

A thin overlay of stone-filled silica sand asphalt (Table 3) is recommended where drainage designs are favorable, bridge designs limit dead load, high skid resistance is desirable or a low-cost pavement is required. Due to its limited thickness, this pavement can evaporate absorbed water more completely than asphaltic concretes. It also reflects very readily deterioration in the underlying concrete surfaces, thereby warning of maintenance problems.

An epoxy coal tar type of thin resurfacer has been tested and is appropriate

for areas requiring high skid resistance, heavy-duty wear characteristics (such as on high-speed curves), a quick setting material, and a waterproofer.

Monel tube drains 1 1/2 in. in diameter are installed vertically through concrete bridge decks and flush with the top of the concrete surfaces of bridges overlaid with asphaltic concrete. These drains are located at predetermined distances along the curb line and at low points. There is a very limited use of these drains on thin overlays.

GEORGE WASHINGTON BRIDGE

Two concrete rehabilitation contracts have been completed on the upper deck of the George Washington Bridge. Work performed provided a roadway that required minimum maintenance until a scheduled major rehabilitation program was undertaken. The concrete deck of this bridge is of the bulb beam-type of design.

After the severe winter of 1960-61, a thorough inspection was made of the bridge roadway. Concrete repair work was deemed necessary but far beyond the scope of bridge maintenance personnel. A contract was prepared that specified concrete repairs to the extent that only normal maintenance would be required during the following year. Available working areas and allowable working hours were very restricted due to the extensive amount of construction then under way on the second deck and new bridge approaches.

Contract work was scheduled from 7:00 PM to 6:00 AM so that all 8 lanes of the bridge were available during peak traffic hours. A minimum of 6 hr for curing concrete before opening the roadway to traffic was specified. Approximately 3,000 sq ft of concrete patches were installed, varying in size from 2 to 100 sq ft. Depth of patch was normally 2 to 3 in.

Areas that required patching were located by visual observation of concrete deterioration and the size of each patch was determined by sounding with hammers to determine limits. Patch areas were prepared by saw cutting a 1- to 1 1/2-in. vertical edge around the perimeter, followed by the removal of deteriorated concrete with pneumatic chipping hammers down to minimum depth located at the bottom of top reinforcing rods. Before placement of concrete, the entire patch area was thoroughly cleaned and coated with polysulfide epoxy adhesive and extended to a point 3 to 4 in. beyond the perimeter of each patch. After concrete placement, this coating was painted over the saw cut edge to seal the joint. Concrete was mixed on the job using Type III cement and a slump of 3 to 4 in. The aggregate was mixed with a 1:5 ratio of Sika-Set additive accelerator to water. To counteract the effects of cold weather, when necessary, the amount of Sika-Set additive was increased and the patches were covered with electric heating blankets to aid in curing. Patches were cured by applying a solution of Antisol white-pigmented curing compound after the concrete surface had lost its sheen. Patches installed under this contract have an excellent performance record over a 3-yr period with only an approximate 1 percent failure rate.

A rescheduling of the major rehabilitation program for the top deck of the Bridge made necessary a second roadway repair contract in 1962, a continuation of the work

performed in 1961. This work was more extensive; the entire deck was sounded for deterioration and all temporary patches of asphaltic concrete were made permanent with portland cement concrete. The purpose of this contract was to limit required work under the major rehabilitation program and provide a roadway that would require a minimum of maintenance over the next few years.

Concrete repair work performed under this second contract totaled approximately 6,000 sq ft of patch repair. Portions of this work could be scheduled during the day shift after the second deck of the bridge was opened to traffic. A recent check of patches installed under this second contract showed the same excellent performance.

APPROACH BRIDGE—GEORGE WASHINGTON BRIDGE

A 10-yr old bridge, approximately 400 ft long, spans the New Jersey approach to the George Washington Bridge from the Palisades Interstate Parkway. Test patches were removed from the 3-in. asphaltic concrete wearing surface to permit examination of the concrete deck. Repairs were found to be required at low points along curb areas and at transverse joints. During the construction season of 1963, the asphaltic concrete wearing surface was removed, concrete deck was sounded, and epoxy coal tar compound or concrete patches were installed. Concrete mix design and patching procedures were similar to those specified on the George Washington Bridge repair work, including the use of high early strength cement and Sika-Set accelerator to speed the curing process. An air-entraining agent and a maximum slump of 3 in. were specified. All steel expansion joints were ramped to permit traffic to pass through the work site during peak traffic hours each morning.

The concrete deck was sealed with a grit tar treatment, after sandblasting the deck. Monel drains were installed and a joint of polysulfide formed or saw cut at the junction of the concrete deck and curb. Existing joints, including sidewalk and both vertical and horizontal joints of each curb, were routed, cleaned and repoured with polysulfide epoxy or rubber asphalt. An epoxy coal tar was used to level and seal an area of the concrete deck where surface depressions were uncovered.

A new wearing surface of a dense-mix asphaltic concrete was placed in two layers, utilizing rubber-tired paving equipment or padded tracks. Each layer was rolled with a three-wheel, a pneumatic-tired and a tandem roller in that order. A rubber asphalt joint filler was poured along both curbs in pre-grooved joints in the asphaltic concrete to provide added protection against water seepage.

GOETHALS BRIDGE

A major maintenance project was completed on the Goethals Bridge in 1963. The bridge roadway had been overlaid with a $\frac{1}{2}$ -in. silica sand asphalt thin resurfacer in 1957, but by 1963 the surface pavement started to show indications of wear and concrete deterioration. Due to expected increases in traffic on completion of the new Verranzano-Narrows Bridge, it was decided to rehabilitate the concrete deck and provide a new riding surface.

The silica sand asphalt pavement was removed by heater planers and infrared heaters. Engineers sounded the concrete deck to locate areas of concrete deterioration and repairs were made using an epoxy coal tar patching compound for thin surface patches (Fig. 1) and portland cement concrete for deep patches.

Polysulfide joint sealer was installed in a joint formed by saw cutting along the junction of the curb and existing concrete deck. All transverse joints were routed, cleaned and repoured with a joint filler of polysulfide or rubber asphalt. Curb joints were cleaned out by specially adapted grinding equipment and repoured with polysulfide joint filler (Fig. 2). The concrete deck was cleaned by sandblasting before application of a grit tar waterproofing system. A $\frac{3}{4}$ -in. wearing surface of stone-filled silica sand asphalt was placed over a tack coat of asphalt cement. Rubber-tired paving equipment was required in addition to steel-wheel and pneumatic-tired rollers. All transverse joints poured with polysulfide were reflected through the new pavement by saw cutting a $\frac{3}{4}$ -in. wide joint in the new pavement and were then poured flush with a rubber asphalt joint filler. This was done to control reflection cracking.



Figure 1. Goethals Bridge, epoxy-coal tar patching compound installed as deck repair.

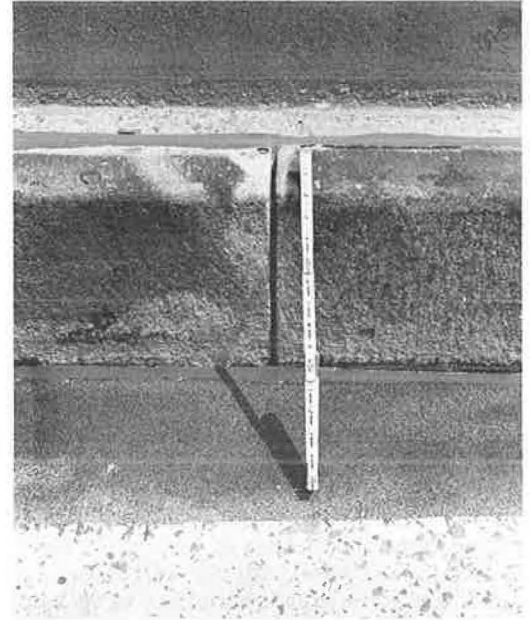


Figure 2. Goethals Bridge, newly poured polysulfide joint at curb and deck junction, polysulfide joint back of curb and cleaned vertical joint adjacent to epoxy-coal tar patch.

A cant strip was formed along both curbs with the new resurfacing material to establish a drainage line approximately 4 in. out from the curb. In addition, a pre-grooved joint was formed along the junction point of curb and resurfacing and poured with asphalt joint filler. Only one-third of the bridge had to be closed for the duration of this project.

BAYONNE BRIDGE

A concrete deck rehabilitation program is presently under way on the Bayonne Bridge, which crosses from Richmond, Staten Island, to Bayonne, N. J. The concrete deck of the 1,675-ft main span of the bridge was rehabilitated in 1962. The rehabilitation of 5,000 ft of approach viaduct is now in progress.

The main span of the bridge deck, resurfaced in 1957 with a $\frac{1}{2}$ -in. overlay of silica sand asphalt pavement, was heater planed and sandblasted. This 6-yr old thin resurfacer pavement gave evidence of normal signs of wear and definite indications of deterioration in the underlying concrete deck. The exposed deck was sounded and deteriorated concrete was replaced.

All rusted exposed reinforcing steel was either wire brushed, sandblasted or replaced if damaged. Exposed steel curb against which new concrete was poured was painted with polysulfide epoxy adhesive. Water-curing techniques were followed. A polysulfide joint was constructed at the junction point of curb and concrete slab. All other joints, as well as the complete deck, were treated by the same processes as in the Goethals Bridge project.

The concrete deck of the approach viaducts to the Bayonne Bridge is presently being rehabilitated, utilizing methods similar to that on the main span. In 1948, the approaches were patched along both curbs with asphaltic concrete due to excessive spalling of the concrete surface. The approaches were then resurfaced in 1955 and 1956 with 3 in. of asphaltic concrete after raising steel expansion joints.

The present contract requires the removal of the asphaltic concrete overlay, replacement of the existing steel plate-type expansion joints with finger joints installed



Figure 3. Bayonne Bridge, concrete rehabilitation of full slab depth.

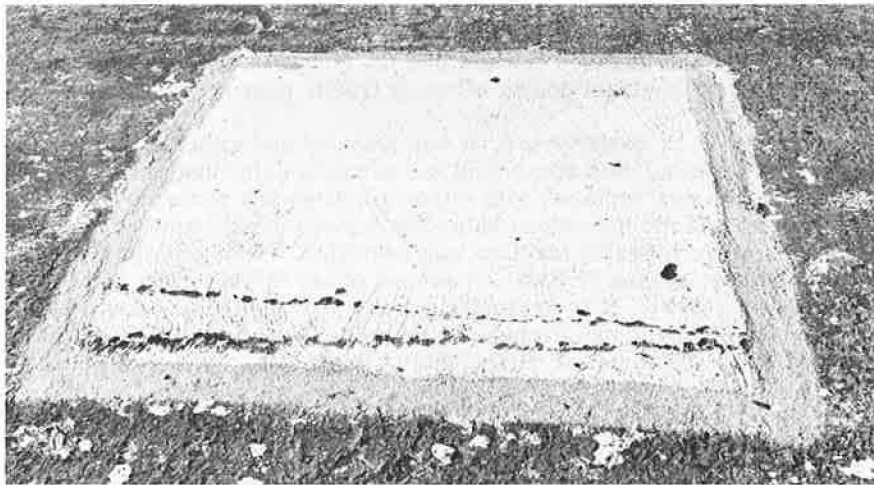


Figure 4. Bayonne Bridge, concrete patch with perimeter seal of sanded polysulfide adhesive.

to the original grade of the concrete deck, repair of the concrete deck where deteriorated, waterproofing of the deck and placing of a new thin resurfacer pavement. The concrete deck was sounded thoroughly with hammers to locate areas of deterioration. The extent of deterioration on this project was found greater than that originally contemplated, with both full slab depth replacement (Fig. 3) and area patching necessary. Due to the unexpected increase in deteriorated concrete requiring patching and the actual size of patches (Fig. 4), the mix design for these areas was changed from a high early strength cement concrete to a special non-shrink type.

LINCOLN TUNNEL APPROACHES

A concrete bridge deck rehabilitation project is also under way at the Lincoln Tunnel. The New Jersey approach to the tunnel is partially constructed on elevated structures having weight limitations that restrict the thickness of a pavement overlay.

The concrete deck of the viaducts required resurfacing in 1959 due to polishing aggregate and rough surfaces. Two overlays of a thin resurfacer of silica sand asphalt have been placed to improve the riding surface. The overlay pavements developed adherence problems, lamination failures and, on steep high-speed curves, short wear life. A research program to find an improved thin resurfacer was instituted by the Authority and resulted in the development of several new pavement designs. Six test strips of thin pavements were installed in 1962 on a high-speed curve of the Helix approach to the New Jersey entrance of the tunnel. The characteristics of the pavements are being evaluated, but of primary concern is the wearing life. These pavements include a $\frac{3}{4}$ -in. strip of stone-filled silica sand asphalt alone, with an asbestos filler or with Miradon or Wyton as binder, asphaltic concrete and a thin pavement of epoxy coal tar resin with both sand and emery chip as grit. Final conclusions have not been reached as to the most serviceable because the pavements have only been under test through one very light winter's weather. There are indications that the asphaltic concrete strip has shodded slightly, the Wyton mix has worn and lost a high percentage of its surface fines, and the epoxy coal tar area has several spots where underlying deteriorated concrete has failed. The entire test strip of epoxy coal tar was not sand-blasted before application of the coating, and those areas that received no surface preparation, except for heater planing of old resurfacer, have a high percentage of coating adherence failure. Further evaluation, after this winter, should provide a more realistic comparison between these test pavements. The remainder of the test strips are still in good condition.

The old silica sand pavement resurfacer was removed this past year from the roadway by heater planers and infrared heaters and the concrete deck was rehabilitated. Work was performed by contract during off-peak traffic hours, primarily during nights and weekends.

After the concrete deck was exposed, it was sounded and areas of deterioration up to 1 in. deep were replaced with epoxy coal tar patching compound. Deterioration exceeding this limitation was replaced with either a non-shrink concrete mix or, if areas were limited in size and did not extend below the top of the top reinforcing bars, a concrete mix with an accelerator additive was specified. This project was completed during the construction season of 1963. A second phase to the repair work for the Helix is scheduled for 1964. It is presently planned that bridge slabs will be coated with a waterproofing resurfacer pavement of epoxy coal tar and sand. Concrete slabs constructed on fill will be surfaced with asphaltic concrete.

CONCLUSION

This summarizes some of the projects undertaken by The Port of New York Authority to protect and extend the life of its concrete bridge decks. Procedures followed under these projects will no doubt be improved on future projects.