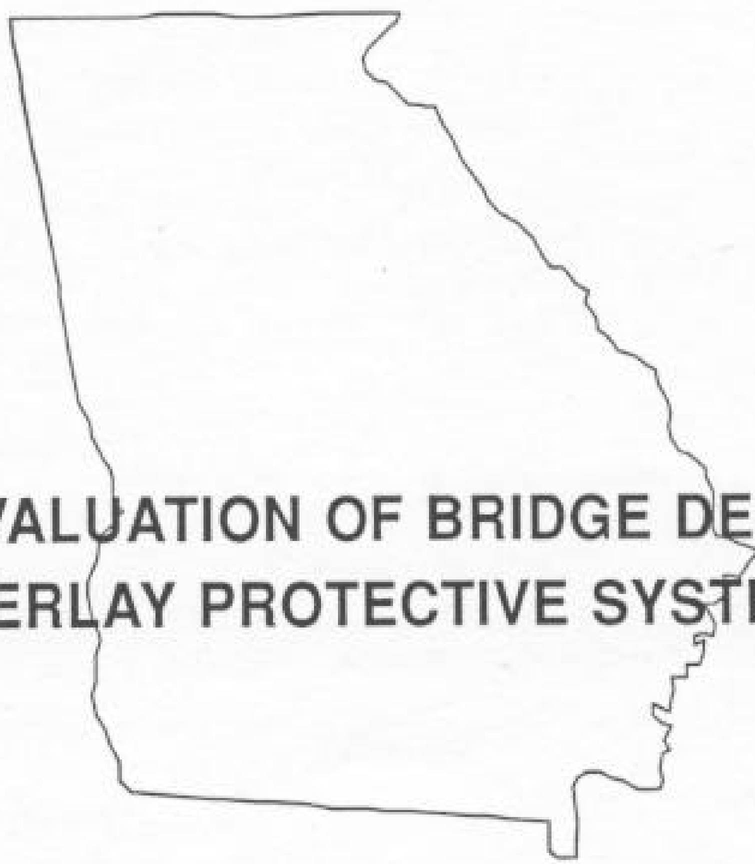
DEPARTMENTAL RESEARCH

GDOT RESEARCH PROJECT NO. 8901

FINAL REPORT

# GEORGIA DEPARTMENT OF TRANSPORTATION



# EVALUATION OF BRIDGE DECK OVERLAY PROTECTIVE SYSTEMS

OFFICE OF MATERIALS & RESEARCH

RESEARCH AND DEVELOPMENT BRANCH

Departmental Research
GDOT Research Project 8901
Final Report

# EVALUATION OF BRIDGE DECK OVERLAY PROTECTIVE SYSTEMS

by

V. Kirk Tatum, P.E.

Georgia Department of Transportation
Office of Materials and Research

In Cooperation With

U.S. Department of Transportation
Federal Highway Administration

APRIL 1993

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policy of the Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

TECHNICAL REPORT STANDARD TITLE PAGE

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| FHWA-GA-93-8901 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| EVALUATION OF BRIDGE DECK OVERLAY PROTECTIVE SYSTEMS | 6. Performing Organization Code |
| 7. Author(s) Kirk Tatum | 8. Performing Organization Report No. RP 8901 |
| 9. Performing Organization Name and Address Georgia Department of Transportation Office of Materials & Research 15 Kennedy Drive Forest Park, Georgia 30050 | 10. Work Unit No. 11. Contract or Grant No. RP 8901 |
| 12. Sponsoring Agency Name and Address Georgia Department of Transportation No. 2 Capitol Square Atlanta, Georgia 30334 | 13. Type of Report and Period Covered FINAL Oct.1, 1991-April 1, 1993 14. Sponsoring Agency Code |

15. Supplementary Notes

In cooperation with the Federal Highway Administration

16. Abstract

During the 1990's it has been reported that 40% of the total highway bridge deck area in the U.S. will be at least 35 years old and ready for replacement or rehabilitation. Corrosion of the reinforcing steel is the major problem that leads to early distresses of the deck surface. There is a need for overlay materials and methods that will protect the reinforcing steel from chlorides, provide adequate friction and cause the least amount of traffic disruption.

The objective of this project was to install and evaluate several low permeable overlays on a bridge for the purposes of field and laboratory performance evaluation and data collection.

Hydrodemolition was used to remove the deteriorated concrete down to 0.5 inch below the top mat of reinforcing steel. This project utilized fast track operations which meant that traffic was restored within 24 hours of placement of the overlay.

Microsilica, latex modified, low slump and a fast track conventional concrete overlay were placed on the same bridge and monitored for 2 years. Results indicate that latex and low slump overlays performed least favorably, particularly when placement costs are considered. Cracking was the major early distress in all of the overlays except for the conventional overlay.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Overlay, Microsilica, Latex, Low Slump, Bridge Deck, Hydrodemolition, Permeability | No restrictions |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | | |

Form DOT F 1700.7 (8-69)

# TABLE OF CONTENTS

Page

## LIST OF TABLES

Table | Page

LIST OF FIGURES

# I. INTRODUCTION

It has been well documented that many bridges and highways are showing signs of early and advanced deterioration. As a result, it is estimated that about $400 billion will be spent in the United States on replacement or rehabilitation of highway pavements and bridges before the year 2000.(1) The largest share of this money will be spent on rehabilitation of concrete bridge decks that have deteriorated due to corrosion of the reinforcing steel. Initially, the alkalinity of the concrete protects the steel from corrosion. Concrete, being a relatively porous material, allows penetration of chlorides, acid rain, carbon dioxide, etc. The infiltration of these substances acts to lower the pH of the concrete, thereby initiating corrosion of the reinforcing steel. Over time, if the concrete is subjected to chlorides or carbonation, the steel will corrode. The corrosion products are 2 to 4 times the volume of the original steel and produce stresses that cause the concrete to crack. Delamination and spalling eventually occur and the integrity of the concrete is lost.

During the 1990's, 40% of the total highway bridge deck area in the U.S. will be at least 35 years old and ready for replacement or rehabilitation.(2) There is a need for overlay materials and methods that will protect the reinforcing steel from chlorides, provide adequate friction and cause the least amount of traffic disruption.

In the summer of 1991 the Georgia DOT initiated a research project to evaluate four different fast track bridge overlay systems. In theory any overlay system should restore the riding surface, guarantee a minimum steel cover and reduce the rate of future chloride intrusion. Thin polymer overlays were not addressed in this research project due to the severity of the deterioration of the decks and because increased steel cover was needed. Also because of the high traffic volumes expected, there was uncertainty as to whether polymer type overlays would perform satisfactorily. Fast track paving meant closing lanes after rush hour Friday evenings, removing one lane of the existing deck to 0.5 inch below the top mat of steel, placing the overlay and opening the bridge to traffic the following Monday morning.

## II. BACKGROUND

As a result of a state-of-the practice literature search it was decided that microsilica, latex modified and Iowa low slump concrete overlays would be placed on a deteriorated bridge deck and compared against a fast track conventional overlay commonly used by the Georgia D.O.T. Specifications for the conventional fast track overlay are shown in Appendix A.

### Microsilica

Microsilica is a highly reactive pozzolan that is collected from exhaust gases during the production of silicon or ferro-silicon alloys. It is extremely small, the average diameter of a microsilica particle is about one-hundredth the size of a cement particle, but it has a very high surface area (approximately 50 times that of a cement particle) which contributes to rapid pozzolanic action. This reaction with calcium hydroxide provides additional calcium silicate hydrate which is the glue that holds the concrete together and results in higher compressive strength. The fact that the microsilica particles are so small creates a filler effect that reduces the permeability of the concrete to water and chlorides. The high surface area of the microsilica increases the water demand of the mix so super plasticizers are necessary for workability without the addition of water. The high surface area also reduces the amount of bleed water available to the surface, therefore precautions must be taken to prevent potential plastic shrinkage cracking. Microsilica is produced in three forms: as produced, densified and as a slurry. The as produced microsilica is economically unfeasible to ship due to its unit weight of 15 PCF. The densified microsilica has a unit weight of 40 PCF and is more easily supplied and less dusty than the as produced material. (3)

Microsilica concrete should be produced at a higher slump than conventional concrete due to its cohesive nature. The increased cohesiveness may trap air that must be removed by vibration unless a more workable mix is produced, therefore it is recommended that the slump be approximately 1 inch greater than conventional concrete.

Studies have shown that for optimum protection against chlorides (based on AASHTO T-277) the dosage rate for microsilica should be between 5 and 10% based on cement weight. For this project the microsilica was supplied as a slurry containing microsilica, water and a high range water reducer (HRWR). Specifications for the microsilica used in this project are shown in Appendix B.

## Latex

Latex, as used in latex modified concrete, is a styrene butadiene polymer in liquid suspension. When added to concrete, the latex forms a film that reduces capillary pores and thus reduces the permeability of the concrete to water and chlorides. The adhesive properties of the dry latex film account for higher tensile and flexural strengths but little is gained in compressive strength. On site mixing is required due to rapid slump loss and because if over mixed the surfactants in the latex will incorporate air and form a froth resulting in unacceptably high air voids. Air entrainment is generally not required due to the fact that the mixture will create sufficient air voids during mixing. Specifications for latex modified concrete are shown in Appendix C.

<u>Low Slump</u>

Low slump concrete is designed at a low water to cement ratio thereby producing a dense, strong mix that is relatively impermeable. In theory the mix will have low permeability resulting from the low capillary porosity which is expected from such a low water to cement ratio. The major drawback is that, as the name implies, it has a slump of about 1 inch and is very hard to mix and handle; therefore, on site mixing and a special heavy vibrating screed are required for placement. Conventional mixes with superplasticizers have made low slump concrete obsolete due to the fact that mixes can be produced at low water to cement ratios and yet have workable slumps. These mixes can also be mixed and placed with much less effort than standard low slump concrete. Specifications for low slump concrete used in this project are in Appendix D.

In order to get a good comparison between the different overlay systems, it was decided that all four overlays would be placed on the same bridge with a different material in each of four lanes. The bridge chosen for this project was Haynes Bridge Road (C.R. 1334) over State Route 400 in Fulton County. This bridge is 297 feet long and 52 feet wide and has an ADT of 13,130 vehicles with 2% trucks.

The existing deck surface had numerous patches and spalls with exposed re-bar, particularly in span 1 where the steel cover was very shy. Steel cover across the whole bridge averaged only 1.7" with span 1 averaging 1.34". Figures

1 and 2 show the patching and steel cover readings for span 1. The chloride content of span 1 at a depth of 1"-2"; which corresponds to the depth of the steel, averaged 4.36 pounds of chloride per cubic yard of concrete. Overall the entire deck averaged 3.25 lbs./cy of chloride at the depth of the reinforcing steel. As a rule, 1.5 lbs./cy of chloride is sufficient to begin corrosion of the reinforcing steel. Since the chloride content of a point in the deck is a function of time and the depth from the surface, it is advantageous to have as much cover as feasible over the steel.

The current practice in Georgia is to provide at least 2.25" of steel cover in the southern half of the state and 2.25" to 2.50" in the northern half of the state. Although span 1 had the most visible signs of distress and corresponding chloride content, it was decided to overlay the entire deck to provide at least 2.25" of steel cover.

## III. LABORATORY MIX DESIGNS

Trial mix designs were prepared in the laboratory for each type overlay except low slump. Because the concrete producer had experience with low slump concrete and because it is hard to work with in the laboratory, low slump preliminary designs were not done.

### Microsilica

All mixing was done in a 1.5 cubic foot mixer. Mixing was done in accordance with AASHTO T-126 except that all the aggregate was added first, followed by the cement and microsilica slurry and appropriate admixtures. This design used microsilica as an additive rather than as a cement replacement. Microsilica can be used as a cement replacement up to about 30%.

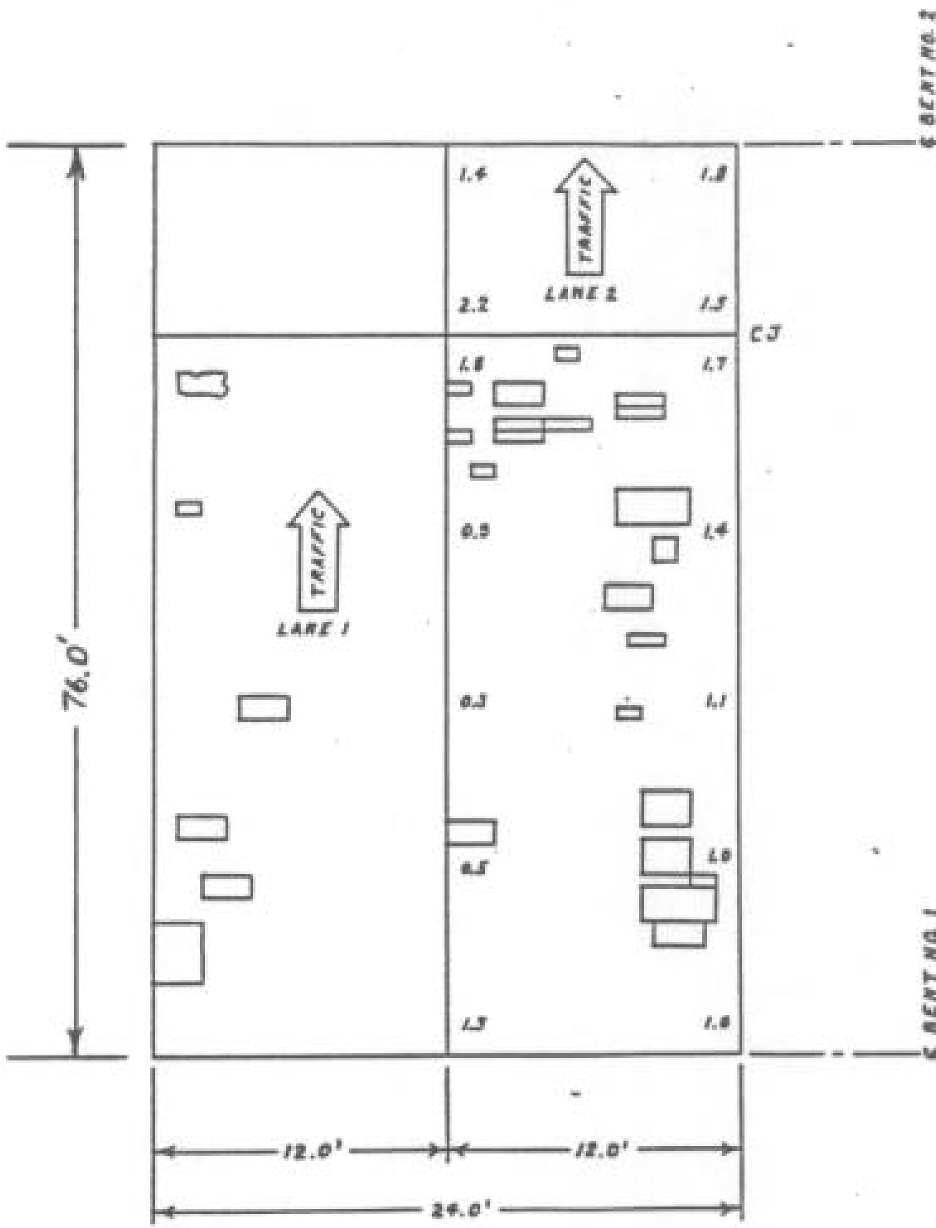



Figure 1. - Existing Deck Span 1
Haynes Bridge Rd. over Ga. 400
Eastbound Lane

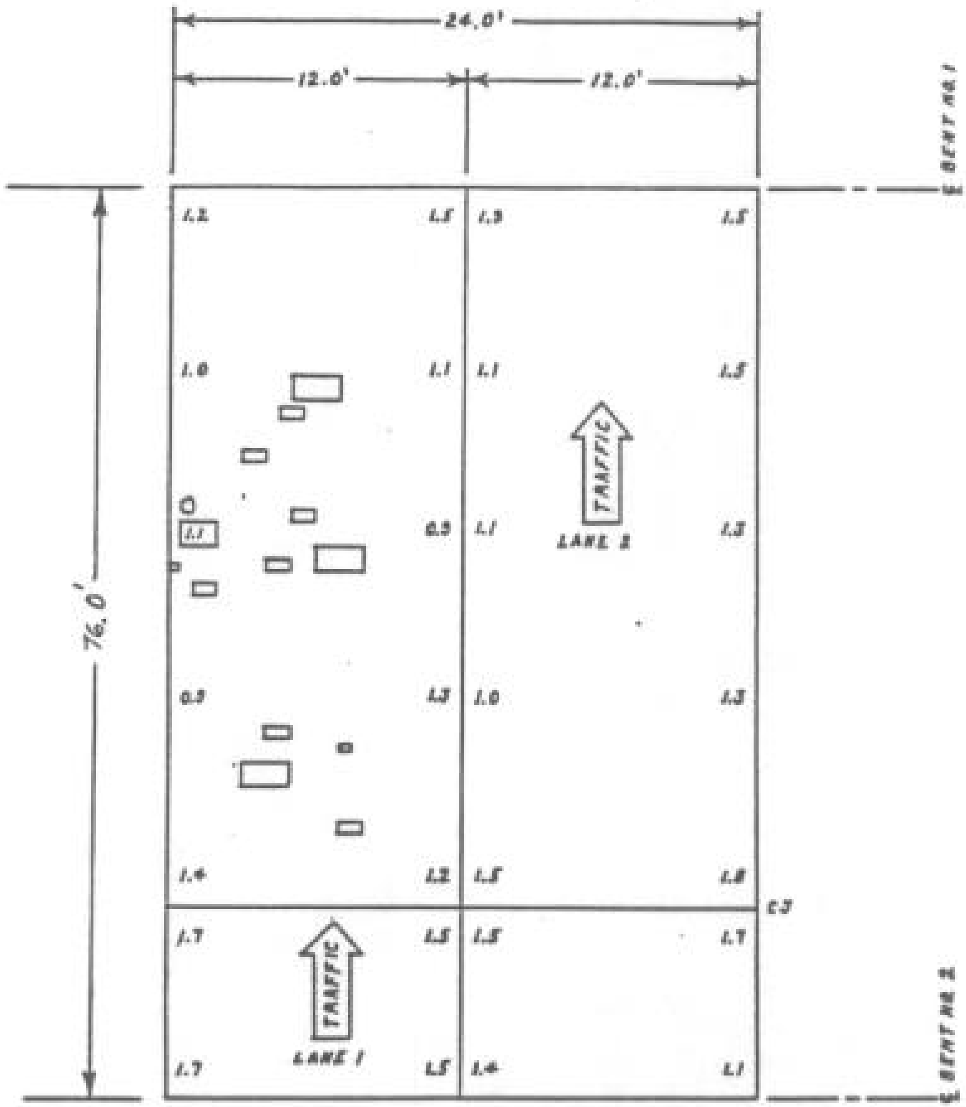



Figure 2. - Existing Deck Span 1
Haynes Bridge Rd. over Ga. 400
Westbound Lane

Table 1 shows the proportions of each ingredient based on a cubic yard of concrete. Also shown is the chloride permeability of each design at various times from initial batch.

The rapid chloride permeability test (AASHTO T-277) involves monitoring the amount of electrical current that is passed through a 4 inch diameter by 2 inch thick specimen when one end of the specimen is immersed in sodium chloride and the other end immersed in sodium hydroxide. A 60 volt potential is maintained across the specimen for six hours. This test is comparable to the 90 day chloride ponding test and is much faster to run. Table 2 is a relative comparison of permeability results using AASHTO T-277.

Each laboratory design consisted of two batches with checks on air content, slump, unit weight and temperature being done on each batch. Two 4" x 8" cylinders were made for compressive strength testing from each batch for testing at 8 hours, 12 hour, 1 day, 3 day and 7 day strengths. Compressive strengths are averages of four cylinders. Cylinders were cured in a 100% humidity moisture room until testing. Figure 3 is a graphical display of laboratory compressive strengths. Figure 4 shows chloride permeability for all the lab designs. Table 1 shows that the Vinsol resin used for air entrainment had to be increased by a factor of almost four over the conventional mix to achieve an acceptable air content. This is not uncommon according to the literature. (4) There are some opinions that an air void system may not be needed for low permeability concrete because the reduced permeability will prevent saturation.

<u>Latex</u>

The latex concrete was mixed similarly to the microsilica except that the coarse aggregate and the latex were mixed together for approximately 30 seconds prior to the introduction of the other ingredients. The sand and cement were

TABLE 1. LABORATORY MIX DESIGNS

| MIX INGREDIENT | CONVENTIONAL | MICROSILICA | LATEX |
|---|---|---|---|
| CEMENT (lbs.) TYPE III (1) | 750 | 750 | 750 |
| MICROSILICA (gals.) (2) | --- | 9.5 ** | --- |
| LATEX (gals.) (3) | --- | --- | 24 |
| COARSE AGG. (lbs.) (4) | 1741 | 1758 | 1741 |
| FINE AGG. (lbs.) (5) | 1145 | 998 | 1157 |
| WATER/CEMENT | 0.39 | 0.39 | 0.26 |
| AIR ENTR. (oz./C.Y.) | 3.0 | 11.0 | --- |
| HIGH RANGE W.R. (oz./cwt) | 5.0 | 4.0 | --- |
| AIR (%) | 5.5 | 4.6 | 3.2 |
| SLUMP (IN.) | 5.5 | 6.25 | 7.5 |
| UNIT WT. (pcf) | 143.2 | 144.4 | 146.0 |
| AIR TEMP. (DEG. F) | 70.8 | 72.0 | 71.4 |
| CONC. TEMP. (DEG. F) | 70.9 | 74.1 | 72.3 |
| CHLORIDE PERMEABILITY<br>28 DAY (Coulombs) | 3596 | 2219 | 748 |
| 56 DAY (Coulombs) | 2207 | 1443 | 558 |
| 84 DAY (Coulombs) | 1684 | 987 | 364 |

** MICROSILICA SLURRY CONTAINS 5.5 lbs. OF MICROSILICA PER GALLON.

(1) BLUE CIRCLE @ ATLANTA
(2) FORCE 10,000, W.R. GRACE & CO.
(3) STYROFAN 1186, BASF CORP.
(4) GRANITE GNEISS, VULCAN @ STOCKBRIDGE
(5) SILICA SAND, HOWARD SAND CO.

TABLE 2.
CHLORIDE PERMEABILITY

| CHARGE PASSED (Coulombs) | CHLORIDE PERMEABILITY | TYPICAL OF - |
|---|---|---|
| >4000 | HIGH | HIGH W/C RATIO,(>0.6) PCC |
| 2000-4000 | MODERATE | MODERATE W/C RATIO,(0.4-0.5) PCC |
| 1000-2000 | LOW | LOW W/C RATIO,(<0.4) PCC |
| 100-1000 | VERY LOW | LATEX MODIFIED,INTERNALLY SEALED PCC |
| <100 | NEGLIGIBLE | POLYMER CONCRETE |

NOTE: FROM "RAPID DETERMINATION OF THE CHLORIDE PERMEABILITY OF CONCRETE," REPORT NO. FHWA/RD-81/119.

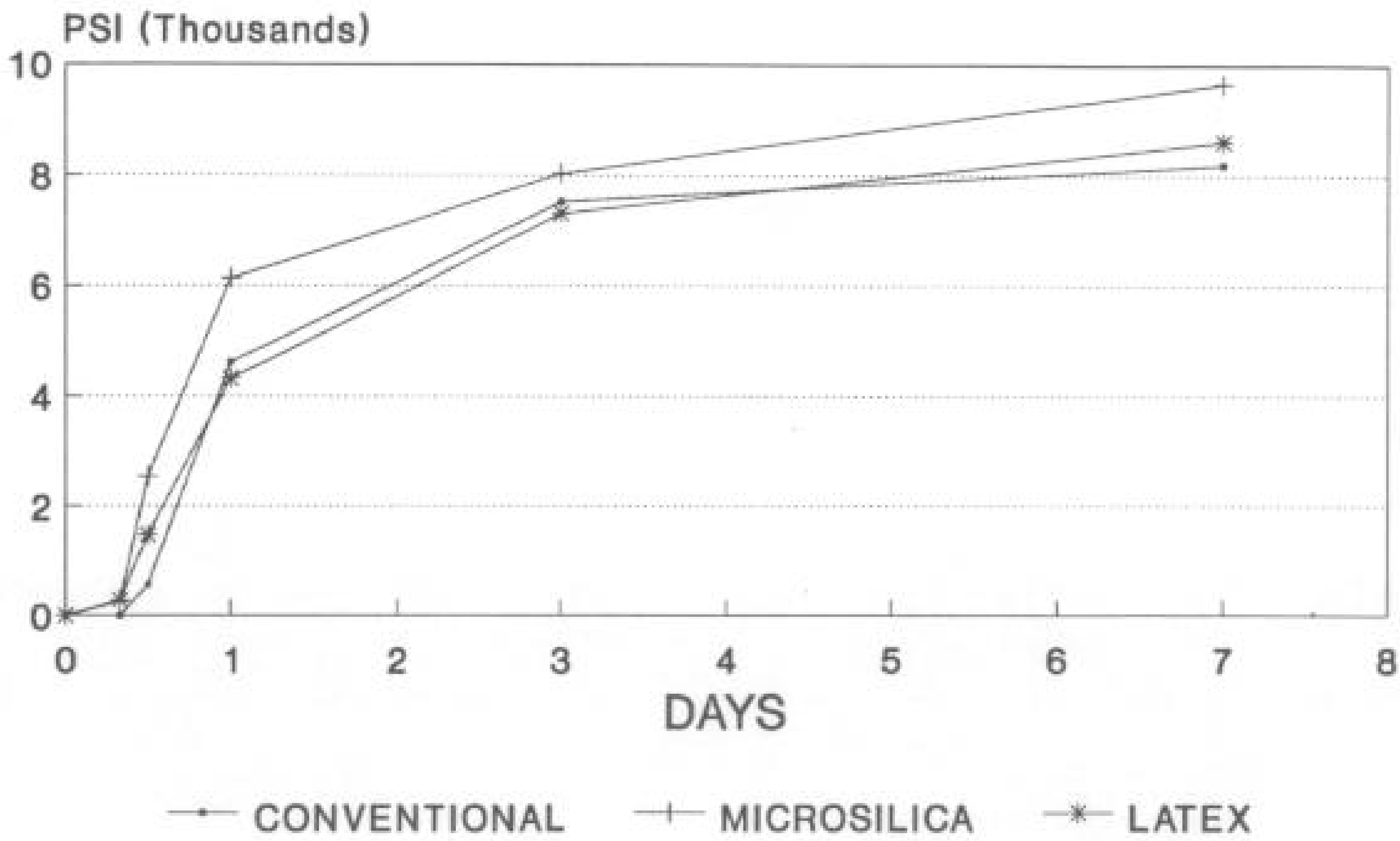



FIGURE 3: LAB MIX DESIGNS
COMPRESSIVE STRENGTH

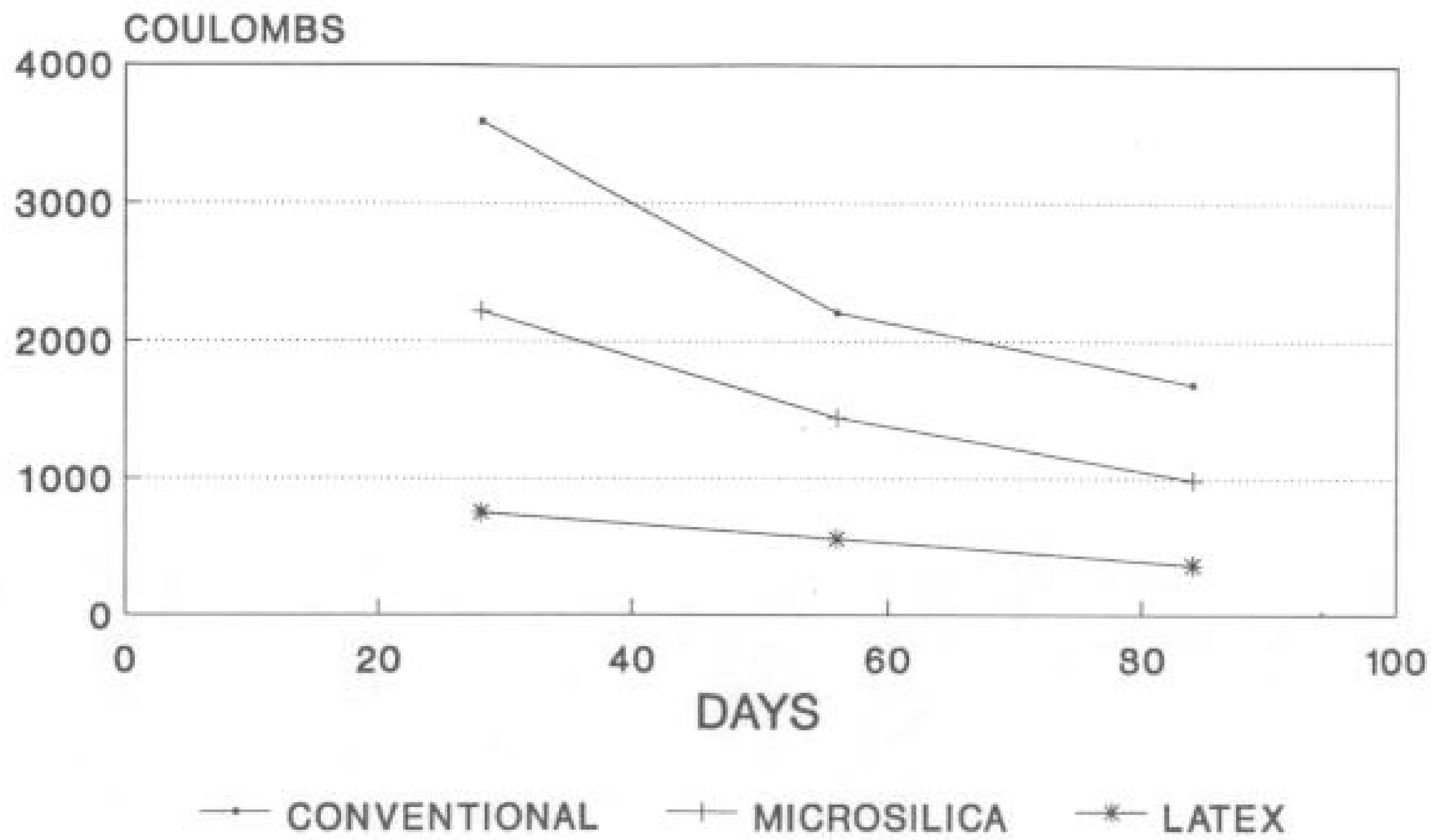



FIGURE 4: CHLORIDE PERMEABILITY
LAB MIX

than added and mixed for an additional minute before the batch water was added. The mixture became so "soupy" during mixing that only half of the computed batch water was added. Even at a water to cement ratio of 0.26, a slump of 7.5 inches was obtained. Increasing the sand content may have helped this situation. The latex design, as can be seen from Table 1, requires no air entrainment, the latex itself provides the freeze-thaw protection. The frothing of the latex during mixing entraps enough air without the need for air entraining admixtures. It has also been suggested that mixtures with low water to cement ratio, less than 0.35, the air voids become discontinuous and the void size will be reduced substantially thereby reducing the freezing point to temperatures well below what may be encountered during even the coldest winters.

The latex concrete had a green film that could be scraped off but would immediately reappear. However, after setting the green color was not noticeable. The latex performed very well in terms of chloride permeability as shown in Figure 4.

Since this project was a fast track overlay, Special Provisions required that the compressive strength at 24 hours be at least 3500 psi. Achieving the required early strengths required using Type III cement. All designs met the early strength requirements (see Figure 3).

Shear bond strength was tested on all three materials in accordance with Section 934 of the Georgia Standard Specifications. Mortar samples were made of microsilica, latex and the conventional mix. Mortar samples were made of a 50/50 blend of cement and sand with the same water to cement ratios as was used in the lab designs. Each mortar was poured into a 16" x 2" x 0.5" form which was placed on a 16" x 3" x 3" cured mortar beam. After curing, the beam and mortar sample was sawed into 2 inch sections for testing. A holding device and plunger was used to apply a shearing load at a rate of 0.05 inches per minute to the overlay until failure occurred. All three materials exceeded the 200 psi requirement and in fact failure occurred in the substrate beam in every case and not along the bond interface. Since this project called for removal of the existing concrete to 0.5 inch below the top mat of reinforcing steel, bond strength was not considered to be a major concern.

## IV. DECK REMOVAL

Removal of the top portion of the existing deck was accomplished using hydrodemolition. Hydrodemolition has advantages over other removal techniques in addition to being much faster. It is selective and removes all the unsound concrete while leaving good, sound concrete. Jack hammers can produce microcracks in the concrete and the heavy vibration may damage the bond between the steel and concrete at depths and areas not to be removed. The hydrodemolition equipment cleans the steel of rust while it removes the deteriorated concrete.

The hydrodemolition equipment on this project consisted of two Luverne Bulldog units and two National Liquid Blaster 4400 units, each capable of removing the existing deck to a depth of 0.5 inch below the top steel and 6 feet wide at a rate of approximately 100 SF/hour. The Contractor had all four units on the deck at all times with at least two and occasionally three machines operating at a given time. Deck removal averaged approximately 200 SF/hour. Water was taken from a fire hydrant and pumped through two large diesel engine pumps providing 40 gpm at 20,000 psi to each unit. Plywood was placed between the girders on the underside of the bridge to protect traffic below from water runoff and in particular from water and debris should the deck be blasted completely through as did happen occasionally. Full depth removal occurred where the existing concrete was very weak and usually in places where water jets from two machines overlapped each other in the same area.

Debris cleanup was closely coordinated with the hydrodemolition so that the cleanup was on-going along with the hydro machines. If the water is allowed to evaporate from the waste, cleanup becomes much more difficult. If the debris dries out it tends to cake together and leave a residue. Two Peabody-Myer industrial vacuum units, each having 2-4" hoses capable of pulling 24" of Hg were used for cleanup.

The project proposal called for lane closures to begin after 7 P.M. on Friday and be removed by 6 A.M. Monday. Deck removal usually started around 8 P.M. Friday with the last machine finishing around 4 P.M. Saturday. Cleanup continued until approximately 8 P.M. Saturday. The new overlay was then ready to be poured. This process was repeated for each of four lanes on four consecutive weekends. The hydrodemolition specifications for this project are shown in Appendix E.

## V. INSTALLATION OF OVERLAYS

### Conventional

APAC-Ga. was the prime contractor for the overlay work. The first overlay placed was a standard fast track concrete mix. This mix was placed in lane 2 which was the outside lane travelling eastward as shown in Figure 1. Prior to

TABLE 3. FIELD MIX DATA

| MIX INGREDIENT | CONVENTIONAL | | MICROSILICA | | LATEX | | LOW SLUMP | |
|---|---|---|---|---|---|---|---|---|
| CEMENT (lbs.) TYPE III (1) | 750 | | 750 | | 750 | | 826 | |
| MICROSILICA (gals.) (2) | --- | | 9.5 ** | | --- | | --- | |
| LATEX (gals.) (3) | --- | | --- | | 24 | | --- | |
| COARSE AGG. (lbs.) (4) | 1849 | | 1850 | | 1843 | | 1503 | |
| FINE AGG. (lbs.) PRIMARY (5) | 540 | | 506 | | 1047 | | 1421 | |
| FINE AGG. (lbs.) BLEND (6) | 540 | | 506 | | N/A | | N/A | |
| WATER/CEMENT | 0.40 | | 0.40 | | 0.26 | | 0.31 | |
| COARSE AGG. SIZE | 7 | | 7 | | 7 | | 7 | |
| FIELD TEST RESULTS | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| AIR (%) | 2.6 | 5.0 | 2.2 | 2.6 | 3.8 | 3.8 | 3.5 | 4.6 |
| SLUMP (IN.) | 7.5 | 6.75 | 7.5 | 7.5 | 7.75 | 5.75 | 1.0 | 0.75 |
| AIR TEMP. (DEG. F) | 58 | 54 | 63 | 57 | 75 | 57 | 55 | 52 |
| CONC. TEMP. (DEG. F) | 83 | 81 | 77 | 77 | 85 | 81 | 76 | 70 |
| COMPRESSIVE STRENGTH (PSI) | | | | | | | | |
| 24 HRS. | 4300 | 3100 | 5250 | 6230 | 2710 | 3780 | 5750 | 4970 |
| 7 DAY | 8117 | 6705 | 9172 | 9908 | 7222 | 7839 | 8714 | 7202 |
| 28 DAY | 9788 | 8217 | 11,022 | 12,374 | 8037 | 8376 | 10,405 | 8754 |
| 56 DAY | 10,604 | 8555 | 12,375 | 13,648 | 8614 | 9291 | 11,141 | 9192 |
| 90 DAY | 11,061 | 8833 | *** | *** | 9330 | 10,086 | 11,479 | 9470 |
| CHLORIDE PERMEABILITY (Coulombs) | | | | | | | | |
| 28 DAY | 4630 | 3977 | 416 | 313 | 1129 | 667 | 3209 | 3956 |

** MICROSILICA SLURRY CONTAINS 5.5 lbs. OF MICROSILICA PER GALLON.
*** MICROSILICA 90 DAY BREAKS MISSING.
(1) BLUE CIRCLE @ ATLANTA
(2) FORCE 10,000, W.R. GRACE & CO.
(3) STYROFAN 1186, BASF CORP.
(4) CALCIUM SILICATE, BLUE CIRCLE @ BALL GROUND
(5) MANUFACTURED SAND, BLUE CIRCLE @ LITHONIA
(6) SILICA SAND, BLUE CIRCLE @ FT. MITCHELL, AL.

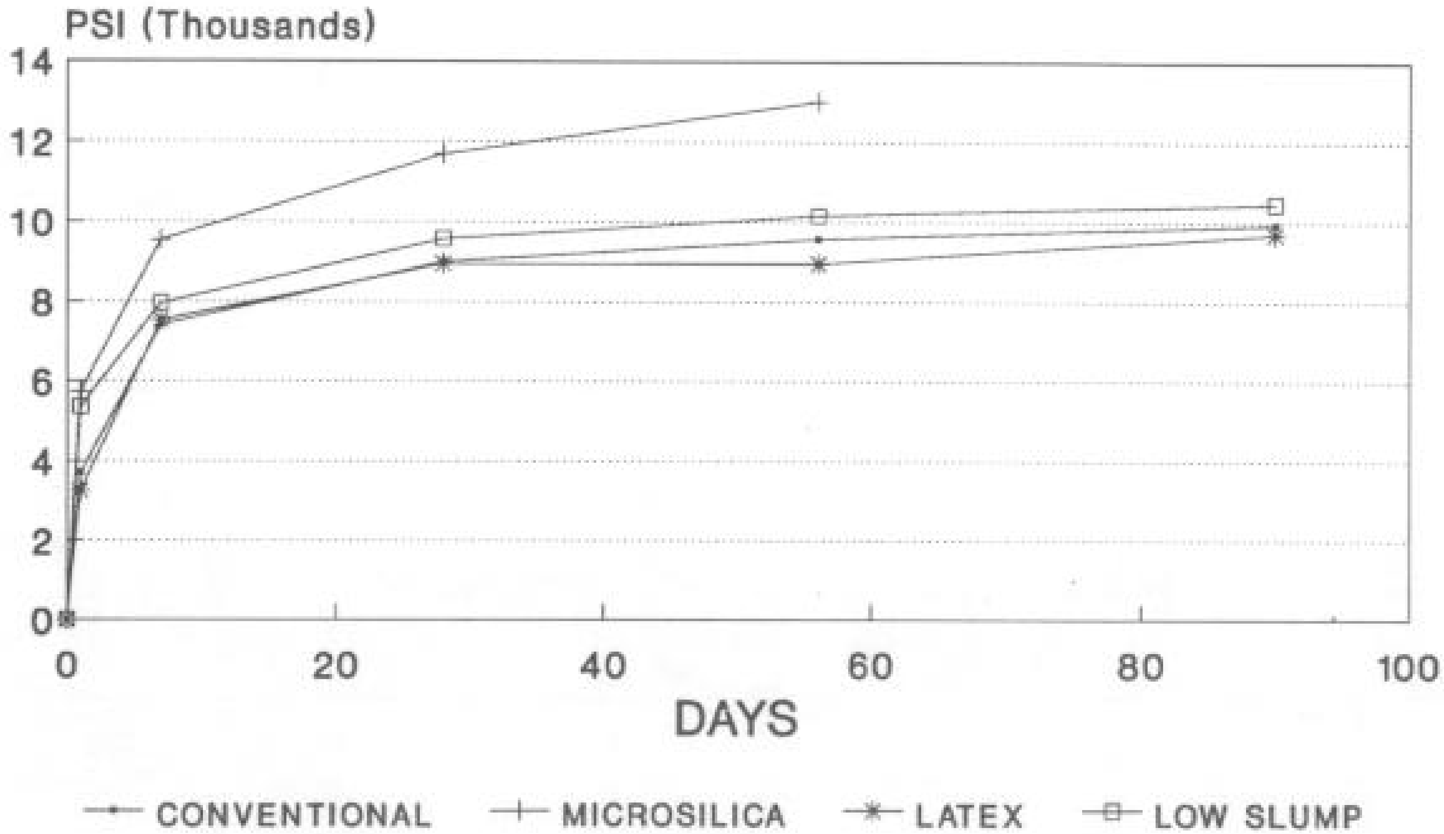



FIGURE 5: FIELD MIX RESULTS
COMPRESSIVE STRENGTH

placing the overlay, the surface of the substrate concrete was dampened and the new longitudinal joint adjacent to the curb line and the transverse joints at the approach slabs on either end received a cement mortar bonding grout. The joint between lanes 1 and 2 was not grouted because specifications required it to be sawn back 3 inches prior to the hydrodemolition of lane 1 the following weekend. This procedure was repeated for each lane.

Table 3 shows the mix design for the conventional overlay. Concrete delivery was by ready mix trucks and a small sidewalk type vibrating screed was used for initial finishing. Additional high range water reducer (HRWR) was added at a rate of 8 oz./cwt. to each truck at the job site for increased workability and to help the concrete flow around the exposed steel. A hand held vibrator was also used to help consolidation. Placement averaged 20 CY/hour with 60 CY being placed. Table 3 shows results of tests performed on the concrete at the job site. Two sets of tests were done for each overlay and compressive strengths are averages of two 4" x 8" cylinders except for 24 hour breaks which were done using 6" x 12" cylinders. Generally, 4" X 8" cylinders exhibit approximately 5% greater compressive strength than the same mix in 6" x 12" cylinders. The smaller cylinders were used because of the high strengths expected. Forces beyond the capacity of the testing machine would be required to break 6" x 12" cylinders beyond 28 days. This is certainly true for the microsilica cylinders. Figure 5 is a graphical display of field compressive strengths and is an average of all four cylinders for a given break time.

**Microsilica**

Microsilica was the next overlay placed and it was placed in the inside eastbound lane. The microsilica concrete was mixed and delivered by ready mix trucks and finished in the same manner as the conventional overlay. The surface texture appeared to be more sticky than the conventional mix. The float man could not bring the float across the lane towards him without marring the surface. Due to the lack of bleed water to the surface, the surface appeared to dry before the underlying concrete making it spongy and hard to finish. This may explain the roughness index values being higher than the conventional.

The microsilica slurry contained a small amount of superplasticizer to help in dispersion when added to the mix but an additional 6 oz./cwt was added to each truck at the job site. Placement averaged 22 cy/hour with about 60 cy being placed. Table 3 shows results of job site tests and Figure 5 is a graphical display of compressive strength.

**Latex**

Due to mixing and handling concerns mentioned previously, a concrete mobile mixer was used to mix and dispense the latex modified concrete. Since the prime contractor had no experience with latex or low slump concrete, these overlays were subcontracted to a company with experience in these type overlays. The latex used was Styrofan 1186 from BASF Corp. From the literature and from the latex manufacturer's recommendations it was decided that the latex would be added at a rate of 3 gallons per bag of cement.

There were two mobile mixing units for this project and since each could carry only enough material for 10-12 cubic yards at a time, placement averaged only about 10 CY/hour. A Bidwell rotating drum screed was used to consolidate and finish the latex although the same screed used for the conventional and microsilica overlays could probably have been used. Table 3 and Figure 5 show the design and strength data for the latex.

The weather started out at a pleasant 75° and dropped steadily during the pour to 57° by the time the second set of cylinders and tests were made. The overnight low was 49° with winds gusting 15 to 20 mph. These cold temperature may have contributed to the low 24 hour breaks shown on Table 3. The cylinders that were tested at 36 hours that had remained indoors the last 12 hours before testing had satisfactory compressive strengths. The latex had a very low water to cement ratio (0.26). Low water to cement ratios generally contribute to higher strengths, all other things being equal. At very low ratios as in the case of the latex mix, self-dessication can occur during hydration and prevent further hydration from taking place. This may explain the relatively low compressive strength exhibited by the latex mix.

<u>Low Slump</u>

The low slump overlay also required the use of the concrete mobile mixer and a special, heavy vibrating screed especially suited for low slump work. As with the latex, the low slump placement averaged 10 CY/hour and approximately 60 CY were placed. Again, Table 3 and Figure 5 show design data. Because low slump concrete is difficult to handle and place there is a tendency to vibrate too much with the hand vibrator which may flush water to the surface leading to cracking, etc.

Curing of each overlay system was critical because of the limited time the overlay could be cured. Placement of the overlays started on Saturday evening and the overlay had to cure and be ready for traffic the following Monday morning. A film of water was kept on the surface by fogging until covering materials were in place. As soon as the surface was firm enough to allow a cover to be placed, two layers of wet burlap were placed over the entire width and length of the overlay. A water truck was kept on hand at all times to keep the burlap wet.

Table 4 shows the comparison between laboratory mix and field mix for compressive strength and chloride permeability. Surface friction values and profilograph readings are also shown for the finished, planed and grooved deck. From Table 4 it is apparent that low slump mixes provide no more protection in terms of permeability than does a conventional mix. The large difference in permeability between lab and field samples of the microsilica may be due to inadequate mixing in the lab. The variability in the permeability data can be attributed to samples being taken from various places in the deck. Also, AASHTO T-277 allows variation as much as 35% in test results on the same sample. As mentioned before, the latex shows good permeability results but nothing is gained in compressive strength.

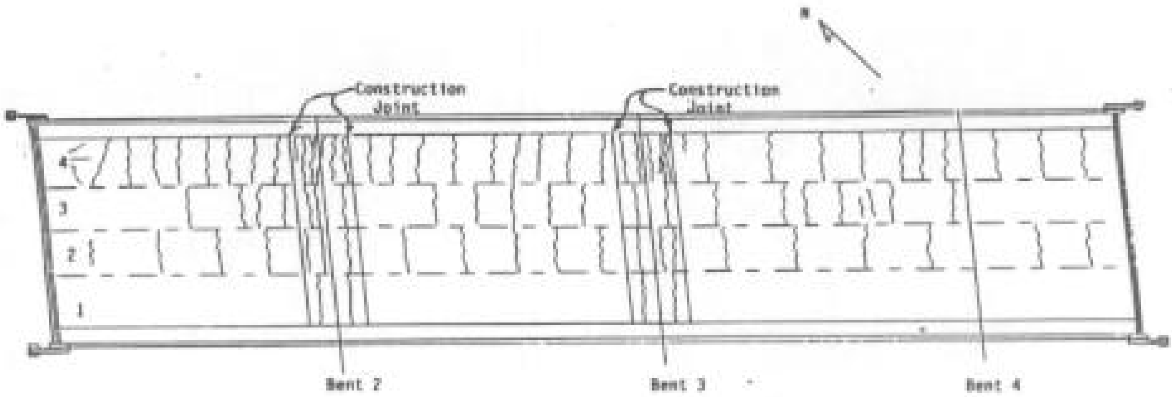
## VI. POST CONSTRUCTION

A crack survey was done approximately two weeks after the last overlay was placed and transverse cracks in each lane were counted and mapped. Figures 6, 7 and 8 show the cracks in the various overlays. The conventional overlay had only 4 transverse cracks, the microsilica and latex had 21 and 22 cracks respectively. The low slump had 42 transverse cracks. The majority of the cracks extended full width of the lane. All of the cracks were hairline to 1/16" or less. The latex and low slump overlays had very low water to cement ratios which limits the amount of bleed water available to the surface and may have accounted for the cracking in those sections. The microsilica overlay had the lowest chloride permeability and thus restricts movement of water to the surface which can contribute to cracking. Plastic shrinkage occurs when

TABLE 4. COMPARISON OF LAB VS. FIELD MIX

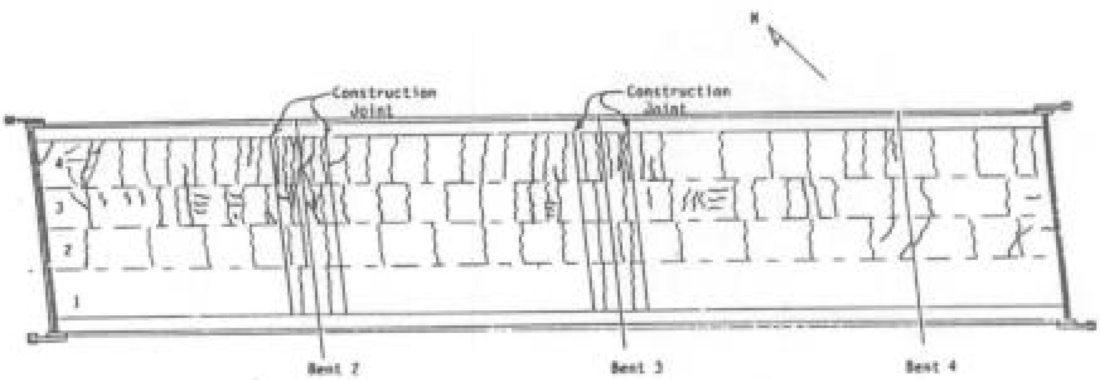
| COMPRESSIVE STRENGTH (PSI) | CONVENTIONAL LAB | CONVENTIONAL FIELD | MICROSILICA LAB | MICROSILICA FIELD | LATEX LAB | LATEX FIELD | LOW SLUMP FIELD | |
|---|---|---|---|---|---|---|---|---|
| 8 HR. | -- | -- | 259 | -- | 285 | -- | -- | |
| 12 HR. | 558 | -- | 2542 | -- | 1472 | -- | -- | |
| 1 DAY | 4615 | 3702 | 6140 | 5740 | 4317 | 3245 | 5360 | |
| 3 DAY | 7528 | -- | 8037 | -- | 7316 | -- | -- | |
| 7 DAY | 8196 | 7411 | 9658 | 9540 | 8614 | 7530 | 7958 | |
| 28 DAY | | 9002 | | 11,698 | | 8206 | 9579 | |
| 56 DAY | -- | 9579 | -- | 13,011 | -- | 8953 | 10,167 | |
| 90 DAY | -- | 9947 | -- | * | -- | 9708 | 10,474 | |
| CHLORIDE PERMEABILITY (Coulombs) 28 DAY | 3596 | 4303 | 2219 | 365 | 748 | 898 | 3583 | |
| 56 DAY | 2207 | -- | 1443 | -- | 558 | -- | -- | |
| 84 DAY | 1684 | 4514 | 987 | 285 | 364 | 629 | 2442 | |
| 7 MONTH | -- | 1475 | -- | 342 | -- | 407 | 2477 | |
| 15 MONTH | -- | 2658 | -- | 290 | -- | 472 | 2525 | |
| SURFACE FRICTION | LWP | RWP | LWP | RWP | LWP | RWP | LWP | RWP |
| (INITIAL) | 39 | 40 | 38 | 40 | 51 | 48 | 48 | 51 |
| (7 MO.) | 42 | 46 | 38 | 40 | 52 | 52 | 47 | 47 |
| (15 MO.) | -- | 49 | -- | 42 | -- | 49 | -- | 47 |
| INITIAL ROUGHNESS INDEX | 47 | 45 | 65 | 36 | 38 | 37 | 103 | 84 |
| FINAL ROUGHNESS INDEX ** | 7 | 4 | 11 | 11 | 4 | 11 | 7 | 13 |

* MICROSILICA 90 DAY BREAKS MISSING.
** AFTER PLANING AND GROOVING.



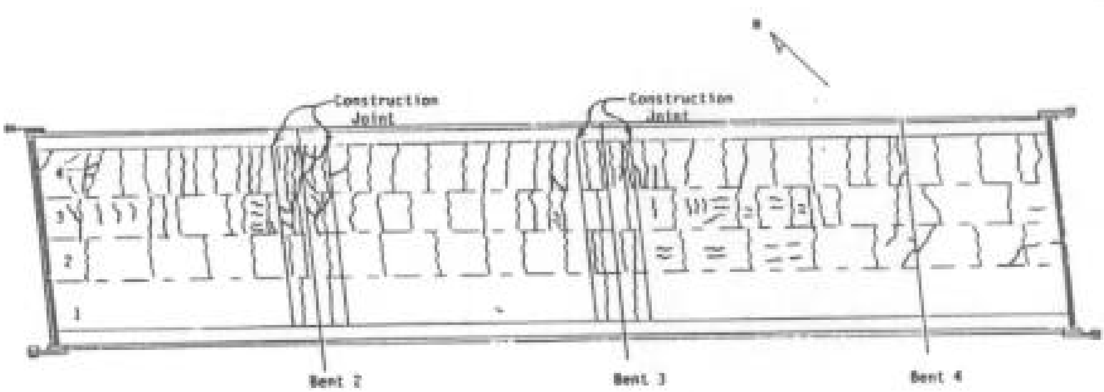

1 - Conventional
2 - Microsilica
3 - Latex
4 - Low Slump

Figure 6. - Overlay Cracks in Haynes Bridge Rd.




1 - Conventional
2 - Microsilica
3 - Latex
4 - Low Slump

Figure 7. - Overlay Cracks in Haynes Bridge Rd.
(7 Months)




1 - Conventional
2 - Microsilica
3 - Latex
4 - Low Slump

Figure 8. - Overlay Cracks in Haynes Bridge Rd.
(15 Months)

moisture evaporates from the surface faster than it is replaced by bleed water. Also, although the temperatures were fairly mild, it was quite windy during some overlay placement which greatly increased the evaporation rate at the deck surface. Bridge decks have a very high surface area to volume ratio and moisture loss due to evaporation can be excessive resulting in plastic shrinkage cracking unless proper curing procedures are followed.

Evaporation rates computed from Figure 9 revealed that except for the latex, there was little difference between curing conditions of the overlays. The latex overlay experienced the most severe conditions with computed evaporation rates of almost 0.4 $lb./ft^2/hr$. Special curing precautions are recommended to prevent cracking if computed evaporation rates exceed 0.2 $lb./ft^2/hr$.

Approximately seven months after the placement of the last overlay, the bridge was again surveyed for cracks that may have developed since the initial investigation. Figure 7 shows the cracks after seven months and Figure 8 shows results of a crack survey done 15 months after initial placement. It is difficult to determine whether cracks that are shown on the later maps developed in the time between surveys or whether they were present but overlooked on the initial survey. It is obvious that the great majority of the cracks are probably plastic shrinkage cracks that developed very early.

Surface friction testing and coring for permeability testing was done in conjunction with the crack surverys. Table 4 shows results of the friction and chloride permeabilities. There is little difference between overlays in friction testing after 15 months. As expected, the conventional overlay performed least favorably in terms of permeability. There was not as much difference in terms of permeability between the conventional and low slump

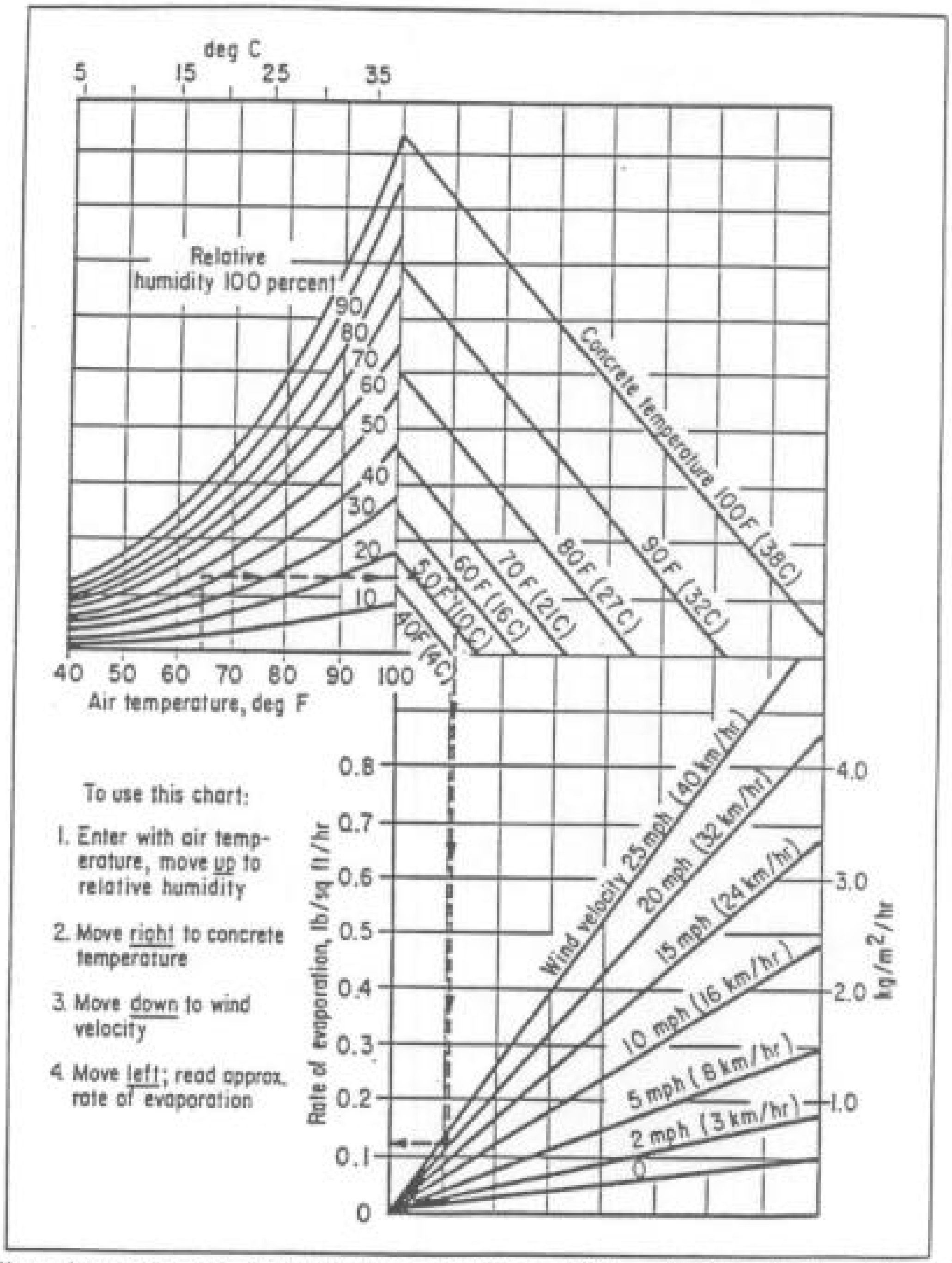



Figure 9. — *Effect of concrete and air temperatures, relative humidity, and wind velocity on the rate of evaporation of surface moisture from concrete.* (5)

overlays as was expected based on lab designs. The microsilica and latex overlays were much more impermeable (approximately 6 to 7 times more) than the other two materials. Although the microsilica and latex overlays are obviously superior to the conventional mix in terms of permeability, the fact that they developed many more cracks seems to defeat the purpose of an impermeable overlay. Although chlorides may have a more difficult time penetrating the concrete itself, the multitude of cracks presents easy entry of chlorides to the reinforcing steel. A core was cut through a typical crack in the latex section to determine if the crack went full depth. The core fell apart upon removing it from the deck revealing that the majority of the cracks probably extended the full depth of the overlay.

As a result of significant commercial development in the area, a contract has been awarded to widen this bridge in the summer of 1993. The latex and low slump overlay sections will be removed and the conventional and microsilica section themselves will be overlayed. This will prohibit long term evaluation of these test sections.

## VII. CONCLUSIONS AND RECOMMENDATIONS

Conclusions derived from this research would be to closely abide by the evaporation chart (Figure 9) for placement guidelines and to avoid placement of low slump and latex concrete overlays. Latex overlays, while being relatively impermeable to chloride intrusion, add nothing in compressive strength and are prone to cracking. Likewise low slump concrete showed no improvement in permeability and very little in compressive strength. Due to the fact that these two overlays must be mixed on site resulting in higher cost and slower production, and that little or no improvements in permeability or strength are gained, these type overlays are not recommended for future work.

Microsilica has promise and should be evaluated further as a viable overlay material. It is much less permeable than conventional mix and not as cost prohibitive as latex or low slump. It is felt that microsilica overlays can be placed with as much success as conventional mix if proper curing procedures are used and placement is not performed under high evaporation conditions. The standard Georgia fast track overlay mix seems to be much more forgiving in terms of susceptibility to shrinkage cracking and should adequately serve its purpose of extending the service life of bridge decks; provided adequate steel cover is achieved. It is felt that the addition of fly ash or smaller doses of microsilica to the conventional mix will produce a less permeable, more crack resistant mix suitable for fast track overlays.

## REFERENCES


1. "Strategic Highway Research Program", Transportation Research Board, Washington D.C., 1986.

2. Bettigole, Neal H., "Replacing Bridge Decks", Civil Engineering, Sept. 1990, p.76.

3. Holland, T.C., "Practical Considerations for Using Silica Fume in Field Concrete", Transportation Research Record 1204, National Research Council, Washington D.C., 1988

4. Kuhlmann, L.A., "Using Styrene-Butadiene Latex in Concrete Overlays", Transportation Research Record 1204, National Research Council, Washington D.C., August 1992.

5. ACI Committee 308, "Standard Practice for Curing Concrete (ACI 308-81)", American Concrete Institute, 1984.

"High Performance Concretes - A State-of-the-Art Report", Strategic Highway Research Program, National Research Council, Washington D.C., 1991.

"NCHRP Synthesis 179, Latex Modified Concretes and Mortars", Transportation Research Board, National Research Council, Washington D.C., August 1992.

Carette, G.G., and Malhotra, V.M., "Mechanical Properties, Durability and Drying Shrinkage of Portland Cement Concrete Incorporating Silica Fume", Cement, Concrete, and Aggregates, Vol. 5, No. 1, Summer 1983.

Chamberlin, W.P., "Performance and Service Life of Low Slump Concrete Bridge Deck Overlays in New York", Engineering Research and Development Bureau, New York State Department of Transportation, October 1990.

Cohen, M.D., and Olek, J., Concrete International, Vol. II, No. 11, Nov. 1989.

APPENDIX A

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SPECIAL PROVISION

IR-285-1 (315) Cobb
FR-056-1 (49) Fulton
MR-9409 (1) Fulton

## SECTION 519 - FAST TRACK BRIDGE DECK CONVENTIONAL CONCRETE OVERLAYS

**519.01 DESCRIPTION:** This Work consists of the construction of a Portland Cement concrete overlay of an existing concrete bridge deck and shall include the furnishing of all material, labor and equipment necessary to prepare and finish the work in accordance with these Specifications and Plan details.

**519.02 MATERIALS:** All materials shall meet the requirements of the Standard Specifications.

Concrete Mix Requirements

| | |
|---|---|
| Type III Cement Minimum (lbs/cu. yd.) | 750 |
| Coarse Aggregate Size No. | 7 |
| Maximum Water/Cement Ratio | .40 |
| Slump Limits (Jobsite) Maximum | 7 inches |
| Air Acceptance Limits (Jobsite) | 3.5 to 7.5% |
| Admixture (Required) | Type F or G |
| Minimum Compressive Strength (Jobsite) @ 24 hours | 3000 psi |

Temperature Limitations

| | |
|---|---|
| Concrete Placement Temperature (Range) | 70°-90°F |
| Air Temperature (Range) | 50°-90°F |

The contractor shall submit a mix design for approval. This submittal shall include the actual quantity of each ingredient and laboratory designs which demonstrate the ability of this design to attain a compressive strength of 3500 psi at 24 hours. Laboratory acceptance strengths shall be determined by at least eight compressive test specimens prepared and cured in accordance with AASHTO T-126. The specimens shall be made from two or more separate batches with an equal number of cylinders made from each batch.

**519.03 CONSTRUCTION:** The construction procedures for the overlay shall be as follows:

A. Concrete Manufacturing: Concrete for Portland cement concrete overlays shall be manufactured in accordance with section 500.05 of the Standard Specifications.

B. The existing deck to be overlaid shall be given a machine preparation consisting of removal of the concrete to a minimum depth of 0.5 inch below the top mat of reinforcement or as shown in the Plans. This operation shall be accomplished by use of high pressure water blasting equipment designed specifically for this purpose. At the contractors option initial removal of deck concrete may be accomplished with milling or grinding equipment in conjunction with high pressure water blasting. Damage to reinforcement steel will not be allowed.

C. After removal of the concrete, the entire area of the deck surface shall be blast cleaned to a bright, clean appearance which is free from dust, dirt, oil, grease and all foreign matter. The blast cleaning will be performed by high pressure water blasting. All debris of any type, including dirty water, resulting from the blast cleaning operation shall be immediately and thoroughly cleaned from the blast cleaned surface. The blast cleaned areas shall be protected, as necessary, against contamination prior to placement of the overlay. Contaminated areas shall be blast cleaned again as directed by the Engineer, at the Contractor's expense. All areas of standing water shall be removed and the surface reasonably dry before the concreting operation begins.

D. The minimum overlay thickness is to be the amount removed plus the minimum additional depth required to provide 2 1/4 inches of concrete cover over the top reinforcement mat or as specified in the Plans.

The finishing machine or approved screeding device shall be passed over the existing deck prior to placing the concrete overlay in order that measurements can be made to insure that proper overlay thickness and steel cover will be achieved. Screeds shall be equipped with surface vibrators sufficient to thoroughly consolidate the overlay full depth, unless other methods are approved by the Engineer. Consolidation using hand-held vibrators shall be required when placing the mixture around steel reinforcement or structural members.

The overlay shall satisfy the surface tolerances as found in Article 500.11.C.6.e of the Standard Specifications. After finishing, the surface shall be textured in accordance with the requirements of Section 500.11.C.6.c(1) or (2) or as required by the Plans and Proposal. Surface grooving shall not begin until the curing period specified herein has expired.

The formation of longitudinal joints and transverse construction joints shall be held to the minimum number necessary, and both type of joints shall be thoroughly blast cleaned and coated with an approved bonding agent before fresh concrete is placed against the hardened sides of the joints. When construction joints are necessary, they shall be formed by use of a header secured to the deck. After removal of the header, the overlay shall be sawed three inches or more inside the formed edge and the overlay outside the saw cut removed before the adjacent overlay is placed. The volume of the overlay removed will not be included in the volume measured for payment.

E. Curing of the overlay shall begin immediately after the water sheen disappears and the surface finish is applied. A film of water shall be kept on the surface by fogging until covering materials are in place. Curing covers shall be applied as soon as the concrete has set sufficiently to prevent marring of the surface. Curing material shall consist of two layers of wet burlap and at least one layer of plastic sheeting conforming to the requirements of AASHTO M-171. Adjacent sheets of curing covers shall be lapped a minimum of six inches. Sheeting materials that become torn, broken or damaged shall be immediately replaced. Provisions shall be made for additional applications of water under the plastic sheeting. This may be accomplished with soaker hoses or other methods approved by the Engineer. In any event, the overlay surface and burlap material shall remain wet throughout the curing period. Curing shall continue for a minimum of 24 hours.

Weather Limitations:

Placement of the overlay shall be performed during favorable weather conditions. When the atmospheric temperature is expected to exceed 90 degrees F. during daylight hours, the Contractor shall schedule work hours that insure complete placement by 10:30 a.m.. Placement shall not be scheduled when wind velocity is expected to exceed 20 mph or when rain is expected. The minimum acceptable temperature of concrete at the point of delivery shall be 70 degrees F.. Overlay concrete shall be kept at a temperature above 70 degrees F. for at least 24 hours after placement.

**519.04 MEASUREMENT:** The concrete overlay shall be measured for payment by the square yard of existing deck surface to be overlayed, complete in place and accepted, and shall include all materials and labor to remove the existing concrete, clean and prepare the deck surface, place and finish the overlay.

**519.05 PAYMENT:** The concrete overlay measured as specified above will be paid for at the Contract Unit price bid per square yard. Such payment shall be full compensation for furnishing all equipment and materials and performing the Work in accordance with the Plans and Specifications.

Payment will be made under:

Item No. 519. Concrete Overlay Variable
Thickness................................................per Square Yard

A P P E N D I X   B

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SPECIAL PROVISION
MR-9409 (1) Fulton

## SECTION 519 - FAST TRACK BRIDGE DECK MICROSILICA CONÇRETE OVERLAYS

**519.01 DESCRIPTION:** This Work consists of the construction of a Microsilica Portland Cement concrete overlay of an existing concrete bridge deck and shall include the furnishing of all material, labor and equipment necessary to prepare and finish the work in accordance with these Specifications and Plan details.

**519.02 MATERIALS:** All materials shall meet the requirements of the Standard Specifications.

Concrete Mix Requirements

| | |
|---|---|
| Type III Cement Minimum lbs/cu. yd. | 750 |
| Coarse Aggregate Size No. | 7 |
| *Maximum Water/Cement plus Microsilica Ratio | .40 |
| Slump Limits (Jobsite) | 4-7 inches |
| Air Acceptance Limits (Jobsite) | 3.5 to 7.5% |
| Admixture (Required) | Type F or G |
| Microsilica (Minimum) | 7% by Weight of cement |
| Minimum Compressive Strength (Jobsite) @ 24 hours | 3000 psi |
| Concrete Placement Temperature (Range) | 70°-90°F |
| Air Temperature (Range) | 50°-90°F |

*Includes water in Microsilica slurry if applicable.

NOTE: Microsilica shall conform to the following chemical and physical requirements:

| | |
|---|---|
| Silica dioxide ($S_iO_2$) Min. | 85% |
| Sulfur trioxide ($SO_3$) Max. | 3% |
| Loss on ignition, Max. | 7% |
| Available alkalies as $Na_2O$, Max. | 1.5% |
| Fineness (amount retained when wet sieved on #500 sieve) | 0% |
| Accelerated Pozzolanic Index with Portland cement @ 7 and 28 days, Min % of control | 100% |
| Soundness: Autoclave expansion or contraction, Max. | 0.80% |

Microsilica typically comes dispersed in a high range water reducer. Additional high range water reducer may be required. The contractor shall submit to the Engineer a manufacturers certification insuring that the product conforms to the specifications. The certification shall include the solids content of the microsilica slurry.

The contractor shall submit a mix design for approval. This submittal shall include the actual quantity of each ingredient and Laboratory designs which demonstrate the ability of this design to attain compressive strengths of 3500 psi at 24 hours. Laboratory acceptance strengths shall be determined by at least eight compressive test specimens prepared and cured in accordance with AASHTO T-126. The specimens shall be made from two or more separate trial batches with an equal number of cylinders made from each batch.

**519.03 CONSTRUCTION:** The construction procedures for the overlay shall be as follows:

A. Concrete Manufacturing: Concrete for microsilica concrete overlays shall be manufactured in accordance with section 500.05 of the Standard Specifications.

B. The existing deck to be overlaid shall be given a machine preparation consisting of removal of the concrete to a minimum depth of 0.5 inch below the top mat of reinforcement or as specified in the Plans. This operation shall be accomplished by use of high pressure water blasting equipment designed specifically for this purpose. At the Contractors option initial removal of deck concrete may be accomplished with milling or grinding equipment in conjunction with high pressure water blasting. Damage to reinforcement steel will not be allowed.

C. After removal of the concrete, the entire area of the deck surface shall be blast cleaned to a bright, clean appearance which is free from dust, dirt, oil, grease and all foreign matter. The blast cleaning will be performed by high pressure water blasting. All debris of any type, including dirty water, resulting from the blast cleaning operation shall be immediately and thoroughly cleaned from the blast cleaned surface. The blast cleaned areas shall be protected, as necessary, against contamination prior to placement of the overlay. Contaminated areas shall be blast cleaned again as directed by the Engineer, at the Contractor's expense. All areas of standing water shall be removed and the surface reasonably dry before the concreting operation begins.

D. The minimum overlay thickness is to be the amount removed plus the minimum additional depth required to provide 2 1/4 inches of concrete cover over the top reinforcement mat or as specified in the Plans.

The finishing machine or approved screeding device shall be passed over the existing deck prior to placing the concrete overlay in order that measurements can be made to insure that proper overlay thickness and steel cover will be achieved. Screeds shall be equipped with surface vibrators sufficient to thoroughly consolidate the overlay full depth, unless other methods are approved by the Engineer. Consolidation using hand-held vibrators shall be required when placing the mixture around steel reinforcement or structural members.

The overlay shall satisfy the surface tolerances as found in Article 500.11.C.6.e of the Standard Specifications. After finishing, the surface shall be textured in accordance with the requirements of Section 500.11.C.6.c(1) or (2) or as required by the Plans and Proposal. Surface grooving shall not begin until the curing period specified herein has expired.

The formation of longitudinal joints and transverse construction joints shall be held to the minimum number necessary, and both types of joints shall be thoroughly blast cleaned and coated with an approved bonding agent before fresh concrete is placed against the hardened sides of the joints. When construction joints are necessary, they shall be formed by use of a header secured to the deck. After removal of the header, the overlay shall be sawed three inches or more inside the formed edge and the overlay outside the saw cut removed before the adjacent overlay is placed. The volume of the overlay removed will not be included in the volume measured for payment.

E. Curing of the overlay shall begin immediately after the water sheen disappears and the surface finish is applied. A film of water shall be kept on the surface by fogging until covering materials are in place. Curing covers shall be applied as soon as the concrete has set sufficiently to prevent marring of the surface. Curing material shall consist of two layers of wet burlap and at least one layer of plastic sheeting conforming to the requirements of AASHTO M-171. Adjacent sheets of curing covers shall be lapped a minimum of six inches. Sheeting materials that become torn, broken or damaged shall be immediately replaced. Provisions shall be made for additional applications of water under the plastic sheeting. This may be accomplished with soaker hoses or other methods approved by the Engineer. In any event, the overlay surface and burlap material shall remain wet throughout the curing period. Curing shall continue for a minimum of 24 hours.

Weather Limitations:

Placement of the overlay shall be performed during favorable weather conditions. When the atmospheric temperature is expected to exceed 90 degrees F. during daylight hours, the Contractor shall schedule work hours that insure complete placement by 10:30 a.m.. Placement shall not be scheduled when wind velocity is expected to exceed 20 mph or when rain is expected. The minimum acceptable temperature of concrete at the point of delivery shall be 70 degrees F.. Overlay concrete shall be kept at a temperature above 70 degrees F. for at least 24 hours after placement.

**519.04 MEASUREMENT:** The concrete overlay shall be measured for payment by the square yard of existing deck surface to be overlayed, complete in place and accepted, and shall include all materials and labor to remove the existing concrete, clean and prepare the deck surface, place and finish the overlay.

**519.05 PAYMENT:** The concrete overlay measured as specified above will be paid for at the Contract Unit price bid per square yard. Such payment shall be full compensation for furnishing all equipment and materials and performing the Work in accordance with the Plans and Specifications.

Payment will be made under:

Item No. 519. Microsilica Concrete Overlay Variable Thickness..................................................per Square Yard

A P P E N D I X   C

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SPECIAL PROVISION
MR-9409 (1) Fulton

## SECTION 519 - FAST TRACK BRIDGE DECK LATEX MODIFIED CONCRETE OVERLAYS

**519.01 DESCRIPTION:** This Work consists of the construction of a latex modified Portland Cement concrete overlay of an existing concrete bridge deck and shall include the furnishing of all material, labor and equipment necessary to prepare and finish the work in accordance with these Specifications and Plan details.

**519.02 MATERIALS:** All materials shall meet the requirements of the Standard Specifications.

Concrete Mix Requirements

| | |
|---|---|
| Type III Cement Minimum (lbs/cu. yd.) | 750 |
| Coarse Aggregate Size | 7 |
| *Maximum Water/Cement Ratio | 0.40 |
| Slump Limits (Jobsite) | 4-7 inches |
| Air Acceptance Limits (Jobsite) Maximum | 7.5% |
| Latex (gal./bag) | 3.0 |
| Minimum Compressive Strength (Jobsite) @ 24 hours | 3000 psi |
| Concrete Placement Temperature (Range) | 70°-90°F |
| Air Temperature (Range) | 50°-90°F |

The latex shall be a styrene butadiene polymer emulsion containing 46% to 49% solids and typically 52% water by weight.

* All non solids in the Latex admixture are considered part of the total water.

The contractor shall submit a mix design for approval. This submittal shall include the actual quantity of each ingredient and laboratory designs which demonstrate the ability of this design to attain compressive strengths of 3500 psi at 24 hours. Laboratory acceptance strengths shall be determined by at least eight compressive test specimens prepared and cured in accordance with AASHTO T-126. The specimens shall be made from two or more separate trial batches with an equal number of cylinders made from each batch.

**519.03 CONSTRUCTION:** The latex manufacturer shall provide a technical representative for start up assistance.

A. Mixing: Concrete for latex overlays shall be mixed at The Work site by either batch or continuous mixers approved by The Engineer. Drum-type transit truck mixers or rotating drum batch-type mixers shall not be used in any circumstance for latex concrete overlays. All batch mixers shall be equipped with rotating blades or paddles. The maximum time between completion of mixing and placement shall not exceed 20 minutes.

Batch-type mixers shall be equipped with or accompanied by suitable devices for accurately measuring the weight of the cement, fine aggregate, and coarse aggregate for each batch and for accurately determining either the volume or the weight of the water, the water-reducing and air-entraining admixtures and latex admixture, as applicable for each batch. Approved methods for adding the air-entraining admixture and the water-reducing admixture shall be provided. The admixtures shall be kept separated and shall be separately added to the mixture. Batch-type mixers which entrap unacceptable volumes of air in the mixture shall not be used. Continuous-type mixers shall be equipped so that the proportions of the latex admixture (when required), cement, fine aggregate, and coarse aggregate can be fixed by calibration of the mixer, and thereafter shall not be changed without approval by the Engineer. The latex admixture supply portion of the mixer shall be equipped with a cumulative-type meter which can be read to the nearest 0.1 of a gallon or one pound. The water supply portion of the mixer shall be equipped with a flow meter or other suitable device for calibrating the water supply, and a cumulative-type water meter which can be read to the nearest 0.1 gallon or one pound. The latex and water meters shall be readily accessible, accurate to within ± 1 percent, and easy to read. Approved methods for adding the air-entraining admixture and the water-reducing admixture, when required, shall be provided. The admixtures shall be added so as to be kept separated as far as is practicable. The continuous type mixer shall be calibrated by the Laboratory prior to starting The Work. It shall be recalibrated thereafter at least once during each 50 cubic yards production if yield checks indicate recalibration is necessary, and at any other times the Engineer deems necessary to ensure proper proportioning of the ingredients. Continuous-type mixers which entrap unacceptable volumes of air in the mixture shall not be used.

The mixer, whether batch or continuous-type, shall be kept clean and free of partially dried or hardened materials at all times. It shall consistently produce a uniform, thoroughly blended mixture within the specified air content and slump limits. Malfunctioning mixers shall be immediately repaired or replaced with acceptable units.

B. The existing deck to be overlaid shall be given a machine preparation consisting of removal of the concrete to a minimum depth of 0.5 inch below the top mat of reinforcement or as specified in the Plans. This operation shall be accomplished by the use of high pressure water blasting equipment designed specifically for this purpose. At the Contractors option initial removal of deck concrete may be accomplished with milling or grinding equipment in conjunction with high pressure water blasting. Damage to reinforcement steel will not be allowed.

C. After removal of the concrete, the entire area of the deck surface shall be blast cleaned to a bright, clean appearance which is free from dust, dirt, oil, grease and all foreign matter. The blast cleaning will be performed by high pressure water blasting. All debris of any type, including dirty water, resulting from the blast cleaning operation shall be immediately and thoroughly cleaned from the blast cleaned surface. The blast cleaned areas shall be protected, as necessary, against contamination prior to placement of the overlay. Contaminated areas shall be blast cleaned again as directed by the Engineer, at the Contractor's expense. All areas of standing water shall be removed and the surface reasonably dry before the concreting operation begins.

D. The minimum overlay thickness is to be the amount removed plus the minimum additional depth required to provide 2 1/4 inches of concrete cover over the top reinforcement mat or as specified in the Plans.

The finishing machine or approved screeding device shall be passed over the existing deck prior to placing the concrete overlay in order that measurements can be made to insure that proper overlay thickness and steel cover will be achieved. Screeds shall be equipped with surface vibrators sufficient to thoroughly consolidate the overlay full depth, unless other methods are approved by the Engineer. Consolidation using hand-held vibrators shall be required when placing the mixture around steel reinforcement or structural members.

The overlay shall satisfy the surface tolerances as found in Article 500.11.C.6.e of the Standard Specifications. After finishing, the surface shall be textured in accordance with the requirements of Section 500.11.C.6.c(1) or (2) or as required by the Plans and Proposal. Surface grooving shall not begin until the curing period specified herein has expired.

The formation of longitudinal joints and transverse construction joints shall be held to the minimum number necessary, and both types of joints shall be thoroughly blast cleaned and coated with an approved bonding agent before fresh concrete is placed against the hardened sides of the joints. When construction joints are necessary, they shall be formed by use of a header secured to the deck. After removal of the header, the overlay shall be sawed three inches or more inside the formed edge and the overlay outside the saw cut removed before the adjacent overlay is placed. The volume of the overlay removed will not be included in the volume measured for payment.

E. Curing of the overlay shall begin immediately after the water sheen disappears and the surface finish is applied. A film of water shall be kept on the surface by fogging until covering materials are in place. Curing covers shall be applied as soon as the concrete has set sufficiently to prevent marring of the surface. Curing material shall consist of two layers of wet burlap and at least one layer of plastic sheeting conforming to the requirements of AASHTO M-171. Adjacent sheets of curing covers shall be lapped a minimum of six inches. Sheeting materials that become torn, broken or damaged shall be immediately replaced. Provisions shall be made for additional applications of water under the plastic sheeting. This may be accomplished with soaker hoses or other methods approved by the Engineer. In any event, the overlay surface and burlap material shall remain wet throughout the curing period. Curing shall continue for a minimum of 24 hours.

<u>Weather Limitations:</u>

Placement of the overlay shall be performed during favorable weather conditions. When the atmospheric temperature is expected to exceed 90 degrees F. during daylight hours, the Contractor shall schedule work hours that insure complete placement by 10:30 a.m.. Placement shall not be scheduled when wind velocity is expected to exceed 20 mph or when rain is expected. The minimum acceptable temperature of concrete at the point of delivery shall be 70 degrees F.. Overlay concrete shall be kept at a temperature above 70 degrees F. for at least 24 hours after placement.

**519.04 MEASUREMENT:** The concrete overlay shall be measured for payment by the square yard of existing deck surface to be overlayed, complete in place and accepted, and shall include all materials and labor to remove the existing concrete, clean and prepare the deck surface, place and finish the overlay.

**519.05 PAYMENT:** The concrete overlay measured as specified above will be paid for at the Contract Unit price bid per square yard. Such payment shall be full compensation for furnishing all equipment and materials and performing the Work in accordance with the Plans and Specifications.

Payment will be made under:

Item No. 519. Latex Modified Concrete Overlay Variable Thickness.................................................per Square Yard

# APPENDIX D

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SPECIAL PROVISION
MR-9409 (1) Fulton

## SECTION 519 - FAST TRACK BRIDGE DECK LOW SLUMP CONCRETE OVERLAYS

**519.01 DESCRIPTION:** This Work consists of the construction of a Low Slump Portland Cement concrete overlay of an existing concrete bridge deck and shall include the furnishing of all material, labor and equipment necessary to prepare and finish the work in accordance with these Specifications and Plan details.

**519.02 MATERIALS:** All materials shall meet the requirements of the Standard Specifications.

Concrete Mix Requirements

| | |
|---|---|
| Type III Cement Minimum (lbs/cu. yd.) | 750 |
| Coarse Aggregate Size No. | 8 or 89 |
| Maximum Water/Cement Ratio | 0.34 |
| Slump Limits (Jobsite) Maximum | 1 inch |
| Air Acceptance Limits (Jobsite) | 3.5 to 7.5% |
| Minimum Compressive Strength (Jobsite) @ 24 hours | 3000 psi |
| Concrete Placement Temperature (Range) | 70°-90°F |
| Air Temperature (Range) | 50°-90°F |

The contractor shall submit a mix design for approval. This submittal shall include the actual quantity of each ingredient and laboratory designs which demonstrate the ability of this design to attain a compressive strength of 3500 psi at 24 hours. Laboratory acceptance strengths shall be determined by at least eight compressive test specimens prepared and cured in accordance with AASHTO T-126. The specimens shall be made from two or more separate batches with an equal number of cylinders made from each batch.

**519.03 CONSTRUCTION:** The construction procedures for the overlay shall be as follows:

A. Mixing: Concrete for low slump concrete overlays shall be mixed at The Work site by either batch or continuous mixers approved by The Engineer. Drum-type transit truck mixers or rotating drum batch-type mixers shall not be used in any circumstance for portland cement concrete overlays. All batch mixers shall be equipped with rotating blades or paddles. The maximum time between completion of mixing and placement shall not exceed 20 minutes.

Batch-type mixers shall be equipped with or accompanied by suitable devices for accurately measuring the weight of the cement, fine aggregate, and coarse aggregate for each batch and for accurately determining either the volume or the weight of the water-reducing and air-entraining admixtures as applicable for each batch. Approved methods for adding the air-entraining admixture and the water-reducing admixture shall be provided. The admixtures shall be kept separated and shall be separately added to the mixture. Batch-type mixers which entrap unacceptable volumes of air in the mixture shall not be used.

Continuous-type mixers shall be equipped so that the proportions of cement, fine aggregate, and coarse aggregate can be fixed by calibration of the mixer, and thereafter shall not be changed without approval by the Engineer. The water supply portion of the mixer shall be equipped with a flow meter or other suitable device for calibrating the water supply, and a cumulative-type water meter which can be read to the nearest 0.1 gallon or one pound. The water meter shall be readily accessible, accurate to within ± 1 percent, and easy to read. Approved methods for adding the air-entraining admixture and the water-reducing admixture, when required, shall be provided. The admixtures shall be added so as to be kept separated as far as is practicable. The continuous type mixer shall be calibrated by the Laboratory prior to starting The Work. It shall be recalibrated thereafter at least once during each 50 cubic yards production if yield checks indicate recalibration is necessary, and at any other times the Engineer deems necessary to ensure proper proportioning of the ingredients. Continuous-type mixers which entrap unacceptable volumes of air in the mixture shall not be used.

The mixer, whether batch or continuous-type, shall be kept clean and free of partially dried or hardened materials at all times. It shall consistently produce a uniform, thoroughly blended mixture within the specified air content and slump limits. Malfunctioning mixers shall be immediately repaired or replaced with acceptable units.

B. The existing deck to be overlaid shall be given a machine preparation consisting of removal of the concrete to a minimum depth of 0.5 inch below the top mat of reinforcement or as specified in the Plans. This operation shall be accomplished by use of high pressure water blasting equipment designed specifically for this purpose. At the Contractors option initial removal of deck concrete may be accomplished with milling or grinding equipment in conjunction with high pressure water blasting. Damage to reinforcement steel will not be allowed.

C. After removal of the concrete, the entire area of the deck surface shall be blast cleaned to a bright, clean appearance which is free from dust, dirt, oil, grease and all foreign matter. The blast cleaning will be performed by high pressure water blasting. All debris of any type, including dirty water, resulting from the blast cleaning operation shall be immediately and thoroughly cleaned from the blast cleaned surface. The blast cleaned areas shall be protected, as necessary, against contamination prior to placement of the overlay. Contaminated areas shall be blast cleaned again as directed by the Engineer, at the Contractor's expense. All areas of standing water shall be removed and the surface reasonably dry before the concreting operation begins.

D. The minimum overlay thickness is to be the amount removed plus the minimum additional depth required to provide 2 1/4 inches of concrete cover over the top reinforcement mat or as specified in the Plans.

Placing and Finishing Equipment: Equipment shall include sufficient hand tools for placement of stiff, plastic concrete and for working it down to approximately the correct elevation for striking off with a screed.

Supporting rails upon which the finishing machine travels shall be placed outside the area to be surfaced, and shall extend beyond each end of the bridge a sufficient distance to accommodate the finishing machine. Anchorage for the supporting rails shall be substantial enough to provide for rigid horizontal and vertical stability of the rails. Methods proposed for anchoring the supporting rails to the deck shall be submitted to the Engineer for approval prior to beginning The Work.

The finishing machine shall be equipped with a strikeoff to provide a uniform thickness of concrete in front of the screeds and with 2 oscillating speeds set accurately to the crown specified. The screeds of the finishing machine shall be of metal.

The front oscillating screed shall be designed to thoroughly consolidate the concrete by vibration to the specified density. A sufficient number of identical vibrators shall be effectively installed on the screed so that at least one vibrator is provided for each 5 feet of screed length. The bottom face of this screed shall be at least 5 inches wide with a turned up or rounded leading edge to minimize tearing of the surface of the plastic concrete. Each screed shall have an effective weight of at least 75 pounds for each square foot of bottom face area. Each screed shall be provided with positive control of the vertical position, the angle of tilt, and the slope of the crown. The final screed shall oscillate and finish without vibration.

Design of the finishing machine together with appurtenant equipment shall be such that positive machine screeding of the plastic concrete will be obtained within one inch of the face of the existing curbs; the vibrating screed shall be of sufficient length to extend at least 6 inches beyond an intended longitudinal joint, and to extend at least 6 inches beyond the longitudinal edge of a previously placed section of overlay.

The finishing machine shall be capable of forward and reverse motion under positive control. Provision shall be made for raising the screeds to clear the screeded surface for traveling in reverse.

The overlay shall satisfy the surface tolerances as found in Article 500.11.C.6.e of the Standard Specifications. After finishing, the surface shall be textured in accordance with the requirements of Section 500.11.C.6.c(1) or (2) or as required by the Plans and Proposal. Surface grooving shall not begin until the curing period specified herein has expired.

The formation of longitudinal joints and transverse construction joints shall be held to the minimum number necessary, and both types of joints shall be thoroughly blast cleaned and coated with an approved bonding agent before fresh concrete is placed against the hardened sides of the joints. When construction joints are necessary, they shall be formed by use of a header secured to the deck. After removal of the header, the overlay shall be sawed three inches or more inside the formed edge and the overlay outside the saw cut removed before the adjacent overlay is placed. The volume of the overlay removed will not be included in the volume measured for payment.

E. Curing of the overlay shall begin immediately after the water sheen disappears and the surface finish is applied. A film of water shall be kept on the surface by fogging until covering materials are in place. Curing covers shall be applied as soon as the concrete has set sufficiently to prevent marring of the surface. Curing material shall consist of two layers of wet burlap and at least one layer of plastic sheeting conforming to the requirements of AASHTO M-171. Adjacent sheets of curing covers shall be lapped a minimum of six inches. Sheeting materials that become torn, broken or damaged shall be immediately replaced. Provisions shall be made for additional applications of water under the plastic sheeting. This may be accomplished with soaker hoses or other methods approved by the Engineer. In any event, the overlay surface and burlap material shall remain wet throughout the curing period. Curing shall continue for a minimum of 24 hours.

Weather Limitations:

Placement of the overlay shall be performed during favorable weather conditions. When the atmospheric temperature is expected to exceed 90 degrees F. during daylight hours, the Contractor shall schedule work hours that insure complete placement by 10:30 a.m.. Placement shall not be scheduled when wind velocity is expected to exceed 20 mph or when rain is expected. The minimum acceptable temperature of concrete at the point of delivery shall be 70 degrees F.. Overlay concrete shall be kept at a temperature above 70 degrees F. for at least 24 hours after placement.

**519.04 MEASUREMENT:** The concrete overlay shall be measured for payment by the square yard of existing deck surface to be overlayed, complete in place and accepted, and shall include all materials and labor to remove the existing concrete, clean and prepare the deck surface, place and finish the overlay.

**519.05 PAYMENT:** The concrete overlay measured as specified above will be paid for at the Contract Unit price bid per square yard. Such payment shall be full compensation for furnishing all equipment and materials and performing the Work in accordance with the Plans and Specifications.

Payment will be made under:

Item No. 519. Low Slump Concrete Overlay Variable
Thickness..................................................per Square Yard

A P P E N D I X   E

February 18, 1991

DEPARTMENT OF TRANSPORTATION

STATE OF GEORGIA

SPECIAL PROVISION

PROJECT; IR-285-1 (315) COBB COUNTY
FR-056-1 (49) FULTON COUNTY
MR-9409 (1) FULTON COUNTY

Applying to the Current Standard Specifications and Supplements

CONCRETE REMOVAL (HYDRODEMOLITION METHOD)

I. GENERAL

A. This section specifies hydrodemolishing equipment for the removal of concrete over the entire bridge deck, capable of removing deteriorated or non-deteriorated concrete and cleaning the existing reinforcing steel of all rust and corrosion products by use of high-velocity water jets acting under continuous automatic control.

The concrete shall be removed to one half inch below the bottom of the top mat of deck reinforcement with a tolerance of plus or minus one quarter of an inch. High areas shall be removed to acceptable tolerances before paving operations during the deck pour at no cost to the Department.

II. EQUIPMENT

A. The hydrodemolishing equipment shall consist of filtering and pumping units operating in conjunction with a remote-controlled robotics device.

B. The equipment must operate at a noise level of less than 90 decibels at a distance of 50 feet from either the powerpac unit or the remote robot.

C. The equipment must be capable of working 24 hours per day.

D. The equipment must be capable of using river, stream or lake water when it is practical to avoid the waste of potable water.

III. CONSTRUCTION

A. All deteriorated concrete shall be removed, and all exposed reinforcing steel shall be cleaned of all rust and corrosive products including oil, dirt, concrete fragments, laitaince, loose scale and other coating of any character that would destroy or inhibit the bond with the new concrete.

B. The Contractor shall take all steps necessary to prevent cutting or otherwise damaging reinforcing steel, including any vertical stirrups, and/or structural steel including welded shear connectors projecting into the slab and designated to remain in place. Any such bars or shear connectors damaged by the Contractor's operations shall be repaired or replaced at the Contractor's expense.

C. Areas of the deck not accessible or otherwise convenient to hydrodemolition operations shall be treated with conventional (jackhammer) removal methods. Such removal may be performed by power chipping or hand tools, except that pneumatic hammers heavier than 15 lb. class (nominal) (30 lb. maximum) will not be permitted. Pneumatic hammers and chipping tools shall not be operated at an angle exceeding 60 degrees relative to the surface of the deck slab. Such tools may be started in the vertical position but must be immediately tilted to a 60 degrees operation angle. Pneumatic hammers heavier than 15 lb. class (nominal) will not be permitted for removals in areas directly below the top longitudinal reinforcing steel or around primary girder reinforcing steel.

IV. CALIBRATION AND TESTING OF HYDRODEMOLITION EQUIPMENT

A. A trial area shall be designated by the Engineer to demonstrate that the equipment, personnel and methods of operation are capable of producing results satisfactory to the Engineer. The trial area shall consist of 2 patches each of approximately 30 sq. ft., one area deteriorated and/or defective concrete and one area of "sound" concrete as determined by the Engineer.

B. After completion of the above test area, the equipment shall be located over the deteriorated and/or defective concrete and using the same parameters for sound concrete removal, remove all deteriorated and/or defective concrete. If a sufficient result is obtained, these parameters shall be used as a basis for the production removal.

C. In the test area, all exposed steel must be completely cleaned of rust, scale and corrosion products by the hydrodemolition process.

V. OPERATION OF THE HYDRODEMOLITION EQUIPMENT

A. Once the operating parameters of the Hydrodemolisher are defined by programming and calibration, they shall not be changed as the machine progresses across the bridge deck or deck unit, in order to prevent the unnecessary removal of sound concrete below the required minimum removal depth. The Contractor shall exercise care to avoid removal of sound concrete below the required depth.

B. Operation of the Hydrodemolition equipment shall be performed by and supervised by qualified personnel.

C. The Contractor shall provide for the disposal of runoff water generated by the Hydrodemolition process. The Contractor shall obtain any required permits and shall comply with applicable regulations concerning such water disposal. The Contractor shall make provision for the safe handling of runoff water insofar as it may constitute a hazard on the adjacent or underlying traveled roadway surface. The Contractor shall exercise care to protect existing berm slopes from scouring by water jet or runoff water.

D. The Contractor shall provide adequate lighting as required to allow for the safe conduct of night time removal operations, and shall obtain the Engineer's approval for same, exercising care to avoid any hazardous glare in the direction of oncoming traffic.

E. The Contractor shall maintain, on the jobsite, an inventory of common wear parts and replacement accessories for the equipment adequate to assure that routine maintenance tasks can be performed readily without undue project delay.

F. Removal of concrete debris shall be accomplished by hand or by mechanical means, and shall be accomplished directly following the Hydrodemolition process, to prevent the debris from re-settling or re-adhering to the surface or remaining sound concrete. Any removal debris which is allowed to re-settle or to re-adhere to the surface of sound concrete shall be carefully removed by the Contractor, and the Contractor shall exercise care to avoid any damage to the remaining sound concrete.

VI. MEASUREMENT AND PAYMENT

A. Payments for deck removal shall be included in Item No. 519 Concrete Overlay.

B. The above payments shall be full compensation for all work, equipment, materials, and incidentals required to complete each item including the furnishing and the appropriate handling of water, jack hammer work required along parapet curbs and other locations, and the required cleanup work, all as required to complete the items.